National Science Foundation

National Science Board

Science & Engineering Indicators

2016

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About Science and Engineering Indicators

Science and Engineering Indicators (SEI) is first and foremost a volume of record comprising high-quality quantitative data on the U.S. and international science and engineering enterprise. SEI is factual and policy neutral. It does not offer policy options, and it does not make policy recommendations. SEI employs a variety of presentation styles—tables, figures, narrative text, bulleted text, highlights, introductions, conclusions, reference lists—to make the data accessible to readers with different information needs and different information-processing preferences.

The data are "indicators." Indicators are quantitative representations that might reasonably be thought to provide summary information bearing on the scope, quality, and vitality of the science and engineering enterprise. The indicators reported in SEI are intended to contribute to an understanding of the current environment and to inform the development of future policies. SEI does not model the dynamics of the science and engineering enterprise. SEI is used by readers for a variety of purposes, and they have different views about which indicators are the most significant for different purposes.

SEI is prepared by the National Science Foundation's (NSF's) National Center for Science and Engineering Statistics (NCSES) under the guidance of the National Science Board (Board). It is subject to extensive review by outside experts, interested federal agencies, Board members, and NSF internal reviewers for accuracy, coverage, and balance.

SEI includes detailed information about measurement in order to help readers understand what the reported measures mean, how the data were collected, and how to use the data appropriately. SEI's data analyses, however, are relatively accessible. The data can be examined in various ways, and SEI generally emphasizes neutral, factual description and avoids unconventional or controversial analysis. As a result, SEI almost exclusively uses simple statistical tools. Readers who are comfortable with numbers and percentages and equipped with a general conceptual understanding of terms such as "statistical significance" and "margin of error" will readily understand the statistical material in SEI. A statistical appendix aids readers' interpretation of the material presented.

SEI's Different Parts

SEI includes an overview and seven chapters that follow a generally consistent pattern. The chapter titles are as follows:

- Elementary and Secondary Mathematics and Science Education
- Higher Education in Science and Engineering
- Science and Engineering Labor Force
- Research and Development: U.S. Trends and International Comparisons
- Academic Research and Development
- Industry, Technology, and the Global Marketplace
- Science and Technology: Public Attitudes and Understanding

In addition, SEI includes an online data tool, State Indicators, which provides state-level data on science and technology (S&T); a digest; and a list of related topics to help users identify cross-cutting topics across the different chapters.

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The Board authors one or more companion pieces, which draw on the data in SEI and offer recommendations on various issues related to national science and engineering research or education policy, in keeping with the Board's statutory responsibility to bring attention to such issues.

The Digest

The *Science and Engineering Indicators Digest* is a condensed version of SEI comprising a small selection of important indicators. It is intended to serve readers with varying levels of expertise. The digest serves two purposes: (1) to draw attention to important trends and data points from across the chapters of SEI and (2) to introduce readers to the data resources available in the main report of *SEI 2016* and associated products.

The Overview

The overview brings together major patterns and trends that unite data in several of the chapters. The overview helps readers to synthesize the findings in SEI as a whole and to draw connections among the separately prepared chapters. Like the digest, the overview is intended to serve readers with varying levels of expertise. Because the overview relies heavily on figures, it is well-adapted for use in developing presentations. Like the core chapters, the overview strives for a descriptive synthesis and a balanced tone, and it does not take or suggest policy positions.

The Seven Core Chapters

Each chapter consists of contents and lists of sidebars, data tables, and figures; highlights; introduction (chapter overview and chapter organization); a narrative synthesis of data and related contextual information; conclusion; notes; glossary; and references.

Highlights. The highlights provide an outline of the major dimensions of a chapter topic. Each highlight starts with a statement that summarizes a key point made in the chapter. Bulleted points supporting the key point follow.

Introduction. The chapter overview provides a brief explanation of the importance of the topic. It situates the topic in the context of major concepts, terms, and developments relevant to the data reported. The introduction includes a brief narrative account of the logical flow of topics within the chapter.

Narrative. The chapter narrative is a descriptive synthesis that brings together significant findings. It is also a balanced presentation of contextual information that is useful for interpreting the findings. As a descriptive synthesis, the narrative aims (1) to enable the reader to assimilate a large amount of information by putting it in an order that facilitates comprehension and retention and (2) to order the material so that major points readily come to the reader's attention. As a balanced presentation, the narrative aims to include appropriate caveats and context to (3) convey what uses of the data may or may not be appropriate and (4) provide contextual information within which the data may be interpreted by users with a range of science policy views.

Figures. Figures provide visually compelling representations of major findings discussed in the text. Figures also enable readers to test narrative interpretations offered in the text by examining the data themselves.

Data Tables. Data tables help to illustrate and to support points made in the text.

Sidebars. Sidebars discuss interesting recent developments in the field, more speculative information than is presented in the regular chapter text, or other special topics. Sidebars can also present definitions or highlight crosscutting themes.

Appendix Tables. Appendix tables provide the most complete presentation of quantitative data, without contextual information or interpretive aids.

Conclusion. The conclusion summarizes important findings. It offers a perspective on important trends but stops short of definitive pronouncements about either likely future trends or policy implications. Conclusions tend to avoid factual syntheses that suggest distinctive or controversial viewpoints.

Notes. Information that augments points of discussion in the text is presented as endnotes.

Glossary. The glossary defines terms used in the chapter.

References. SEI includes references to data sources cited in the text, stressing national or internationally comparable data. SEI does not attempt to review the analytic literature on a topic or summarize the social science or policy perspectives that might be brought to bear on it. References to that literature are included where they help to explain the basis for statements in the text.

The State Indicators Data Tool

This online tool provides data to assess trends in S&T-related activities in states that can be used by people involved in state-level policy making, journalists, and interested citizens. SEI includes state-level indicators to call attention to state performance in S&T and to foster consideration of state-level activities in this area.

Indicators are drawn from a range of variables, most of which are part of the subject matter of the seven core chapters. The text explains the meaning of each indicator and provides important caveats about how to interpret it. No interpretive narrative synthesizes overall patterns and trends. Approximately three to five bullets highlight significant findings covering a 10-year span, when available. Data for the indicators are graphically displayed in tables that detail state data, in U.S. maps that code states into quartiles, and in histograms that show how state values are distributed. Users also have access to long-term trend data for each indicator.

Presentation

Beginning in 2016, SEI will be published as a Web-based digital report. The complete content of SEI is downloadable as a PDF, with data tables, appendix tables, and source data for each figure available in both PDF and spreadsheet (MS Excel) formats. In addition, figures are also available in a presentation-style format.

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Front Matter

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Image Credit

Gemini North with Laser Guide Star. A 180-degree fisheye view of the Gemini North Telescope on Mauna Kea, Hawaii, as it is lit by moonlight and the red glow of a passing automobile's taillights shining through the wind-vent gates. At the top of the seven-story-high telescope structure, the laser guide star (LGS) can be seen extending into the sky where it creates an artificial star used by an adaptive optics system, to correct for distortions caused by turbulence in the Earth's atmosphere.

Fireworks Galaxy. The face-on spiral galaxy NGC 6946 is ablaze with colorful galactic fireworks fueled by the births and deaths of multitudes of brilliant, massive stars. Astronomers suspect that massive stellar giants have been ending their lives in supernova explosions throughout NGC 6946 in rapid-fire fashion for tens of millions of years.

This Gemini image of NGC 6946 utilizes a selective filter specifically designed to detect the radiation emanating from the starbirth regions. Additional filters help to distinguish other details in the galaxy, including clusters of massive blue stars, dust lanes, and a yellowish core where older more evolved stars dominate.

The Gemini Observatory consists of twin, eight-meter optical/infrared telescopes located on two of the best sites on our planet for observing the universe. Together, these telescopes can access the entire sky. The Gemini South Telescope is located at almost 9,000 feet on a mountain in the Chilean Andes called Cerro Pachon. The Frederick C. Gillett Gemini North Telescope is located on Hawaii's Mauna Kea. It is part of the international community of observatories that have been built to take advantage of the superb atmospheric conditions on this long dormant volcano that rises almost 14,000 feet into the dry, stable air of the Pacific.

Gemini was built and is operated by a partnership of seven countries, including the United States, United Kingdom, Canada, Chile, Australia, Brazil and Argentina. Any astronomer in each partner country can apply for time on Gemini, which is allocated in accordance with the amount of financial support provided by each country. To learn more about Gemini, visit the observatory's website at http://www.gemini.edu/. (Dates of Images: June 2007 and January 2005.)

Credit: Gemini Observatory

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Letter of Transmittal

National Science Board

January 11, 2016

MEMORANDUM FROM THE CHAIR OF THE NATIONAL SCIENCE BOARD

TO: The President and Congress of the United States

SUBJECT: *Science and Engineering Indicators 2016*

As Chair of the National Science Board (Board), it is my honor to transmit, on behalf of the Board, *Science and Engineering Indicators* (*Indicators*) *2016*. The Board submits this biennial report "on indicators of the state of science and engineering in the United States" as required by 42 U.S.C. § 1863 (j) (I).

The *Indicators* series provides a broad base of quantitative information about U.S. science, engineering, and technology for use by policymakers, researchers, and the general public. *Indicators 2016* contains analyses of key aspects of the scope, quality, and vitality of the nation's scientific enterprise in the context of global developments in science and technology.

Beginning with this 2016 edition, *Indicators* will be published as a web-based digital report, rather than a printed volume. The Board believes that the report's new digital format will improve access to and understanding of this rich statistical resource.

Like the 21 prior print editions, the digital report presents information on science, technology, engineering, and mathematics education at all levels; the scientific and engineering workforce; U.S. and international research and development performance; U.S. competitiveness in high technology; and, public attitudes and understanding of science and engineering. The digital edition of *Indicators 2016* also includes an online tool containing state-level data. This tool enables state comparisons on a variety of science and engineering indicators and allows users to explore the data in much greater detail than was possible in the print edition. An Overview chapter synthesizes some of the report's cross-cutting themes.

The Board hopes that the Administration and Congress find the quantitative information and analysis in the report useful and timely for the planning of national priorities, policies, and programs in science and technology.

Dan E. Arvizu

Chair

National Science Board

Acknowledgments

The National Science Board remembers the many contributions of Alan I. Rapoport, former Executive Secretary to the Science and Engineering Indicators Committee and longtime chapter and section author. Alan's connection to Science and Engineering Indicators *began with the 1991 edition and continued uninterrupted through the release of the 2008 report. Over the years, he served as analyst, author, and reviewer. He was also a member of the* Indicators *management team, coordinated the editorial review, and assisted with the review of blueline and press proofs. Alan really enjoyed his work and his colleagues at the National Science Foundation. His dedicated efforts have helped ensure that* Indicators *continues as the gold standard for quantitative information about the nation's science and engineering enterprise.*

The National Science Board (NSB) extends its appreciation to the staff of the National Science Foundation and to the many others, too numerous to list individually, who contributed to the preparation of this report.

Primary responsibility for the production of the volume was assigned to Beethika Khan, Director, Science and Engineering Indicators Program of the National Center for Science and Engineering Statistics (NCSES); John R. Gawalt, Director, NCSES; and the Directorate for Social, Behavioral and Economic Sciences under the leadership of Fay Lomax Cook. The authors were

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Jeri Mulrow managed the overall production process of moving *Science and Engineering Indicators* to its new digital platform. Nirmala Kannankutty, Robin Pentola, May Aydin, and Jaquelina Falkenheim helped develop, coordinate, and monitor the volume’s production schedule. Christine Hamel managed editorial and composition services, and Robin Pentola was responsible for the production, direction, and management of the website. Tanya Gore managed the proofing and concordance services. Rajinder Raut assisted with the final review of the website.

Front Matter

August Gering and Marceline Murawski led the editing team at RTI International: Michelle Back, Justin Faerber, Anne Gering, August Gering, Crystal Smith, Margaret Smith, Roxanne Snaauw, and Nathan Yates. Staff at Penobscot Bay Media, LLC—Heidi Hunt, Cristina Galli, Dan Kemish, and Caleb Winslow—developed a content management system (CMS), the key component in transforming *Indicators* into a primarily digital publication. Betty Baker, Kanika Dutt, Sally Leighton, and Bansari Patidar from Penobscot Bay Media, LLC, contributed to the import and edit of the volume's content into the CMS for display on the Web. Eileen Kessler and staff at OmniStudio, Inc., Washington, D.C., provided the final proofing and concordance check of the website. Many others provided much appreciated advice and assistance and are listed under Contributors and Reviewers.

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Acronyms and Abbreviations

AAAS	American Association for the Advancement of Science
ACE	American Council on Education
ACS	American Community Survey
ADEA	Age Discrimination in Employment Act of 1967
ADP	American Diploma Project
AFGR	average freshman graduation rate
AFT	American Federation of Teachers
AID	Agency for International Development
ANBERD	Analytical Business Enterprise R&D
AP	Advanced Placement
APL	Applied Physics Laboratory
ARC	Average of Relative Citations
ARPA-E	Advanced Research Projects Agency–Energy
ARRA	American Recovery and Reinvestment Act
ATP	advanced technology products
AUTM	Association of University Technology Managers
BBVA	Banco Bilbao Vizcaya Argentaria
BEA	Bureau of Economic Analysis
BLS	Bureau of Labor Statistics

BRDIS	Business R&D and Innovation Survey
CALDER	National Center for Analysis of Longitudinal Data in Education Research
CCA	Council of Canadian Academies
CCCS	Common Core State Standards
CCSSI	Common Core State Standards Initiative
CEO	chief executive officer
CGS	Council of Graduate Schools
CIP	Classification of Instructional Programs
CIS	Community Innovation Survey
CNSTAT	Committee on National Statistics
CPS	Current Population Survey
CRADA	cooperative research and development agreement
CRISP	China Research Institute for Science Popularization
CSEP	Center for the Study of Education Policy, Illinois State University
DHS	Department of Homeland Security
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOL	Department of Labor

DOT	Department of Transportation
EC	European Community
ECLS-K	Early Childhood Longitudinal Study-Kindergarten
ECS	Education Commission of the States
ED	Department of Education
ELS	Education Longitudinal Study
EPA	Environmental Protection Agency
EP	European Patent Office
EPSCoR	Experimental Program to Stimulate Competitive Research
Esnet	DOE’s Energy Sciences Network
EU	European Union
FCC	Federal Communications Commission
FDA	Food and Drug Administration
FDI	foreign direct investment
FDIUS	Survey of Foreign Direct Investment in the United States
FFRDC	federally funded research and development center
FPL	Federal Poverty Level
FY	fiscal year
GAO	Government Accountability Office
GBAORD	government budget appropriations or outlays for R&D

GDP	gross domestic product
GE	genetically engineered
GED	General Equivalency Diploma
GERD	gross domestic R&D expenditures
GM	genetically modified
GMO	genetically modified organism
GNP	gross national product
GPA	grade point average
GSS	General Social Survey, or Survey of Graduate Students and Postdoctorates in Science and Engineering
GUF	general university fund
HBCU	historically black college or university
HDI	Human Development Index
HERD	Higher Education Research and Development Survey
HHS	Department of Health and Human Services
HPC	high performance computing
HS&B	High School and Beyond survey
HSLS	High School Longitudinal Study
HSTS	High School Transcript Study
HT	high technology
I/UCRC	Industry/University Cooperative Research Centers

ICE	Immigration and Customs Enforcement
ICT	information and communications technologies
IDeA	Institutional Development Award
IDR	interdisciplinary research
IEA	International Energy Agency
IOF	involuntarily out-of-field
IPO	initial public offering
IRC	Internal Revenue Code
IRI	Industrial Research Institute
IRS	Internal Revenue Service
ISIC	International Standard Industrial Classification of All Economic Activities
K–12	kindergarten through twelfth grade
KI	knowledge intensive
KOFAC	Korea Foundation for the Advancement of Science and Creativity
KTI	knowledge- and technology-intensive
LEHD	Longitudinal Employer-Household Dynamics
LEP	limited English proficient
LTT	long-term trend
MEDC	more economically developed country
MEP	Manufacturing Extension Partnership

MER	market exchange rate
MIT	Massachusetts Institute of Technology
MNC	multinational company
MOFA	majority-owned foreign affiliate
NAEP	National Assessment of Educational Progress
NAGB	National Assessment Governing Board
NAICS	North American Industry Classification System
NASA	National Aeronautics and Space Administration
NASBE	National Association of State Boards of Education
NASF	net assignable square feet
NCEE	National Center on Education and the Economy
NCES	National Center for Education Statistics
NCLB	The No Child Left Behind Act of 2001
NCRPA	National Cooperative Research and Production Act
NCSES	National Center for Science and Engineering Statistics
NCTQ	National Center for Teaching Quality
NELS	National Education Longitudinal Study
NGA	National Governors Association
NGSS	Next Generation Science Standards
NIH	National Institutes of Health

NIPA	national income and product accounts
NIST	National Institute for Standards and Technology
NISTEP	National Institute of Science and Technology Policy (Japan)
NLR	National Lambda Rail
NLS	National Longitudinal Study
NOAA	National Oceanic and Atmospheric Administration
NORC	National Opinion Research Center
NRC	National Research Council
NS&E	natural sciences and engineering
NSB	National Science Board
NSCG	National Survey of College Graduates
NSF	National Science Foundation
NSRCG	National Survey of Recent College Graduates
NTIA	National Telecommunications and Information Administration
OCR	Office of Civil Rights
OECD	Organisation for Economic Co-operation and Development
OES	Occupational Employment Statistics
OPM	Office of Personnel Management
OSTP	Office of Science and Technology Policy
PCAST	President’s Council of Advisors on Science and Technology

PEJ	Project for Excellence in Journalism
PISA	Program for International Student Assessment
PPP	purchasing power parity
PSM	Professional Science Master's
PST	professional, scientific, and technical
PUMS	Public Use Microdata Sample
R&D	research and development
R&E	research and experimentation
RA	research assistantship
RD&D	research, development, and demonstration
RDT	research, development, and testing
S&E	science and engineering
S&T	science and technology
SASS	Schools and Staffing Survey
SBIR	Small Business Innovation Research
SCI	Science Citation Index
SDR	Survey of Doctorate Recipients
SED	Survey of Earned Doctorates
SEH	science, engineering, and health
SESTAT	Scientists and Engineers Statistical Data System

SET	science, engineering, and technology
SLDS	statewide longitudinal data systems
SLSP	Secondary Longitudinal Studies Program
SOC	Standard Occupational Classification
SOI	Statistics of Income
SSCI	Social Sciences Citation Index
STEM	science, technology, engineering, and mathematics
STTR	Small Business Technology Transfer
TA	teaching assistant
TFA	Teach for America
TIMSS	Trends in International Mathematics and Sciences Study
TIP	Technology Innovation Program
TNTP	The New Teacher Project
U&C	universities and colleges
UK	United Kingdom
UNESCO	United Nations Educational, Scientific and Cultural Organization
USCIS	U.S. Citizenship and Immigration Services
USDA	Department of Agriculture
USDIA	Survey of U.S. Direct Investment Abroad
USGS	U.S. Geological Survey

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USPTO	U.S. Patent and Trademark Office
VA	Department of Veterans Affairs
WebCASPAR	Integrated Science and Engineering Resources Data System
WTO	World Trade Organization
WVS	World Values Survey

Overview

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Overview

Introduction

Social development and different regional growth trends have produced dramatic shifts in the global landscape of science and engineering (S&E) research, education, and business activities. An increasingly multipolar world for S&E is emerging after many decades of leadership by the United States, the European Union, and Japan. This overview presents the changing picture of the world of S&E by highlighting activities in which the developing world is approaching parity with the developed world, activities in which the developed world maintains preeminence, and also activities in which smaller nations have emerged as prominent contributors.

The international and domestic S&E trends that *Science and Engineering Indicators* describes can be understood in light of the worldwide trend toward more knowledge-intensive economies and increasing global collaboration and competition in S&E. In knowledge-intensive economies, S&E research, its commercial utilization, and other intellectual work are of growing importance. Wide access to education as well as to information and communication technologies (ICT) produces technologically empowered populations. Such economies rely on a skilled workforce and on sustained investment in research and development to produce knowledge streams that form the core of knowledge-intensive production in the manufacturing (e.g., spacecraft, pharmaceuticals, computers) and services (e.g., financial, business, education, health) industries. The goods and services of these industries, many of them new in this century, have developed markets that did not exist previously; these goods and services help nations integrate and compete in the global marketplace. International trade, supplier chains, and global infrastructure tie this global marketplace together.

Rapid growth rates frequently accompany the early stages of economic and technical development, but they slow as societies mature (Price 1963). As developing nations focus resources in R&D, education, and knowledge-intensive production and trade, their initially rapid growth rates in these areas can exceed those of developed nations and allow some of them to approach the capabilities of the developed world.

This overview is not intended to be comprehensive; instead, it highlights information in *Science and Engineering Indicators* that offers insights into major global trends. The focus is on broad comparisons in indicators across countries, economies, and regions that cover S&E training, research outputs, the creation and use of intellectual property, and the output of knowledge-intensive industries. More detailed findings on particular topics can be found in the "Highlights" sections that appear at the beginning of chapters 1–7.[i]

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[i] The indicators included derive from a variety of national, international, public, and private sources and are not always strictly comparable in a statistical sense. In addition, the metrics and models relating them to each other and to economic and social outcomes need further development. Individual data points and findings should be interpreted with care.

Science and Technology in the World Economy

Workers with S&E Skills

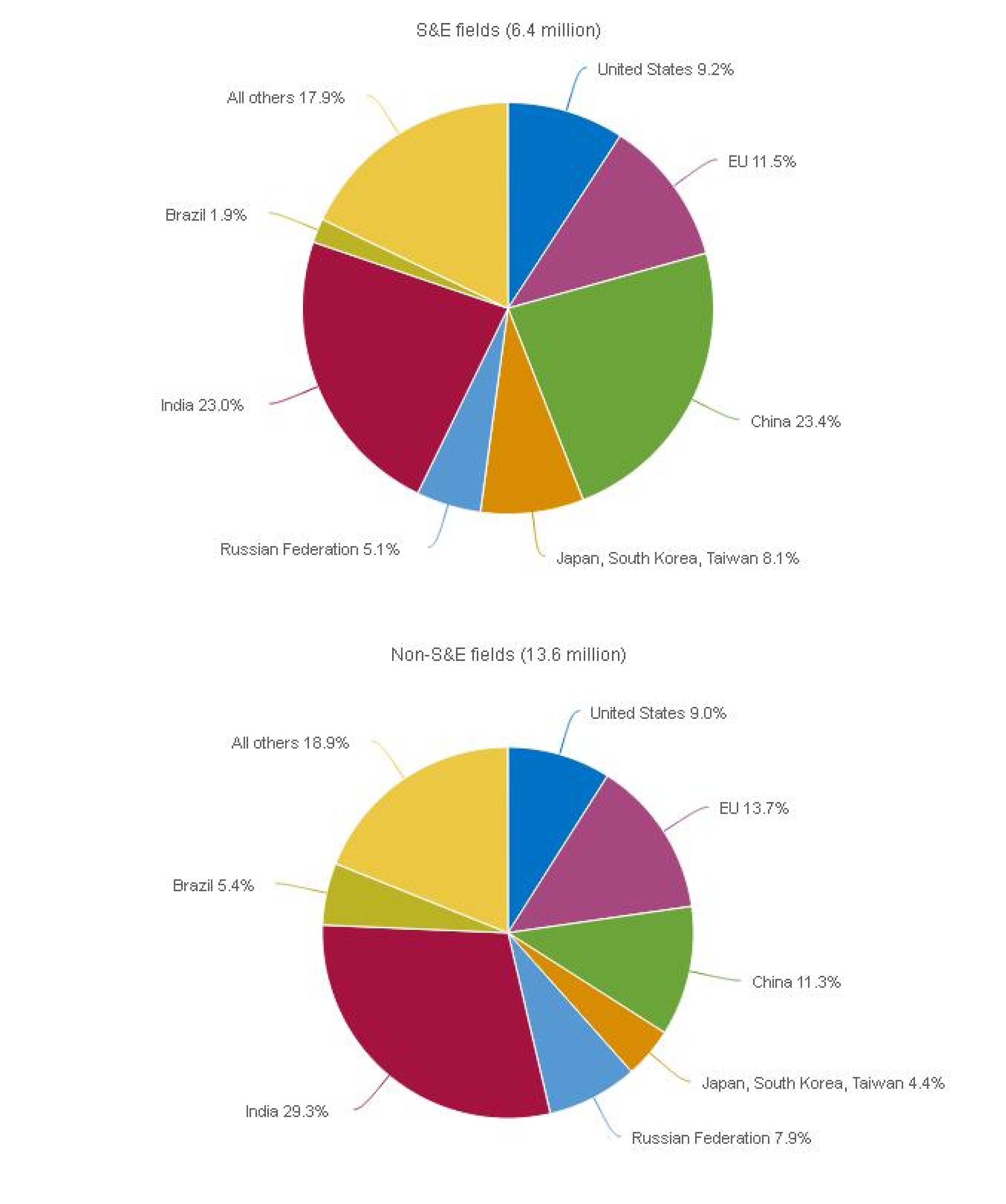
In the increasingly interconnected world of the 21st century, workers with S&E skills are integral to a nation's innovative capacity and economic competitiveness. Governments in many countries have made increased access to S&E-related postsecondary education a high priority. At the same time, they are faced with increased mobility of high-skill workers, including those educated or employed in S&E fields, as countries compete to attract the best talent (OECD 2012:54). Comprehensive and internationally comparable data on the global S&E workforce, while limited, suggest that work requiring S&E skills is occurring throughout the world, with concentrations in specific regions.

S&E degrees, important for an innovative knowledge economy, have become relatively more prevalent in some Asian countries than in the United States: in China, nearly half of all first university degrees (49%) awarded in 2012 were in S&E, compared with 33% in the United States. Globally, the number of first university degrees in S&E reached about 6.4 million, according to the most recent estimates. Almost half of these degrees were conferred in China (23%) and India (23%); another 21% were conferred in the European Union (EU; see "Glossary" for member countries) (12%) and in the United States (9%) (Figure O-1).

Overview

Figure O-1

First university degrees, by selected region/country/economy: 2012



EU = European Union.

Overview

SOURCES: Organisation for Economic Co-operation and Development, Education Online database, http://www.oecd.org/education; national statistical offices.

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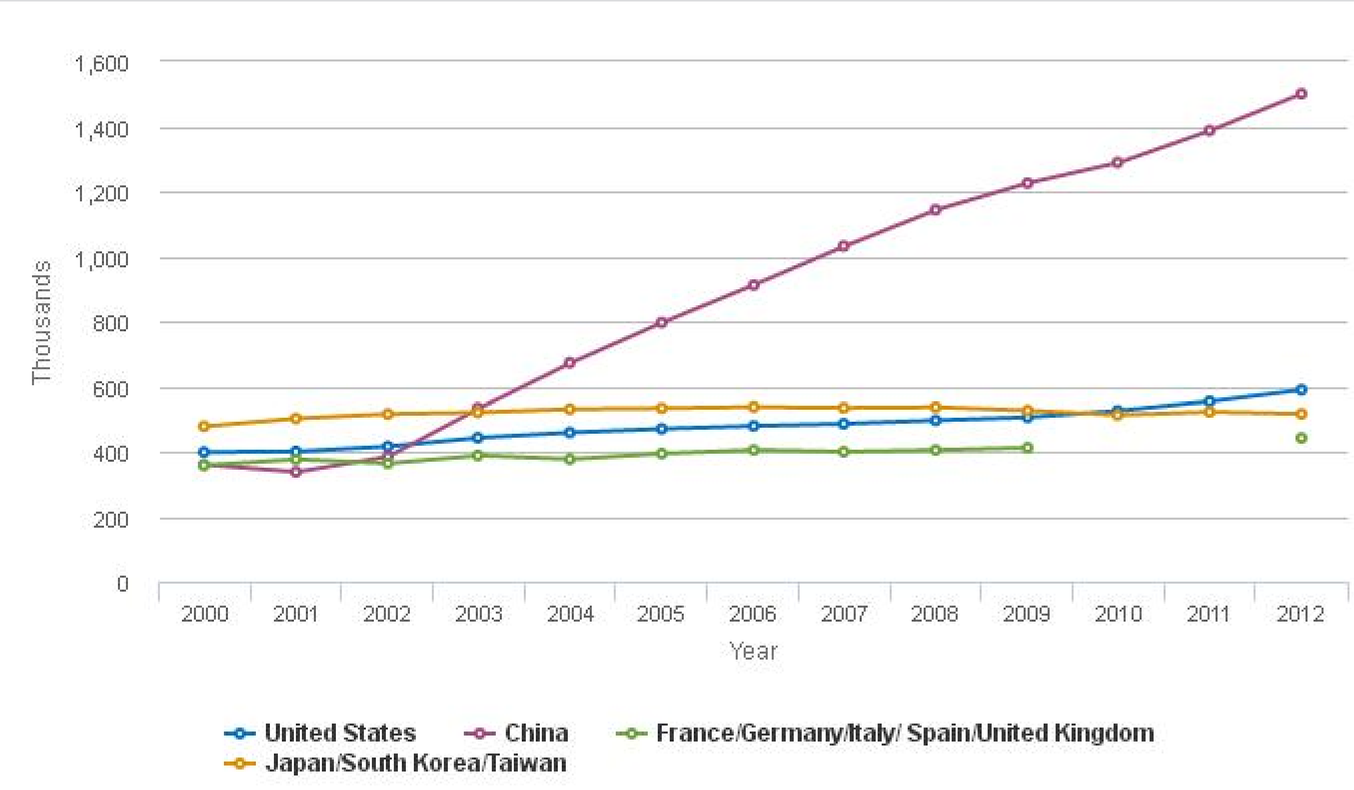
University degree production in China has grown faster than in major developed nations and regions. Between 2000 and 2012, the number of S&E bachelor's degrees awarded in China rose more than 300%, significantly faster than in the United States and in many other European and Asian regions and economies (Figure O-2). Additionally, during the same period, the number of non-S&E degrees conferred in China also rose dramatically (by 1,000%), suggesting that capacity building in China, as indicated by bachelor's degree awards, is occurring in both S&E and non-S&E areas. In fact, the S&E proportion of all first university degrees decreased significantly in China, from 73% in 2000 to 49% in 2012. In other major economies, this proportion has fluctuated within a relatively narrow range.

Overview

Figure O-2

S&E first university degrees, by location: 2000–12



NA = not available.

NOTE: Data are not available for all locations in all years.

SOURCES: Organisation for Economic Co-operation and Development, Education Online database, http://www.oecd.org /education; national statistical offices.

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Understanding the relationship between degrees conferred in a country and the capabilities of its workforce is complicated by the fact that increasing numbers of students are receiving higher education outside their home countries.[i] The United States remains the destination of choice for the largest number of internationally mobile students worldwide. The number of such students enrolled in the United States rose from 475,000 in 2000 to 784,000 in 2013. Yet, due to efforts by other countries to attract more foreign students, the share of the world's internationally mobile students enrolled in the United States fell from 25% in 2000 to 19% in 2013. Other popular destinations for internationally mobile students are the United Kingdom, Australia, France, and Germany (Figure O-3).

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[i] An additional complexity, as data from the United States show, is that a direct correlation often does not exist between an individual's study field of degree and occupation. S&E degree holders report applying their S&E expertise in a wide variety of occupations, including S&E and non-S&E occupations. This indicates that the

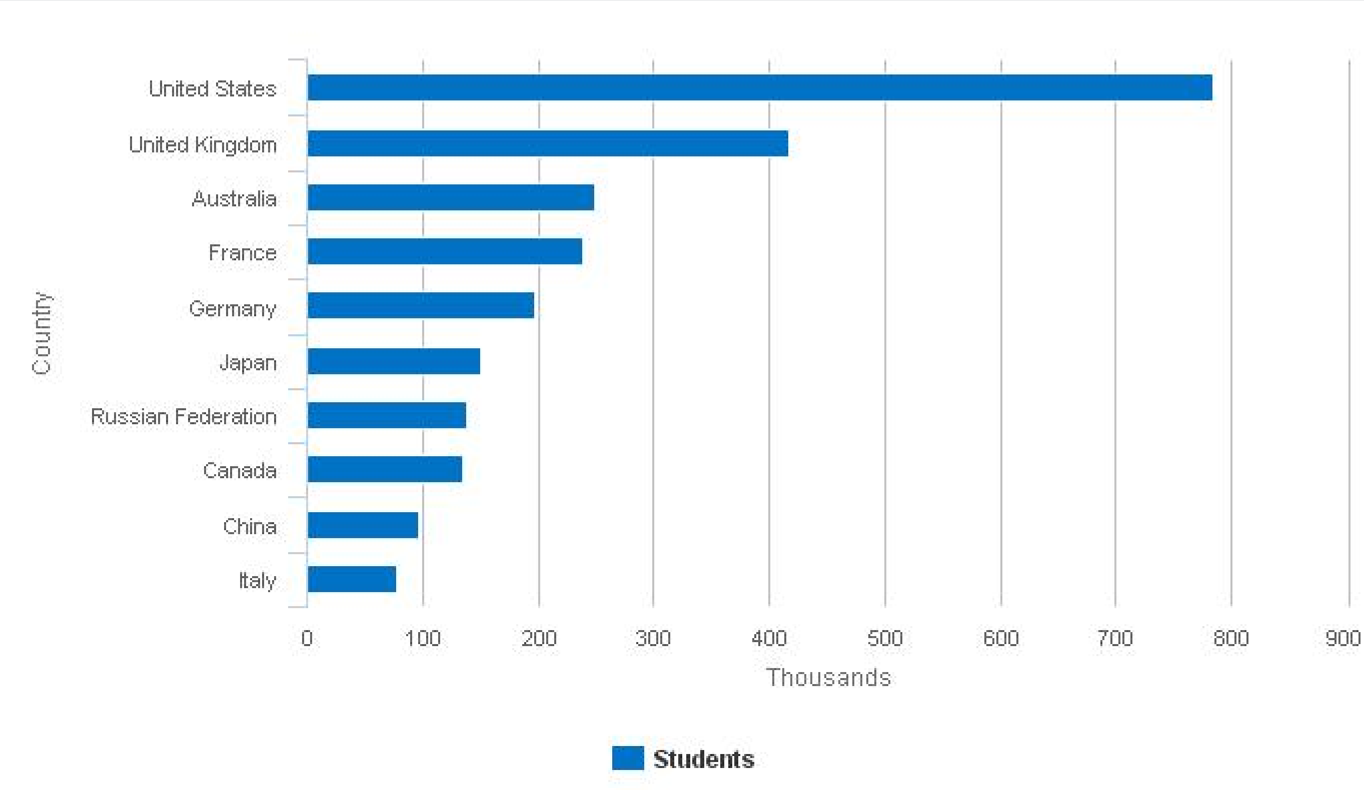
Overview

application of S&E knowledge and skills is widespread across the technologically sophisticated U.S. economy and not just limited to occupations classified as S&E. For more information on this and the U.S. S&E workforce, see National Science Board (2015).

Overview

Figure O-3

Internationally mobile students enrolled in tertiary education, by selected region/country/economy: 2013



NOTES: Data are based on the number of students who have crossed a national border and moved to another country with the objective of studying (i.e., mobile students). Data for Canada, Italy, and Japan correspond to 2012.

SOURCE: United Nations Educational, Scientific and Cultural Organization Institute for Statistics database, special tabulations (2015).

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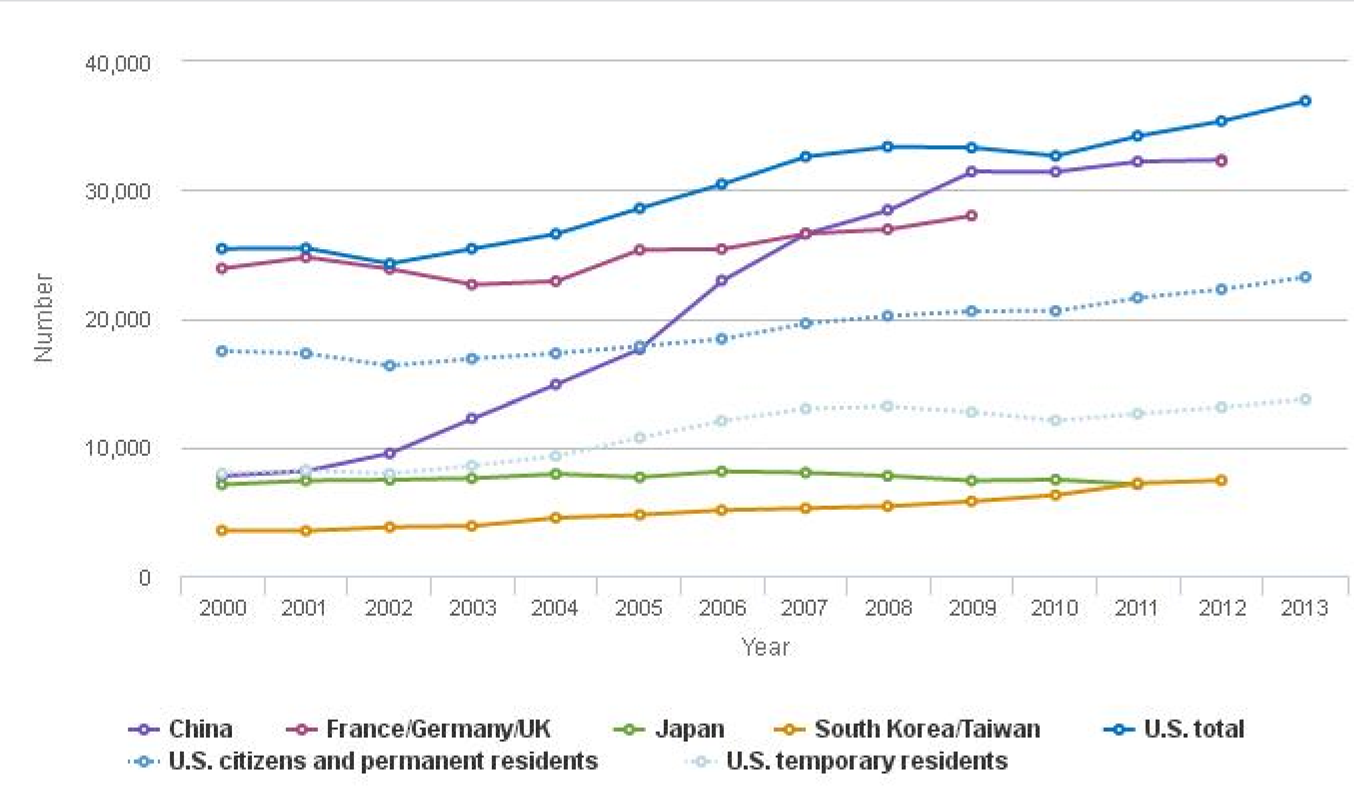
Graduate education in the United States remains particularly attractive to international students. Unlike S&E bachelor's-level degrees, the United States awards a larger number of S&E doctorates than China (Figure O-4). However, a substantial proportion of U.S. S&E doctoral degrees are conferred to international students with temporary visas. In 2013, temporary visa holders, not counting foreign-born students with permanent visas, earned 37% of S&E doctoral degrees. Temporary visa holders are particularly concentrated in engineering, computer sciences, and economics; in 2013, temporary residents earned half or more of the doctoral degrees awarded in these fields. Overall, nearly half of the post-2000 increase in U.S. S&E doctorate production reflects degrees awarded to temporary visa holders, mainly from Asian countries such as China and India. If past trends continue, however, a majority of the S&E doctorate recipients with temporary visas—more than 60%—will remain in the United States for subsequent employment.

Overview

Figure O-4

Doctoral degrees in S&E, by selected region/country/economy: 2000–13



NA = not available.

UK = United Kingdom.

NOTE: Data are not available for all regions/countries/economies in all years.

SOURCES: Organisation for Economic Co-operation and Development, Education Online database, http://www.oecd.org /education; national statistical offices.

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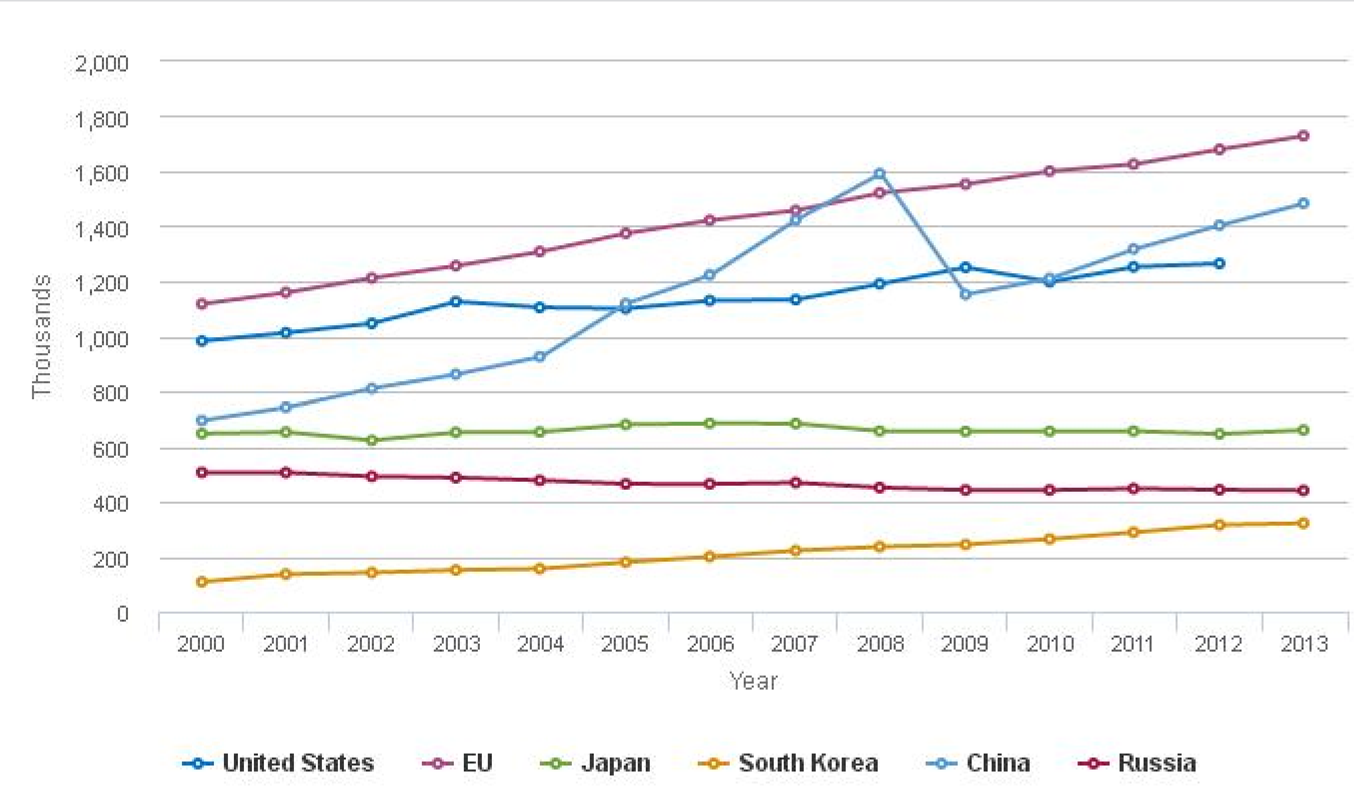
These doctorate recipients add to the most highly trained segment of the international S&E workforce, whose size cannot readily be estimated using fragmentary data. Comprehensive, internationally comparable data on the worldwide S&E workforce is very limited, making it difficult to analyze the precise size of this workforce. However, the Organisation for Economic Co-operation and Development (OECD) provides international estimates on one particularly salient component of this workforce, researchers, who are defined as “professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of the projects concerned” (OECD 2002:93). Although national differences in these estimates may be affected by survey procedures and interpretations of international statistical standards, they can be used to describe broad national and international trends of this highly specialized component of the larger S&E workforce.

The United States and the EU continue to enjoy a distinct but decreasing advantage in the supply of human capital for research. In absolute numbers, these two regions had some of the largest populations of researchers at the latest count, but China has been catching up (Figure O-5).

Overview

Figure O-5

Estimated number of researchers in selected regions/countries/economies: 2000–13



NA = not available.

EU = European Union.

NOTES: Data are not available for all regions/countries/economies for all years. Researchers are full-time equivalents. Counts for China before 2009 are not consistent with Organisation for Economic Co-operation and Development (OECD) standards. Counts for South Korea before 2007 exclude social sciences and humanities researchers.

SOURCE: OECD, *Main Science and Technology Indicators* (2015/1), http://www.oecd.org/sti/msti.htm.

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The worldwide total of workers engaged in research has been growing rapidly, and growth has been more robust in parts of Asia. The most rapid expansion has occurred in South Korea, which nearly doubled its number of researchers between 2000 and 2006 and continued to grow strongly thereafter, and in China, which reported more than twice the number of researchers in 2008 compared with 2000 and likewise reported substantial growth in later years. (China's pre-2009 data did not correspond to the OECD definition and are therefore not comparable to China's data for 2009 onward.) The United States and the EU experienced steady growth at lower rates, with a 29% increase in the United States between 2000 and 2012 and a 55% increase in the EU between 2000 and 2013. Exceptions to the worldwide trend included Japan (which remained relatively flat) and Russia (which experienced a decline).

Researchers measured as a share of employed persons is another indicator of national competitiveness in a globally integrated knowledge economy. Several economies in Asia have shown a sustained increase in that statistic over

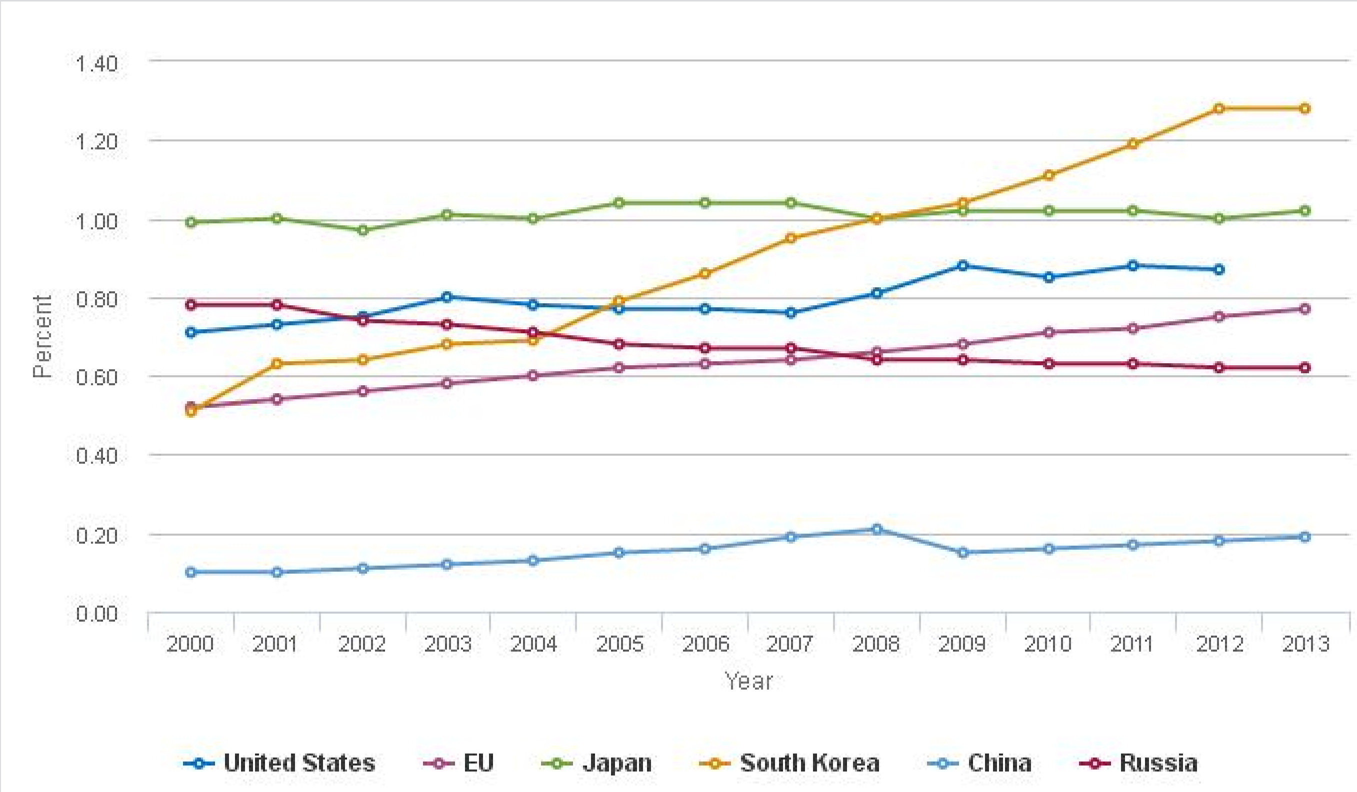
Overview

time. Foremost among them is South Korea (Figure O-6), but growth is also evident in Singapore, Taiwan, and China. Although China reported a large number of researchers, these workers represent a much smaller percentage of China's workforce (0.19%) than in the United States, EU, South Korea, and Japan (Figure O-6).

Overview

Figure O-6

Researchers as a share of total employment in selected regions/countries/economies: 2000–13



NA = not available.

EU = European Union.

NOTES: Data are not available for all regions/countries/economies for all years. Researchers are full-time equivalents. Counts for China before 2009 are not consistent with Organisation for Economic Co-operation and Development (OECD) standards. Counts for South Korea before 2007 exclude social sciences and humanities researchers.

SOURCE: OECD, *Main Science and Technology Indicators* (2015/1), http://www.oecd.org/sti/msti.htm.

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R&D Performance

The rising number of researchers and their growing share of the labor force are reflected in strong and widespread growth in R&D expenditures. The worldwide estimated total of R&D expenditures continues to rise at a significant pace, doubling over the 10-year period between 2003 and 2013. While the global trends toward more knowledge- and technology-intensive economies are continuing, countries vary in their R&D intensity, their relative focus on early versus later stages of R&D, and their dependence on the business sector for R&D funding.

Notwithstanding their overall growth, global R&D expenditures continue to be concentrated in North America, Europe, and East and Southeast Asia (Figure O-7). Among individual countries, the United States is by far the largest performer in R&D, followed by China, whose R&D spending is nearing that of the EU total (Figure O-8).

Overview

Together, the United States and China accounted for almost half of the estimated $1.67 trillion in global R&D in 2013. Japan is third, at 10%, and Germany is fourth, at 6%. South Korea, France, Russia, the United Kingdom, and India make up the next tier of performers—each accounting for 2%–4% of the global R&D total.

Figure O-7

Global R&D expenditures, by region: 2013

PPP = purchasing power parity.

NOTES: Foreign currencies are converted to dollars through PPPs. Some country data are estimated. Countries are grouped according to the regions described by *The World Factbook*, www.cia.gov/library/publications/the-world-factbook/.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics estimates, August 2015. Based on data from the Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2015 /1); and the United Nations Educational, Scientific and Cultural Organization Institute for Statistics Data Centre, http://www.uis.unesco.org/DataCentre/Pages/BrowseScience.aspx, accessed 23 January 2015.

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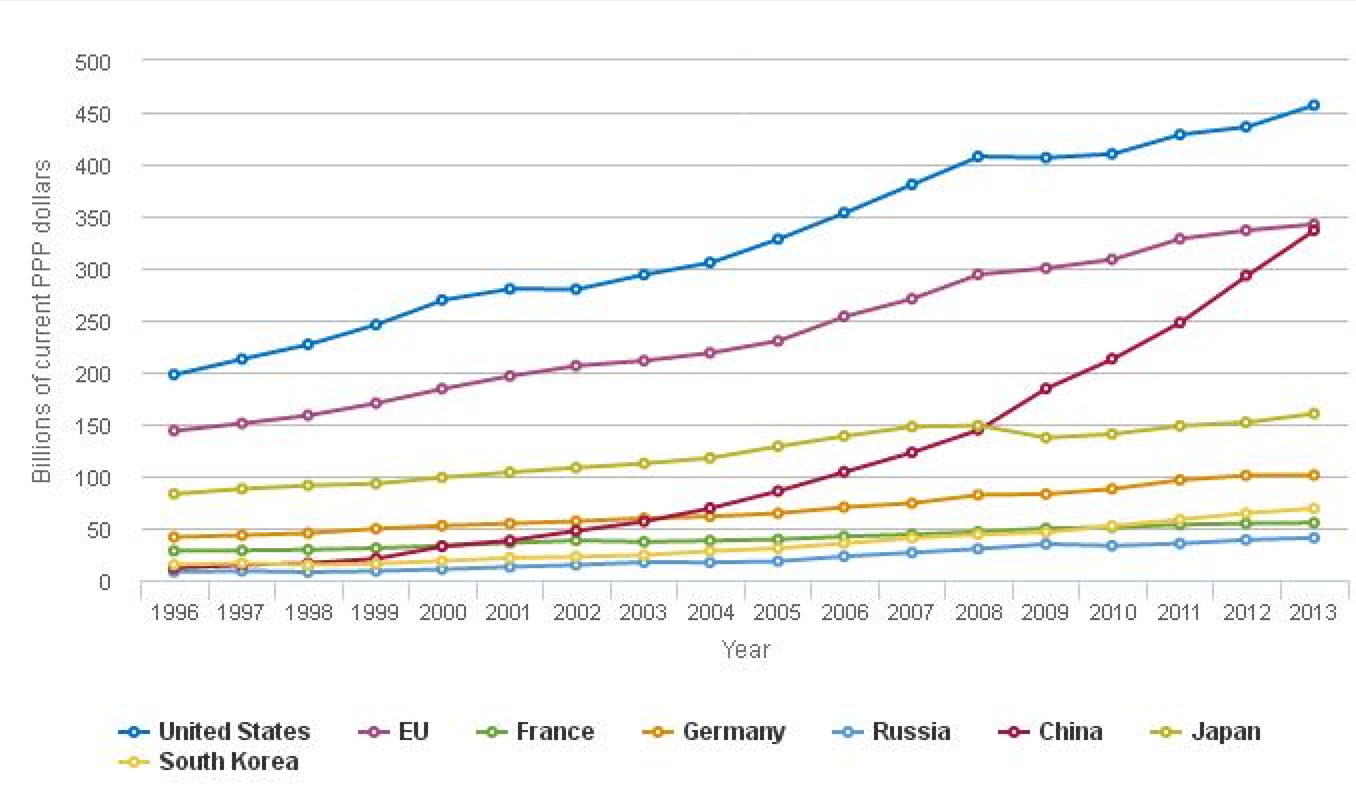
Overview

Figure O-8

Gross domestic expenditures on R&D, by the United States, EU, and selected other countries: 1996–2013



EU = European Union; PPP = purchasing power parity.

NOTES: Data are for the top seven R&D-performing countries and the EU. Data for the United States in this figure reflect international standards for calculating gross expenditures on R&D, which vary slightly from the National Science Foundation's (NSF's) protocol for tallying U.S. total R&D.

SOURCES: NSF, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series); Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2015/1); and United Nations Educational, Scientific and Cultural Organization Institute for Statistics Data Centre, http://www.uis.unesco.org /DataCentre/Pages/BrowseScience.aspx, accessed 23 January 2015.

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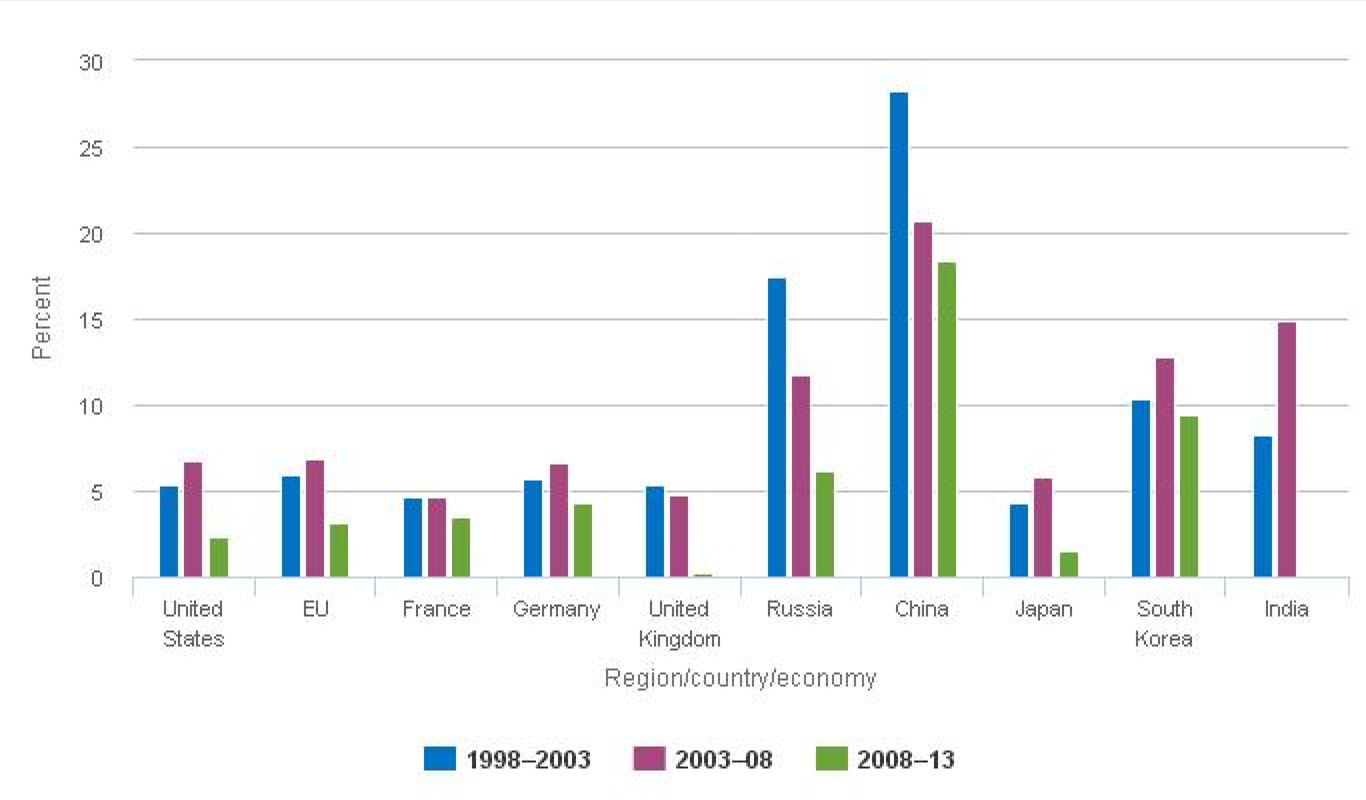
A notable trend over the past decade has been the growth in R&D spending in East and Southeast Asia compared to the other major R&D performing areas. China continues to display the most vigorous R&D growth (Figure O-9), accounting for about one-third of the global increase in R&D spending over the 2003–13 period. These differences in growth rates led to substantial share losses for both the United States (from 35% to 27%) and Europe (from 27% to 22%). During the same period, the combined share of the East and Southeast Asian economies—including China, Japan, Malaysia, Singapore, South Korea, and Taiwan—rose from 25% to 37% of the global total.

Overview

Figure O-9

Average annual growth in gross domestic expenditures on R&D for the United States, EU, and selected other countries: 1998–2013



NA = not available.

EU = European Union.

NOTES: Data are for the top nine R&D-performing countries and the EU. International data on gross domestic expenditures on R&D measured in foreign currencies are converted into U.S. dollars using purchasing power parity exchange rates. Data are not available for all countries for all years. Data for the United States in this figure reflect international standards for calculating gross expenditures on R&D, which vary slightly from the National Science Foundation's (NSF's) protocol for tallying U.S. total R&D.

SOURCES: NSF, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series); Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2015/1); and United Nations Educational, Scientific and Cultural Organization Institute for Statistics Data Centre, http://www.uis.unesco.org /DataCentre/Pages/BrowseScience.aspx, accessed 23 January 2015.

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The share of total R&D spending relative to the size of the economy is often used as a convenient indicator of innovative capacity. Although the United States invests far more in R&D than any other individual country, several other, smaller economies have greater *R&D intensity*—that is, a higher ratio of R&D expenditures to gross domestic product (GDP). A stated goal by the EU (one of the five targets for the EU in 2020 [EC 2013]) is to achieve a 3% R&D-to-GDP ratio. In 2013, the United States had an R&D intensity of 2.7% (Figure O-10). Israel and South Korea are essentially tied for the top spot, with ratios of 4.2% each. Over the past decade, the ratio has fluctuated within a relatively narrow range in the United States and rose gradually in the EU as a whole; in South Korea—and particularly in China, which started with a low base—the R&D-to-GDP ratio rose substantially, nearly doubling in both countries in the last 10 years (Figure O-10).

Overview

The use of this indicator in policymaking has its limitations. Governments have limited control over the size of their economies and over annual R&D spending, which makes achieving a specific R&D-to-GDP ratio a matter of some chance, magnified by the fact that businesses tend to be a leading source of R&D funding. In the United States, businesses funded about 61% of all U.S. R&D in 2013. While the corresponding business sector shares are higher, around 75%, in China, Japan, and South Korea and about the same or lower in Germany (66%), France (55%), United Kingdom (47%), and Russia (28%), they complicate achieving a specific R&D-to-GDP target.

The production sectors supported by business R&D also vary across countries. The manufacturing sector accounts for about 86%–88% of business R&D in Germany, Japan, South Korea, and China—considerably higher than in the United States (69%), France (50%), and the United Kingdom (40%). In the United States, business R&D is spread broadly across manufacturing and services categories: computer, electronic, and optical products; pharmaceuticals; air and spacecraft; information and communication services, including software publishing; and professional, scientific, and technical services including R&D services.

Countries also vary in their relative focus on basic research, applied research, and (experimental) development.[i] In 2012, China spent only 5% of its R&D funds, compared to 17% in the United States, on *basic research*—work aimed at gaining comprehensive knowledge or understanding of the subject under study without specific applications in mind. On the contrary, China spent 84% of its R&D funds, compared to 62% in the United States, on *development*—work that is directed toward the production of useful materials, devices, systems, or methods, including the design and development of prototypes and processes. The lack of specific applications as a goal introduces an element of risk and uncertainty in basic research, which is why a substantial amount of basic research is typically funded by the government. China's more limited focus on basic research may reflect the large business sector role in R&D funding as well as the opportunity to build on basic research done elsewhere (Qui 2014).

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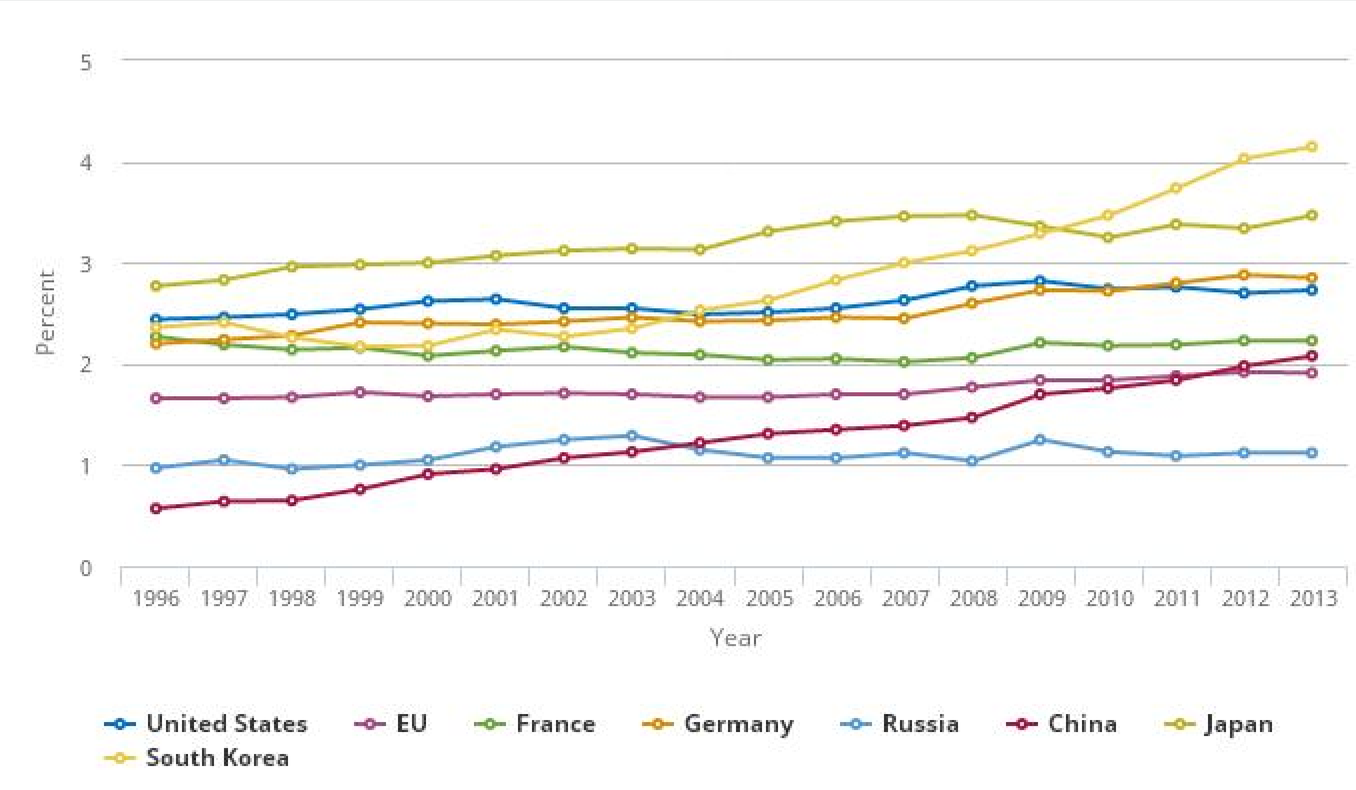
[i] These terms are defined in the chapter "Glossary."

Figure O-10

Gross domestic expenditures on R&D as a share of GDP for the United States, EU, and selected other countries: 1996–2013



EU = European Union; GDP = gross domestic product.

NOTES: Data are for the top seven R&D-performing countries and the EU. Data for the United States in this figure reflect international standards for calculating gross expenditures on R&D, which vary slightly from the National Science Foundation's (NSF's) protocol for tallying U.S. total R&D.

SOURCES: NSF, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series); Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2015/1); and United Nations Educational, Scientific and Cultural Organization Institute for Statistics Data Centre, http://www.uis.unesco.org /DataCentre/Pages/BrowseScience.aspx, accessed 23 January 2015.

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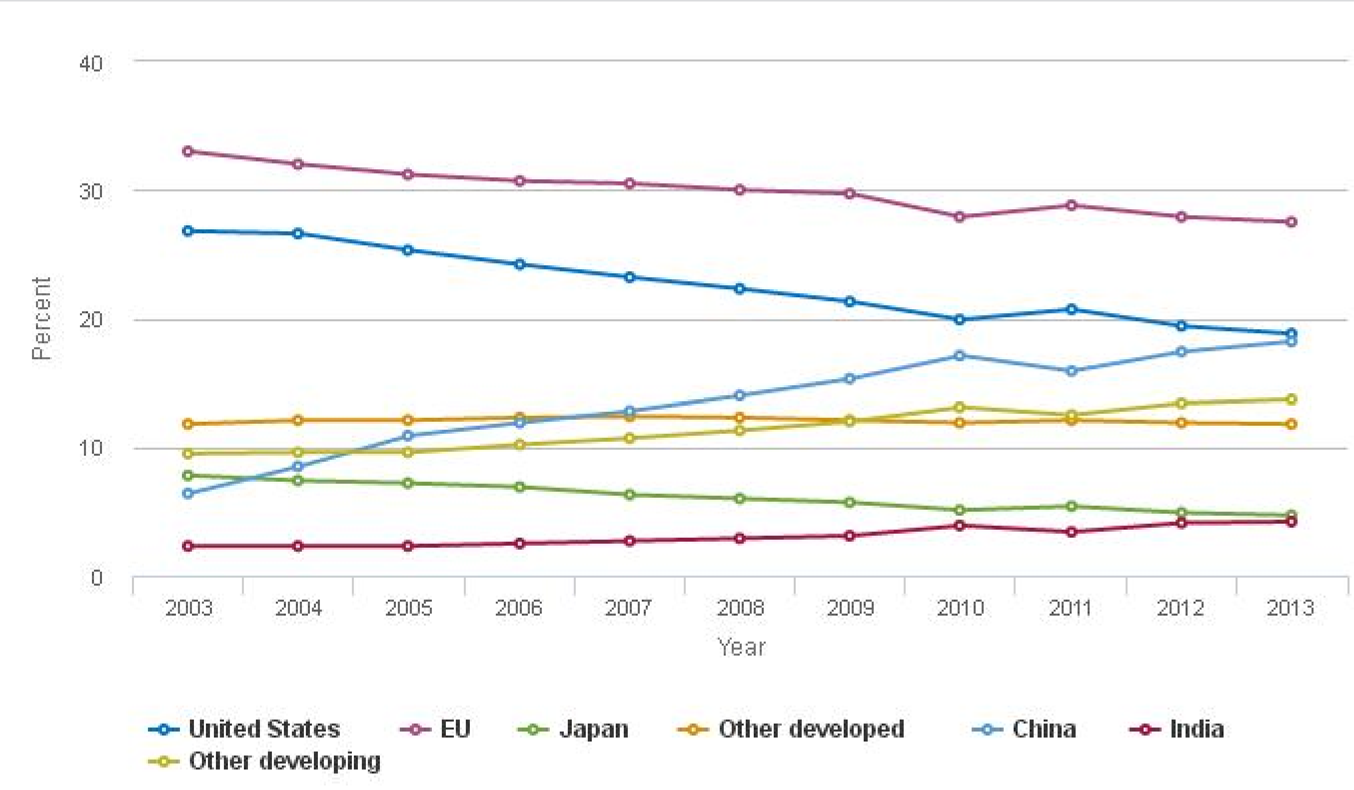
Research Publications

Research produces new knowledge; refereed S&E publications are one of the tangible measures of research activity that have been broadly available for international comparison. The United States, the EU, and the developed world produce the majority of refereed S&E publications. However, similar to the trends for researchers and R&D spending, S&E research output in recent years has grown much more rapidly in China and other developing countries when compared with the output of the United States and other developed countries. China's global share of S&E publications tripled from 6% in 2003 to 18% in 2013. As a result, China's share is now comparable—in terms of the number of publications—to that of the United States (Figure O-11). Research output has also grown rapidly in other developing countries, particularly Brazil and India.

Overview

Figure O-11

S&E articles, by global share of selected region/country/economy: 2003–13



EU = European Union.

NOTES: Publication counts are from a selection of journals, books, and conference proceedings in S&E from Scopus. Publications are classified by their year of publication and are assigned to a region/country/economy on the basis of the institutional address(es) listed in the article. Articles are credited on a fractional-count basis (i.e., for articles from multiple countries/economies, each country/economy receives fractional credit on the basis of the proportion of its participating authors). Some publications have incomplete address information for coauthored publications in the Scopus database and cannot be fully assigned to a country or economy. These unassigned counts, 1% of the world total in 2013, are used to calculate this figure but are not shown. See appendix table 5-26.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com).

Science and Engineering Indicators 2016

The subject matter emphasis of scientific research varies somewhat across geographic locations. In 2013, the United States and the EU produced significant shares of the worldwide biomedical sciences (biological sciences, medical sciences, and other life sciences) articles, each larger than China's share. However, China produced a significant share of the worldwide total of engineering articles, larger than the share of the United States and the EU.

When researchers in one country cite the published work of researchers in another country, the resulting citation patterns are an indication of knowledge flows across regions. These patterns are influenced by cultural, geographic, and language ties as well as perceived impact. All other things being equal, researchers are more likely to cite work written in their native language. U.S. articles are disproportionately cited by Canadian and United Kingdom authors.

Overview

In comparison, U.S. authors cite Chinese articles less than would be expected based on the overall number of global citations to Chinese articles. These factors notwithstanding, citations to refereed articles and presentations are an oft-used indicator of the impact of research output.

U.S. publications receive the largest absolute number of citations; when adjusted for the size of each country's research pool, it joins in this measure with Canada, Switzerland, the Nordic countries, and the United Kingdom in setting the bar in the production of influential research articles. The impact of EU publications is also enhanced by recent improvement in citations for the relatively new members of the EU: Hungary, Poland, Romania, Slovakia, and Slovenia.

One measure of the influence of a country's or region's research is its share of the world's top 1% of cited articles compared to what would be expected based on the size of each country's pool of S&E publications. With this measure, if a country's share is exactly what would be expected based on size, the percentage is 1%. The U.S. percentage has held fairly steady at about twice the expected value (1.8%–1.9%), while the percentage of articles from the EU in the top 1% grew from 1.0% to 1.3% between 2001 and 2012 (Figure O-12). China's share of this top 1%, starting from a low base, almost doubled in the same period, from 0.4% to 0.8%.[i]

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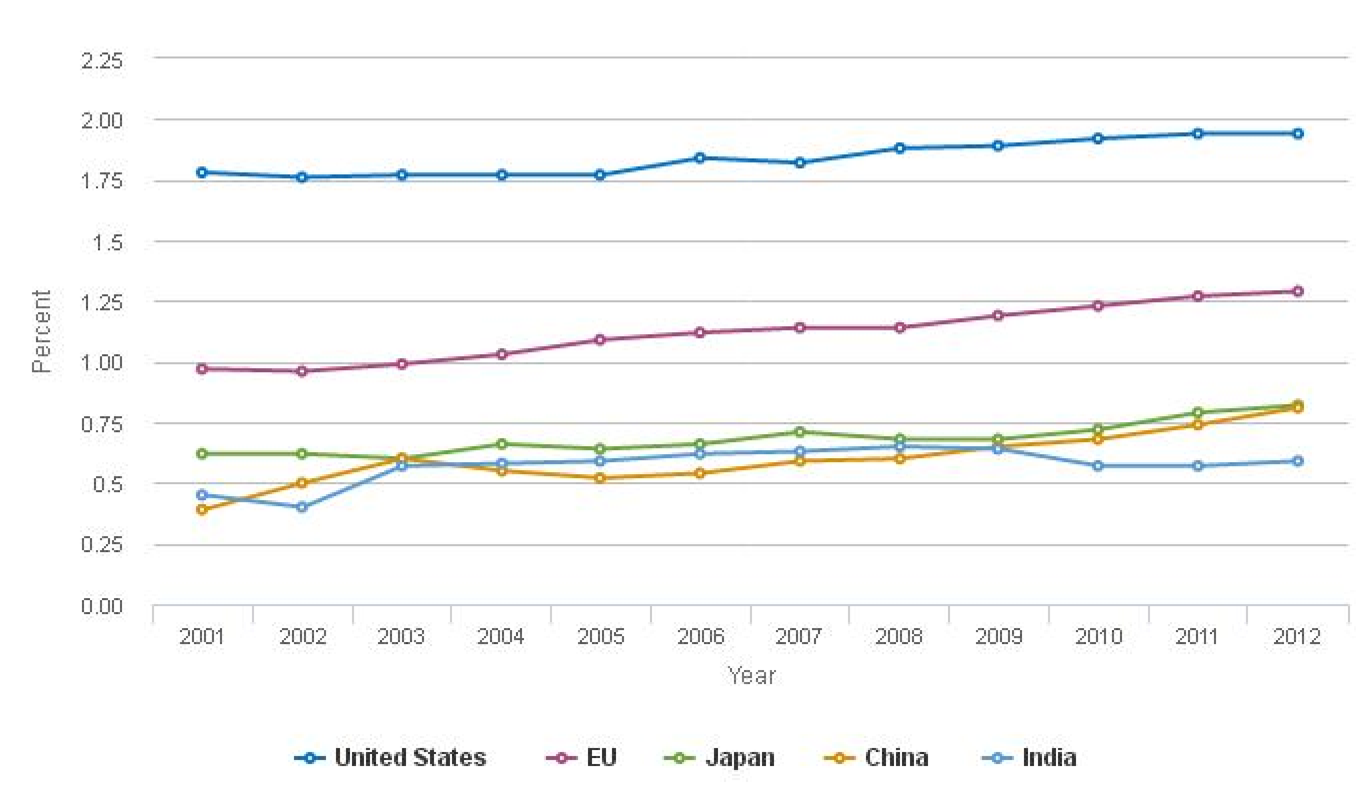
[i] The implications of these differences in top citations should be drawn with care because the data used for the analysis require that article abstracts are provided in the English language. Many publications from China have English-language abstracts but Chinese-language text, limiting their accessibility and likelihood of citation for researchers not fluent in Chinese.

Overview

Figure O-12

Share of U.S., EU, Japan, China, and India S&E articles that are in the world's top 1% of cited articles: 2001–12



EU = European Union.

NOTES: The figure depicts the share of publications that are in the top 1% of the world's citations, relative to all the country's publications in that period and field. It is computed as follows: $Sx = HCPx/Px$, where Sx is the share of output from country x in the top 1% most-cited articles; $HCPx$ is the number of articles from country x that are among the top 1% most-cited articles in the world; and Px is the total number of papers from country x in the database that were published in 2012 or earlier. Citations are presented for the year of publication, showing the counts of subsequent citations from peer-reviewed literature. At least 3 years of data following publication are needed for a meaningful measure. Publications that cannot be classified by country or field are excluded. Articles are classified by the publication year and assigned to a country/economy on the basis of the institutional address(es) listed in the article. See appendix table 5-25 for countries/economies included in the EU. The world average stands at 1.00% for each period and field.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com).

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Collaboration on S&E publications between authors of different countries has been increasing in recent years, reflecting an increased pool of trained researchers, improvements in communication technologies, and the growing international mobility of researchers. Other drivers include budget pressures on R&D spending that increase the incentives for collaboration and sharing resources and also the need to coordinate globally on challenges like climate change, infectious diseases, and the allocation of scarce natural resources (Wagner, Park, and Leydesdorff 2015).

Indicators of Innovation and Intellectual Property

Overview

S&E research and the scientific and technological knowledge produced thereby are an important, though incomplete, part of the overall innovation process (Pavitt 2005). This relationship, combined with the role of innovation as an important contributor to economic growth, drives interest in internationally comparable measures of innovation. The international standard for innovation measurement defines innovation as "the implementation of a new or significantly improved product or process, a new marketing method, or new organizational method" (OECD/Eurostat 2005:46–7). Despite this agreed standard, internationally comparable data on innovation are limited. Starting in 2008, the National Science Foundation's Business R&D and Innovation Survey provides data for the United States on the share of companies that report innovative activities. These data currently allow for cross-industry comparability within the United States. [i]

When the results of S&E research, innovative activity, or other intangibles are granted legal protection that allows their owners the right to prevent others from benefitting from their use, these intangibles are considered to be *intellectual property.* Patenting confers the rights of property to novel, useful, and nonobvious inventions for a specified period of time. While academic studies question the strength of the link between patents and innovation, strengthening of intellectual property regimes has been found to promote foreign investment, which may in turn provide a pathway for knowledge flows (Boldrin and Levine 2013). Although the propensity to patent varies across technology areas and many patents do not become commercialized or lead to practical innovations, patent grants and applications are a broad partial indicator of invention, an activity that is an important part of the innovation process.

Existing indicators in this area show dominance in the developed world, with notable growth (albeit from low bases) in the Asian economies. The United States Patent and Trademark Office (USPTO) grants patents to inventors worldwide. These patents are increasingly granted to inventors outside of the United States who are attracted by the size of the U.S. economy and the protection afforded in the United States to intellectual property. The USPTO granted nearly 300,000 patents in 2014, of which the largest share was to U.S. inventors (48%), followed by Japan (18%) and the EU (15%) (Figure O-13). Although the absolute number of USPTO patents granted to U.S. inventors increased by 61% between 2003 and 2014, the U.S. share declined by 4 percentage points in this period. Conversely, the shares of USPTO patents granted to inventors in both developed and developing economies grew.

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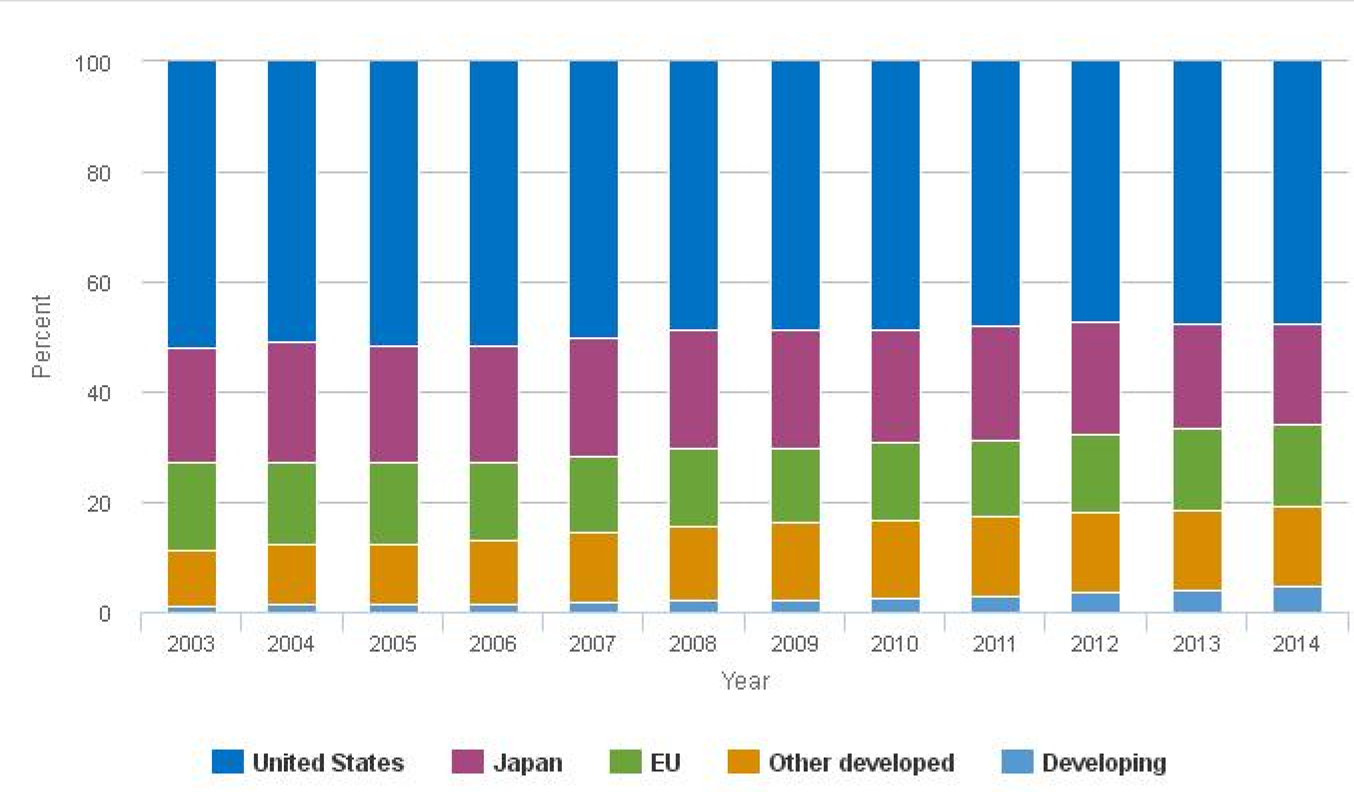
[i] The U.S. data from the Business R&D and Innovation Survey are described in chapter 6. European countries gather data on innovative activities conducted by firms in their Community Innovation Survey. Differences in survey methodologies, industry structure, and cultural differences affect the international comparability of such data. As of fall 2015, U.S. innovation data are not included in the OECD's cross-country comparisons of innovation rates. For a further discussion on this topic, see Jankowski (2013).

Figure O-13

USPTO patents granted, by location of inventor: 2003–14



EU = European Union; USPTO = U.S. Patent and Trademark Office.

NOTES: Patents are fractionally allocated among regions/countries/economies based on the proportion of residences of all named inventors. The EU includes 28 member countries. See appendix table 6-34. Developed economies are classified by the International Monetary Fund (IMF) as advanced. Developing economies are classified by IMF as emerging.

SOURCES: Science-Metrix; LexisNexis; SRI International.

Science and Engineering Indicators 2016

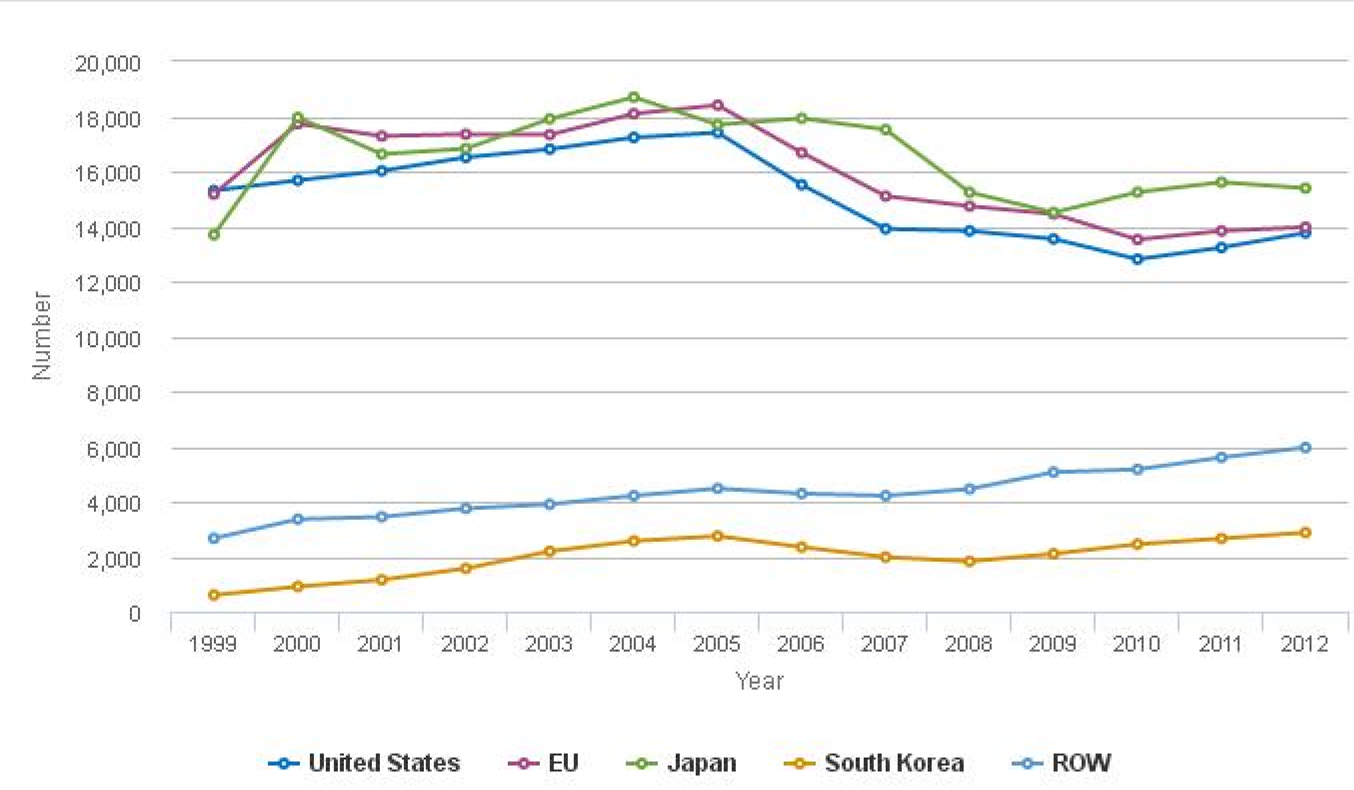
Nevertheless, the shares of U.S. patents awarded to inventors in China (3%) and India (1%) remain modest. In recent years, applications to China's patent office rose much faster than those to the USPTO and other major patent offices (WIPO 2014). Unlike USPTO patents, utility patents in China are not subject to extensive examination, and while the foreign share is growing, patents in China's patent office are overwhelmingly filed by residents of China (Hu 2010).

For any national patent office, data on the numbers of patents granted provide no indication of patent quality. *Triadic patents,* in which inventors simultaneously seek patent protection in three of the world's largest markets—the United States, Europe, and Japan—indicate patents expected to have relatively higher commercial value. In 2012, the number of these triadic patents was estimated to be about 52,000. The shares of the United States, the EU, and Japan stayed roughly similar (at around 30% each) during the 2003–12 period. Although South Korea (6%) and China (4%) increased their respective shares, they receive far fewer triadic patents than the long-standing global leaders (Figure O-14; China is included in the total for the rest of the world).

Overview

Figure O-14

Global triadic patent families, by selected region/country/economy: 1999–2012



EU = European Union; ROW = rest of the world.

NOTES: Triadic patent families include patents applied in the U.S. Patent and Trademark Office, European Patent Office, and Japan Patent Office. Patent families are fractionally allocated among regions/countries/economies based on the proportion of the residences of all named inventors.

SOURCES: Science-Metrix; LexisNexis; SRI International. See appendix table 6-51.

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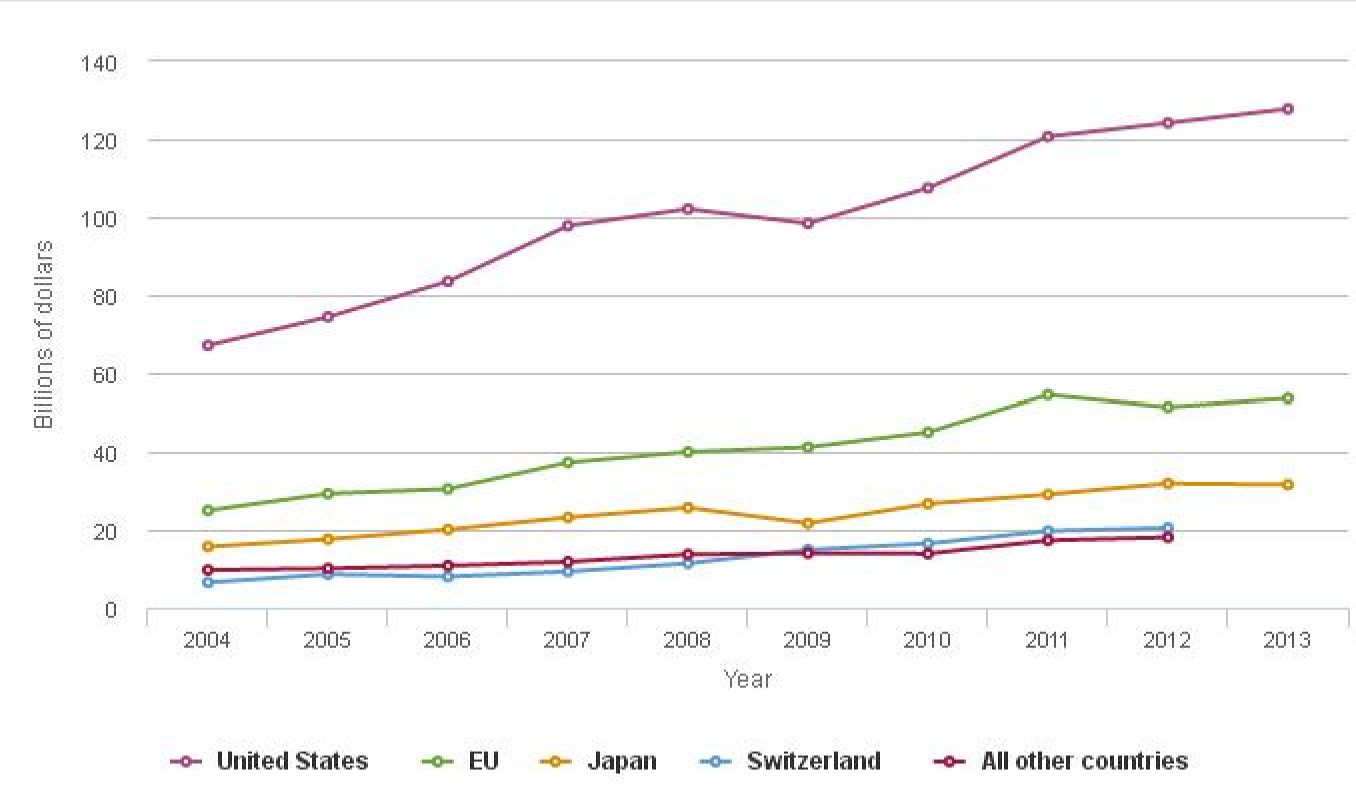
The benefits of innovation are shared when technology spreads from inventors to users. Trade in intellectual property is an indicator of the market-based diffusion of technology and innovation. One measure of intellectual property trade is the cross-border royalties and fees collected for licensing or franchising proprietary technologies.[ii] Although research in recent years has suggested that trade patterns in royalties and licensing fees are affected by different tax treatments, income from intellectual property broadly indicates which nations are producing intellectual property products with commercial value. They generally correspond to the countries and economies holding USPTO and triadic patents. Export income from royalties and fees has exhibited a strongly positive trend over the last decade (Figure O-15), not only among the major players (the United States, EU, and Japan) but also in Switzerland, Singapore, and South Korea.

[ii] For a broader discussion of this trade and the role of intellectual property protection, see The White House (2015, box 7-1).

Overview

Figure O-15

Global exports of royalties and fees, by selected region/country/economy: 2004–13



NA = not available.

EU = European Union.

NOTES: EU exports do not include intra-EU exports. Data are not available for all countries for all years.

SOURCE: World Trade Organization, International trade and tariff data, http://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 15 February 2015.

Science and Engineering Indicators 2016

Despite the rapid increase in many other S&E indicators in recent years, export income for royalties and licensing fees in the developing world is still relatively limited, consistent with these countries' relatively low shares of USPTO and triadic patents. Export income from royalties and licensing fees in 2013 was less than $0.5 billion in India and less than $1 billion in China.

Knowledge- and Technology-Intensive Economic Activity

R&D translates not only in articles, patents, and intangibles; with time, its outcomes become a visible part of economic activity in the form of products, services, and processes. S&E knowledge is increasingly a key input to production in the marketplace. Industries that intensely embody new knowledge and technological advances in their production account for 29% of global economic output. They span both manufacturing (e.g., aircraft and spacecraft, computer equipment, communications and semiconductors, pharmaceuticals, and scientific instruments) and services sectors (e.g., education, health, business, financial, and information services) (OECD 2001).

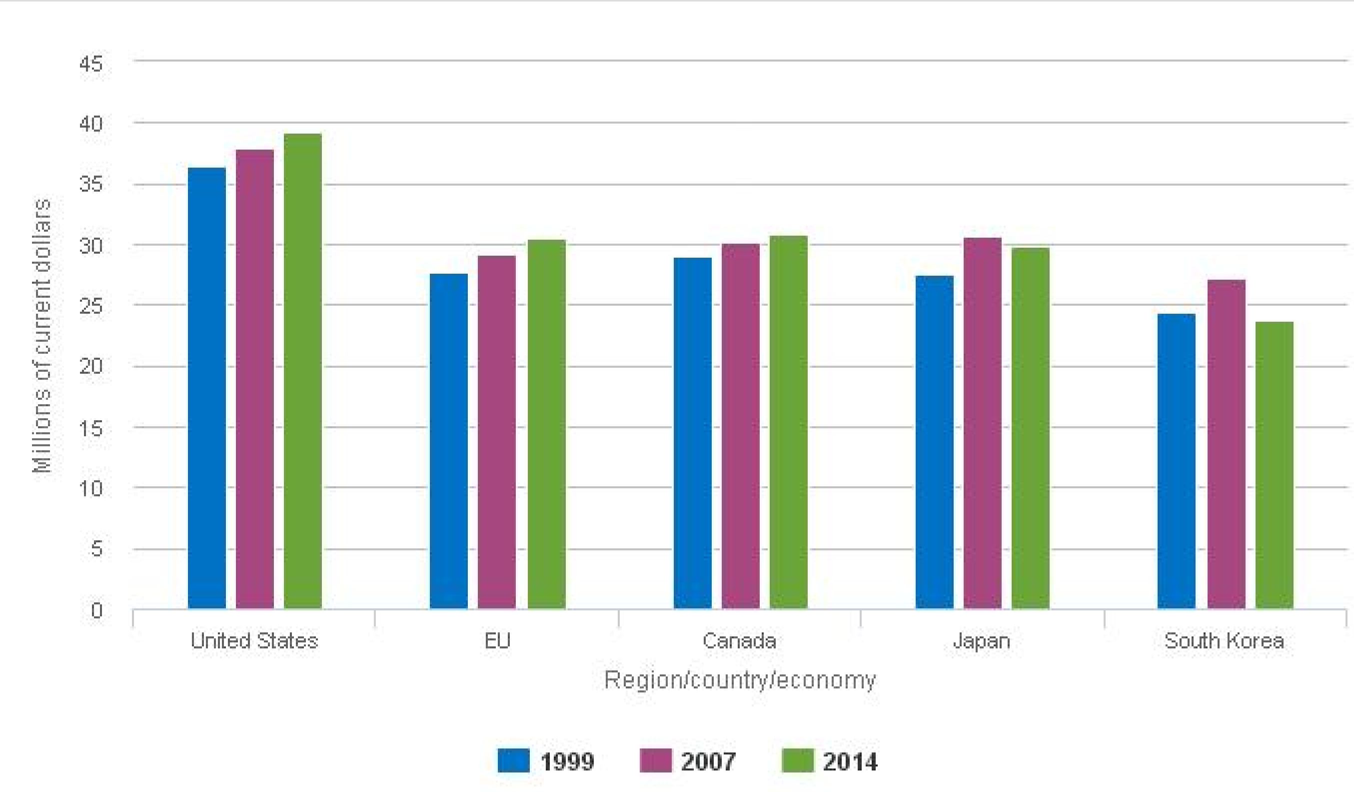
Overview

At 39%, the United States leads the world in the percentage of its GDP that comes from these high-technology (HT) manufacturing and knowledge-intensive (KI) service industries. Historically concentrated in the developed world, these industries typically make up a larger percentage of GDP in developed countries than in developing countries (Figure O-16 and Figure O-17). However, differing growth rates by sectors and by countries and economies as well as globalization of the world economy illustrate how this element of the S&E landscape is shifting globally. Advances in science and technology (S&T) now enable companies to spread knowledge- and technology-intensive (KTI) activity to various locations around the globe and to develop strong interconnections among geographically distant entities. International trade and an interconnected global supply chain link the geographically shifting KTI components together. A country's exports of goods and services produced by its KTI industries indicate its ability to compete in the world market; the supply chain underlying a country's production reflects the interdependence in the production process.

Overview

Figure O-16

KTI share of GDP, by selected region/country/economy: 1999, 2007, and 2014



EU = European Union; GDP = gross domestic product; KTI = knowledge and technology intensive.

NOTES: KTI industries include knowledge-intensive (KI) services and high-technology (HT) manufacturing industries classified by the Organisation for Economic Co-operation and Development. KI services include business, financial, communications, education, and health. HT manufacturing industries include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. Data are not available for EU members Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

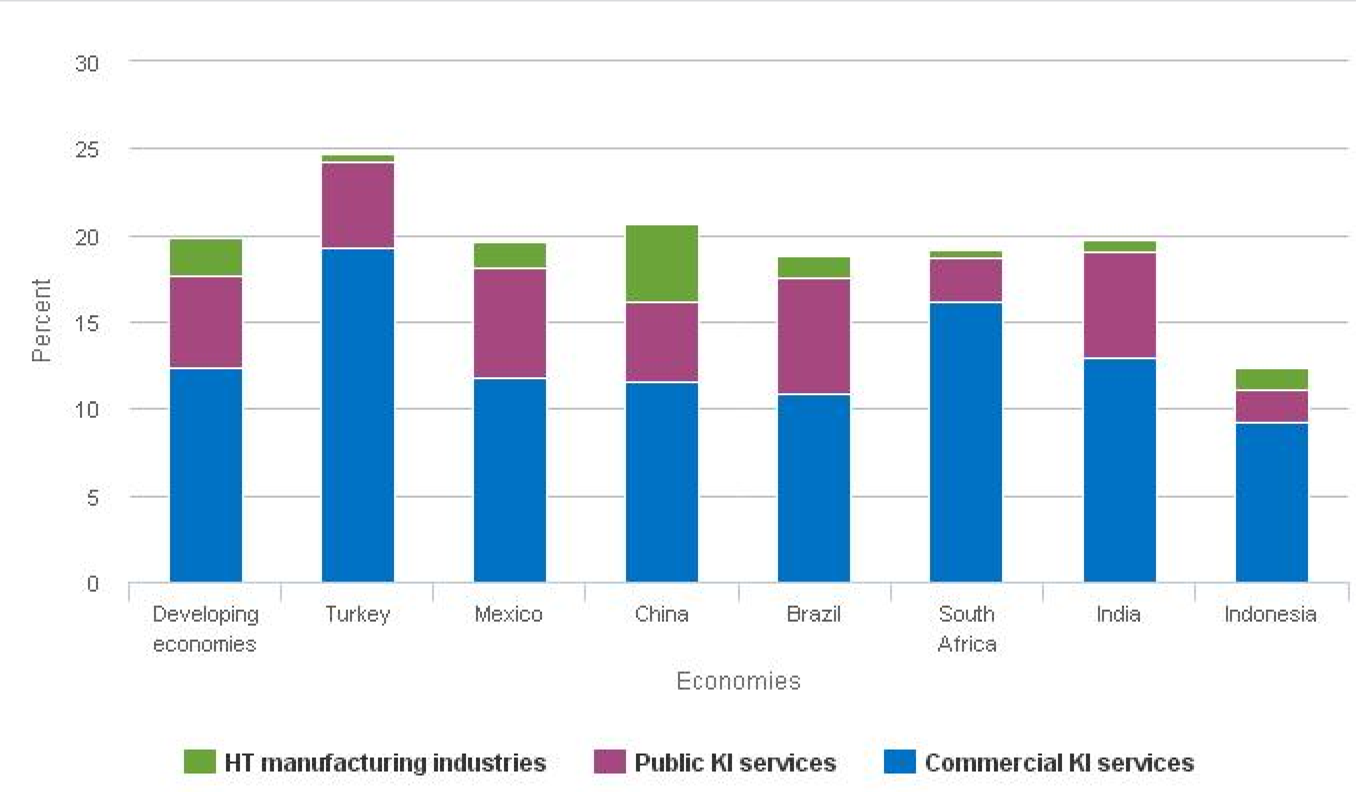
SOURCE: IHS Global Insight, special tabulations (2015) of the World Industry Service database.

Science and Engineering Indicators 2016

Overview

Figure O-17

Output of KTI industries as a share of GDP for selected developing economies: 2014



GDP = gross domestic product; HT = high technology; KI = knowledge intensive; KTI = knowledge and technology intensive.

NOTES: Output of KTI industries is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. KTI industries include KI services and HT manufacturing industries classified by the Organisation for Economic Co-operation and Development. KI services include business, financial, communications, education, and health. Commercial KI services include business, financial, and communications services. Public KI services include education and health. HT manufacturing industries include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and measuring, testing, and control instruments. Developing economies are classified by the International Monetary Fund as emerging markets.

SOURCE: IHS Global Insight, World Industry Service database (2015).

Science and Engineering Indicators 2016

In HT manufacturing (globally $1.8 trillion in value-added terms in 2014), the United States retains a slim lead as the largest global provider (29%) over China (27%), whose global share rose steeply since the turn of the century. Each country, however, concentrates in somewhat different types of activities. The United States has particular strength in aircraft and spacecraft and scientific instruments (areas where a considerable amount of U.S. business R&D resources are focused). Manufacturing of aircraft and spacecraft involves a supply chain of other HT inputs—navigational instruments, computing machinery, and communications equipment—many of which continue to be provided by U.S. suppliers.[i] China—whose output of HT manufacturing rose by a factor of 10 between 2001 and 2014 (Figure O-18)—is the largest producer of ICT goods (communications, computers, and semiconductors), in which it holds a 39% global share,[ii] and of pharmaceuticals (28%). In both countries, output growth was only briefly slowed by the Great Recession and has rebounded in recent years (Figure O-18). In the EU and Japan, however, HT manufacturing output has stagnated or declined over the same time frame.

Overview

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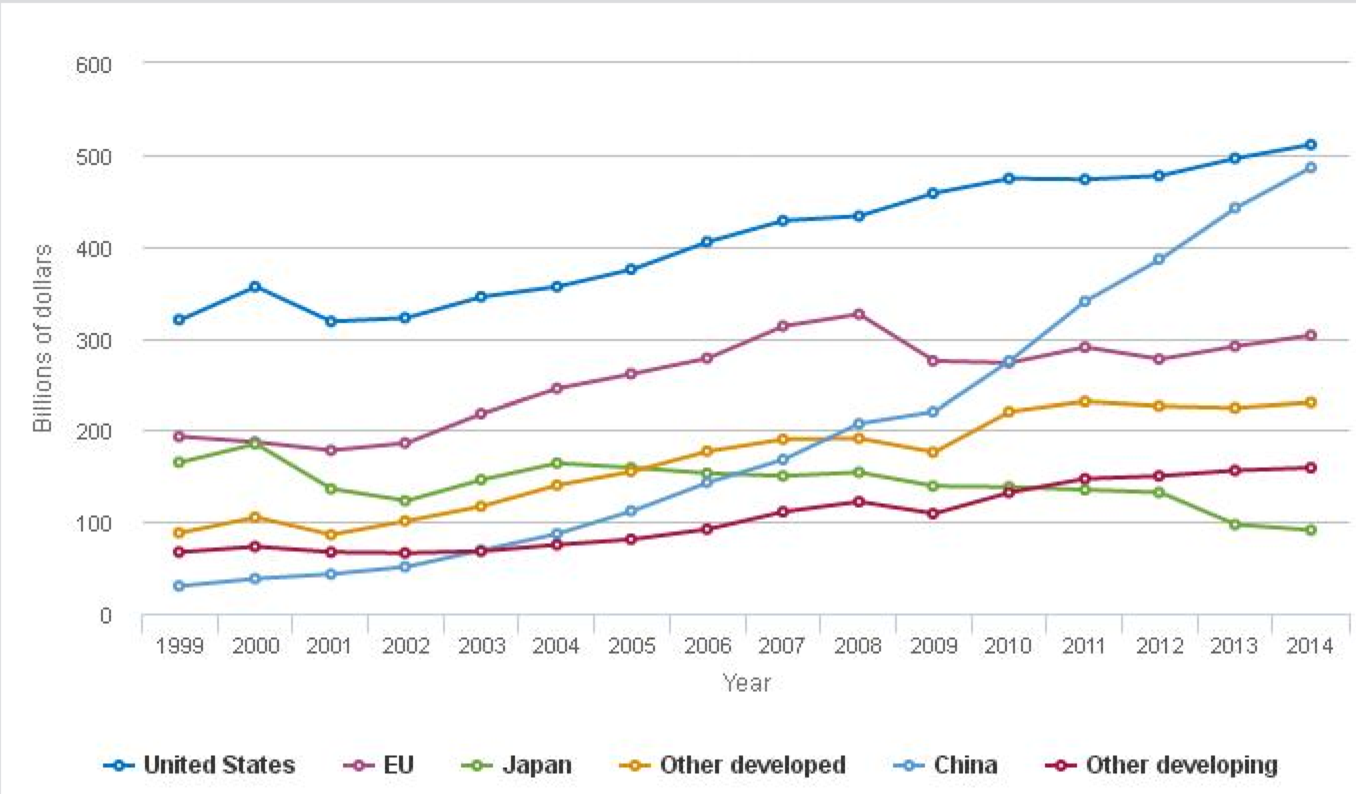
[i] As of 2012, Boeing reported that U.S. companies supply 75% of its supply chain inputs (http://787updates.newairplane.com/787-Suppliers/World-Class-Supplier-Quality).

[ii] The ICT sector includes communications equipment, computers, and semiconductors.

Overview

Figure O-18

Value added of HT manufacturing industries for selected regions/countries/economies: 1999–2014



EU = European Union; HT = high technology.

NOTES: Output of HT manufacturing industries is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. HT manufacturing industries are classified by the Organisation for Economic Co-operation and Development and include aircraft and spacecraft, communications, computers, pharmaceuticals, semiconductors, and testing, measuring, and control instruments. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Developed countries classified are those classified as advanced by the International Monetary Fund (IMF). Developing countries are those classified as emerging by IMF.

SOURCE: IHS Global Insight, World Industry Service database (2015).

Science and Engineering Indicators 2016

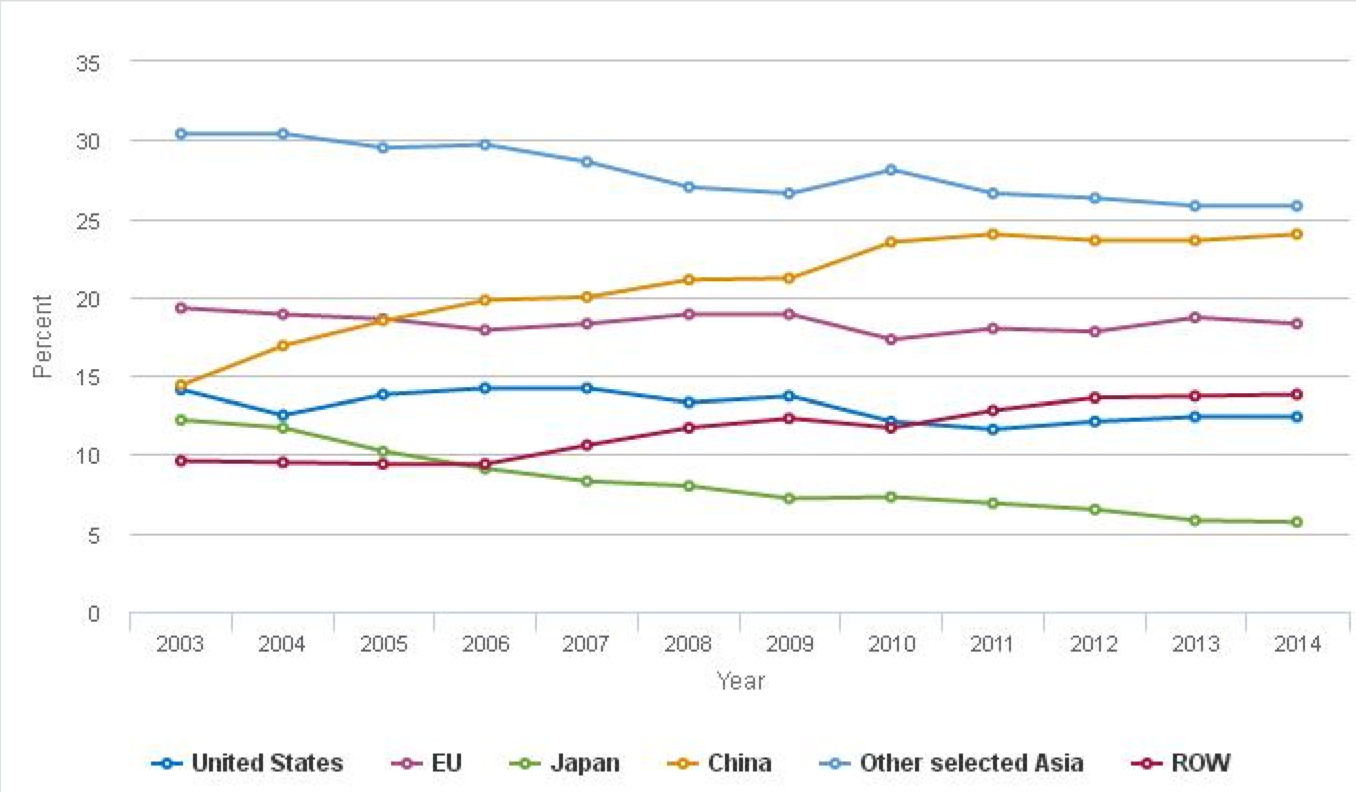
Notwithstanding China's rapid advances, HT manufacturing in this country continues to be heavily dependent on lower value-added activities, such as final assembly. In semiconductors, for example, although Chinese companies have gained global market share, China remains largely reliant on semiconductors supplied by foreign firms for most of its production of smartphones and other electronic products (PwC 2014). In the pharmaceutical sector, output is largely made up of the production of generic drugs by China-based firms and the establishment of production facilities controlled by U.S. and EU multinational corporations (MNCs) (Huang 2015). Many MNCs continue to conduct their higher value-added activities in developed countries because of the greater availability of skilled workers and stronger intellectual property protection. However, China's rapid investments in R&D (much of which is focused on manufacturing), education, and scientific publications may unfold a potential path toward producing more high value-added products, although many social, economic, and political factors in addition to S&E capabilities will likely affect such a path.

Overview

Globally, exports of HT products totaled $2.4 trillion in 2014. ICT products account for more than half of global HT exports, with a large share of ICT concentrated in East and Southeast Asia (China, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand). China alone accounts for about one-quarter of the global share, but its activities remain focused on low-value activities—final assembly of advanced inputs and components imported from other countries and manufacture of low-technology inputs and components. As a result, China's exports of certain finished products are likely overstated because existing trade statistics include the total market value of finished products. The countries that manufacture and supply advanced inputs and components to China, including the United States, EU, Japan, South Korea, and Taiwan, account for much greater value added than China. In the years since 2007, the growth of HT exports from the rest of the world (Figure O-19), particularly Brazil, the United Arab Emirates, India, and Australia, has been relatively rapid. Vietnam experienced the fastest rate of HT export growth, expanding from $3 billion in 2007 to $39 billion in 2014. Vietnam has become a low-cost location for assembly of cellular phones and smartphones and other ICT products, with some firms shifting production out of China, where labor costs are higher.

Figure O-19

Exports of HT products, by selected region/country/economy: 2003–14



EU = European Union; HT = high technology; ROW = rest of the world.

NOTES: HT products include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. China includes Hong Kong. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Exports of the United States exclude exports to Canada and Mexico. Exports of the EU exclude intra-EU exports. Exports of China exclude exports between China and Hong Kong. Other selected Asia consists of Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand.

SOURCE: IHS Global Insight, World Trade Service database (2014).

Science and Engineering Indicators 2016

In addition to HT manufacturing, KTI industries include KI services consisting of commercial services (business, financial, and communication) and public services (education and health).[iii] The largest commercial KI service is business services, which includes the technologically advanced industries of computer programming and R&D services. The large size of business services reflects the widespread practice of businesses and other organizations to purchase various services rather than provide them in-house, particularly in developed countries.

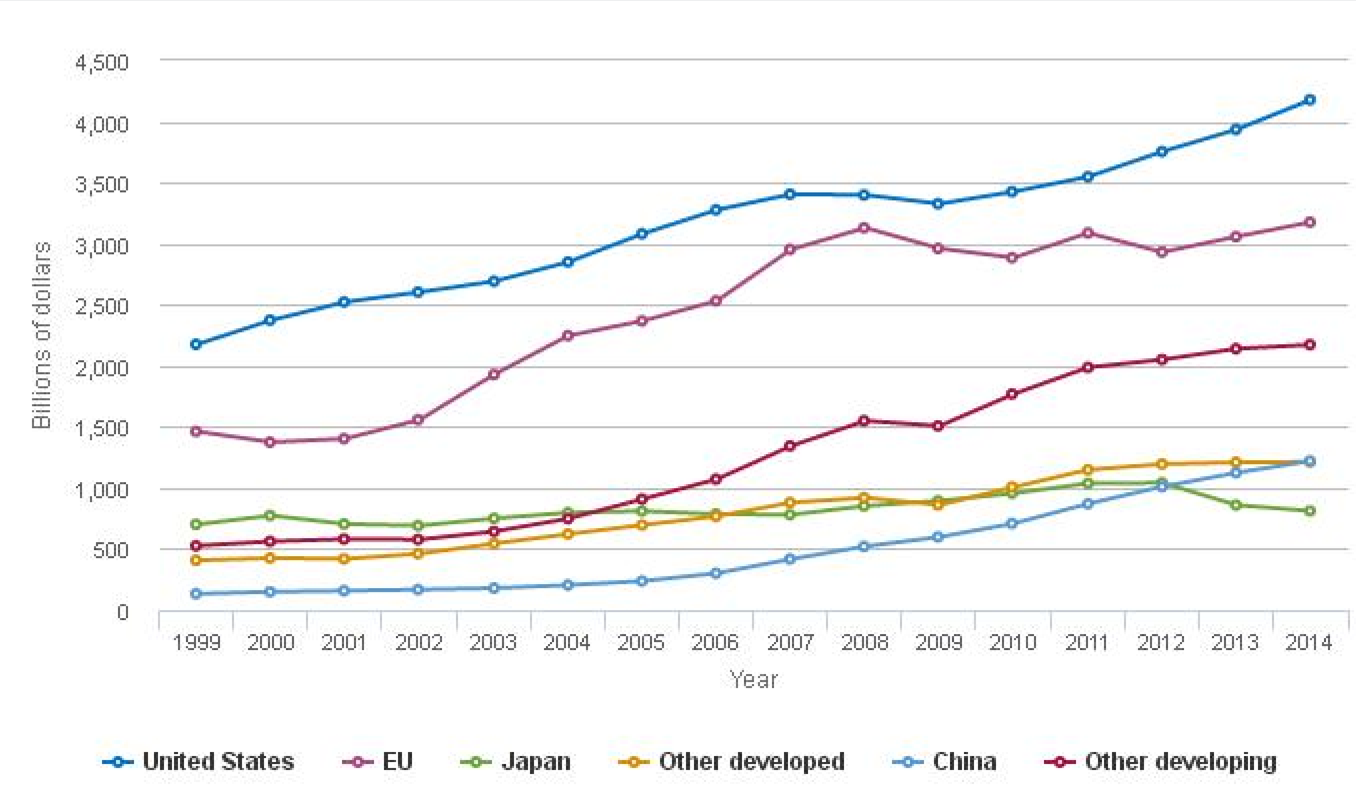
The global output of commercial KI services (which total $12.8 trillion in value-added terms in 2014) is concentrated in the developed world, with the United States (33%) and the EU (25%) accounting for more than half of the global output. Much like HT manufacturing, however, commercial KI services output has stagnated in the EU following the Great Recession due to member countries' overall weak economic growth. In the United States, output rebounded, led by business services and financial services. One source of growth of U.S. business services has been the infrastructure boom in developing countries, which has resulted in the employment of U.S. firms in areas including architecture, engineering, and consulting services. China remains relatively weak in commercial KI services, accounting for 10% of global output, but is making increasingly rapid progress. China's commercial KI services, led by financial and business services, were largely unaffected by the Great Recession (Figure O-20). In the rest of the developing world, Brazil, India, and Russia accounted for growing shares of global commercial KI services output. Brazil's growth was led by financial and information services, and India's growth was led by business services, particularly in computer programming.

[iii] Public KI services—health and education—are much less market driven than other KTI industries. Additionally, international comparison of these sectors is complicated by variations in the size and distribution of each country's population, market structure, and the degree of government involvement and regulation. As a result, differences in market-generated value-added data may not accurately reflect differences in the relative value of these services. The overview presents other indicators for education, such as data on degrees awarded.

Overview

Figure O-20

Value-added output of commercial KI services for selected regions/countries/economies: 1999–2014



EU = European Union; KI = knowledge intensive.

NOTES: Output of knowledge- and technology-intensive industries is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Developed countries are those classified as advanced by the International Monetary Fund (IMF). Developing countries are those classified as emerging by IMF.

SOURCE: IHS Global Insight, World Industry Service database (2015).

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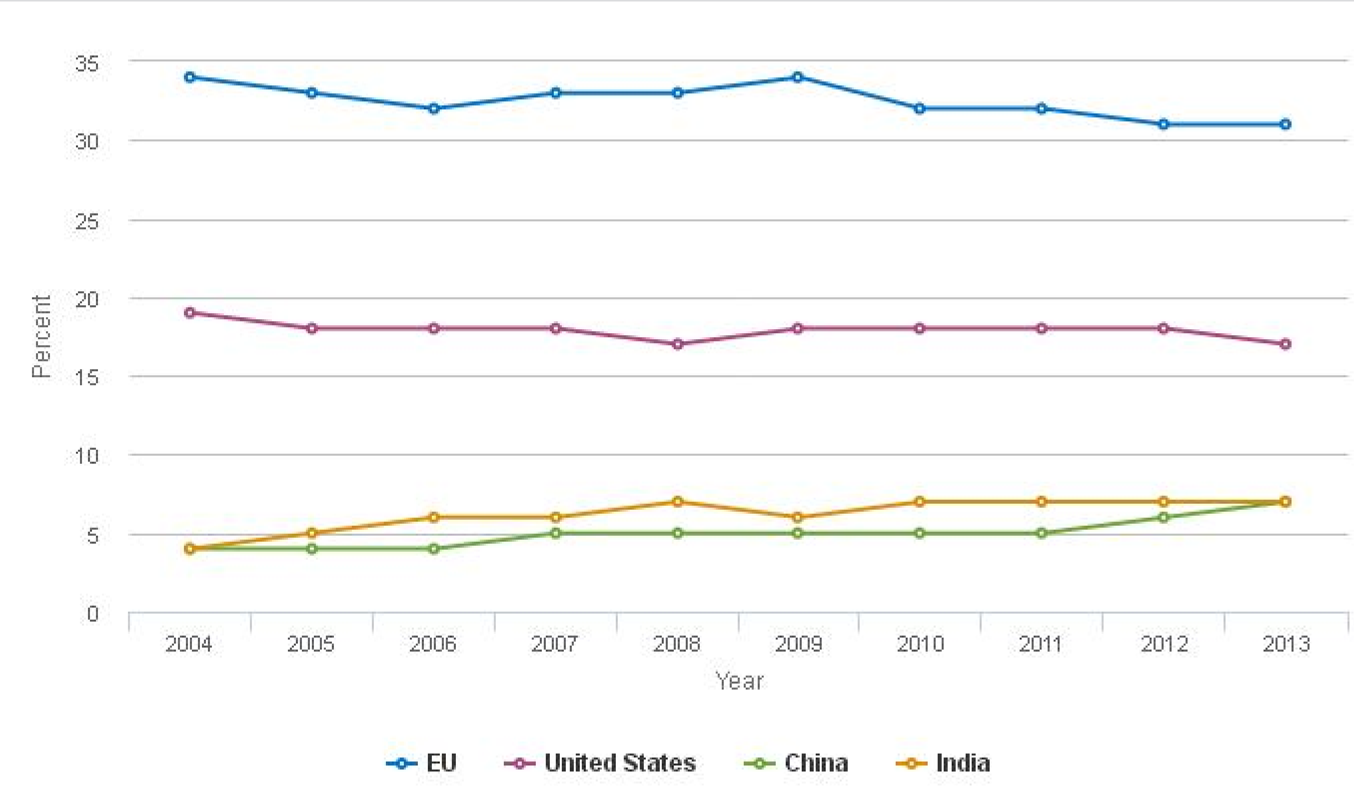
Globally, exports of commercial KI services totaled $1.5 trillion in 2013. The trade of commercial KI services around the world is facilitated in part by the outsourcing activities of multinational corporations, taking advantage of economies with well-educated and multilingual populations. In 2013, the EU and the United States together accounted for just under half (48%) of the exports in commercial KI services; China and India each accounted for 7% (Figure O-21). India, however, represents a considerable share (26%) of global exports in computer and information services, primarily reflecting IT, accounting, legal, and other services provided to developed countries.

Overview

Figure O-21

Commercial KI service exports, by selected region/country/economy: 2004–13



EU = European Union; KI = knowledge intensive.

NOTES: Commercial KI service exports consist of communications, business services, financial services, and computer and information services. Financial services includes finance and insurance services. EU exports do not include intra-EU exports.

SOURCE: World Trade Organization, International trade and tariff data, http://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 15 February 2015.

Science and Engineering Indicators 2016

Global S&E Activity to Address Energy and Health Challenges

Globally, many S&E activities are focused on addressing urgent challenges in the domains of health and energy. These activities are developing knowledge and technologies that aim to cure diseases, generate clean and affordable energy, and contribute to improved living standards. They are closely linked to scientific R&D, are often global in scope, and involve developed and developing nations, as different nations bring different perspectives and approaches to this endeavor. The United States and the EU, for example, have more-focused efforts on research and knowledge production, whereas China continues to concentrate on later-stage commercial production.

Energy

Global activity aimed at generating alternative and affordable energy includes financing, research, patenting, and production in the areas of biofuels, solar, wind, energy efficiency, pollution prevention, smart grid, and carbon sequestration. In response to rising energy demand, volatile costs of fossil fuels, and efforts to reduce emissions of greenhouse gases, governments around the world have enacted various policy measures, including subsidies and tax incentives. Governments have also increased funding to spur both public and private efforts to develop effective and affordable alternative energy sources. Public investment in research, development, and demonstration in alternative energy and other non-fossil fuel technologies totaled an estimated $12.7 billion in 2013. It is led by the EU, with $4.4 billion in investment, followed by the United States ($3.5 billion), Japan ($2.6 billion), and Canada ($0.8 billion).

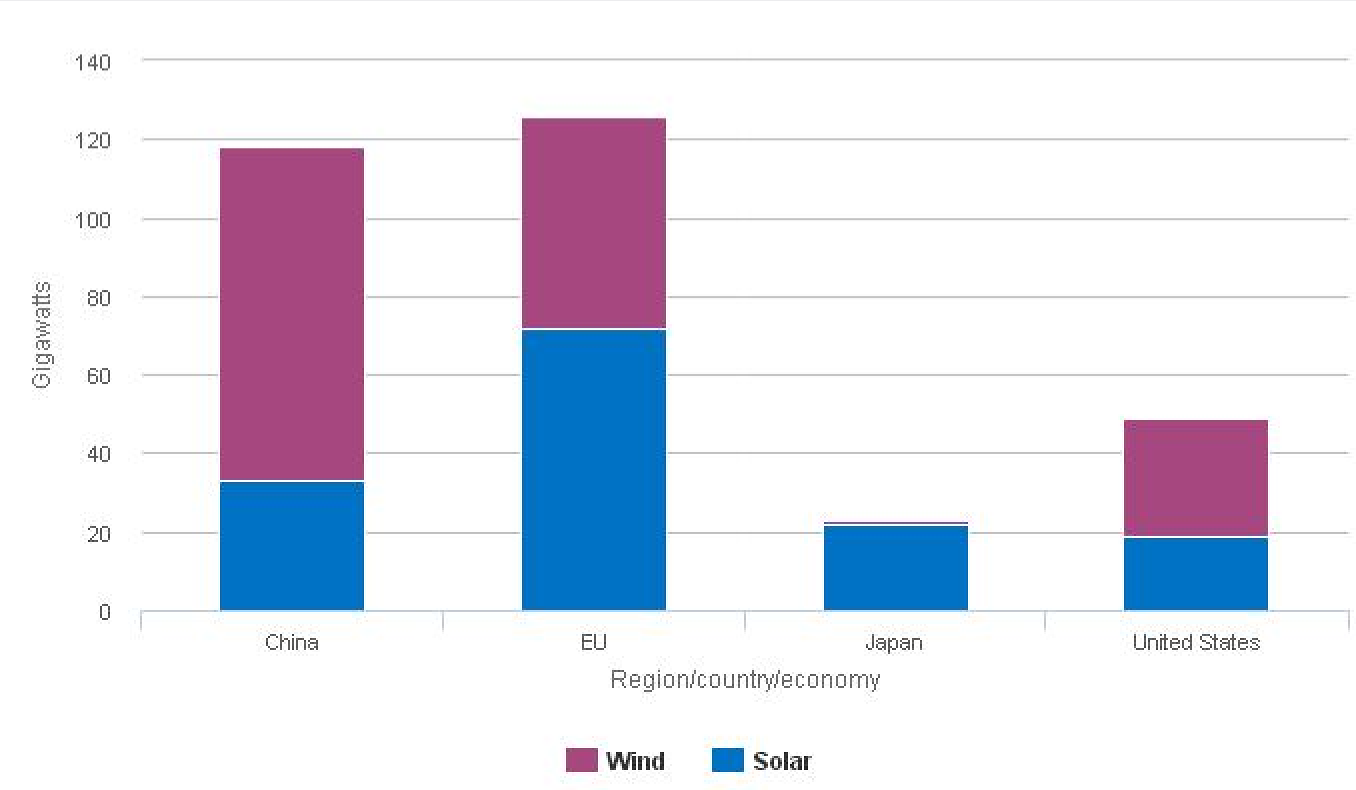
Globally, among the non-fossil fuel technologies, renewable energy was the largest area of public investment, followed by nuclear energy and energy efficiency. The large role of the public sector in these areas is not surprising, given that these technology areas require establishment of regulatory and safety frameworks as well as large investment for testing and demonstration. EU investment has grown due to increases in funds for carbon dioxide capture and storage, renewables, and energy efficiency. Following the earthquake in northeast Japan in 2011, Japanese investment in nuclear energy has fallen.

With respect to production, commercial investment in clean and renewable energy totals about $281 billion in 2014. China attracts 31% of the global commercial investment in clean energy, followed by the EU (17%) and the United States (15%). Solar and wind are the largest components of renewable energy. In commercial investment for both solar and wind, China is the leading country. The production components resulting from such commercial investment support the generation capacity of renewable energy across the globe. China has become the leader in the production of low-cost photovoltaic modules that convert sunlight into electricity. In the areas of solar and wind generation capacity, an indicator of potential production of renewable energy, China has grown rapidly. Notably, the EU has the highest solar generation capacity, whereas China has the highest wind generation capacity (Figure O-22).

Overview

Figure O-22

Cumulative installation of generation capacity of solar and wind, by energy source and selected region/country/economy: 2010–14



EU = European Union.

NOTE: Renewable energy includes biomass and waste, geothermal, hydropower, marine, solar, and wind.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2014).

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China's leadership in total commercial investment in clean energy primarily reflects financing of later stages of development in relatively mature areas of clean energy. By contrast, the United States leads in the small share of commercial investment (2% of total commercial investment) that reflects venture capital and private equity investment. These investments primarily focus on emerging and future trends in clean energy technologies. Over the 2010–14 period, smart energy (e.g., digital energy applications, efficient lighting, electric vehicles, efficient smart grid) has been the largest technology area in the United States attracting such investment from all over the world, followed by solar and biofuels.

Patenting in alternative energy and pollution control technologies is also concentrated in the developed world. U.S. inventors were granted 43% of all USPTO clean energy and pollution control patents in 2014, followed by Japan (21%), the EU (17%), and South Korea (9%). Between 2003 and 2014, South Korea's share rose from 2% to 9% due to strong growth in hybrid and electric vehicles, battery, and fuel cell technology. USPTO patents granted to China and Taiwan remain low, with each accounting for about 2% of global share in 2014, up from 1% or less in 2003.

Health

Overview

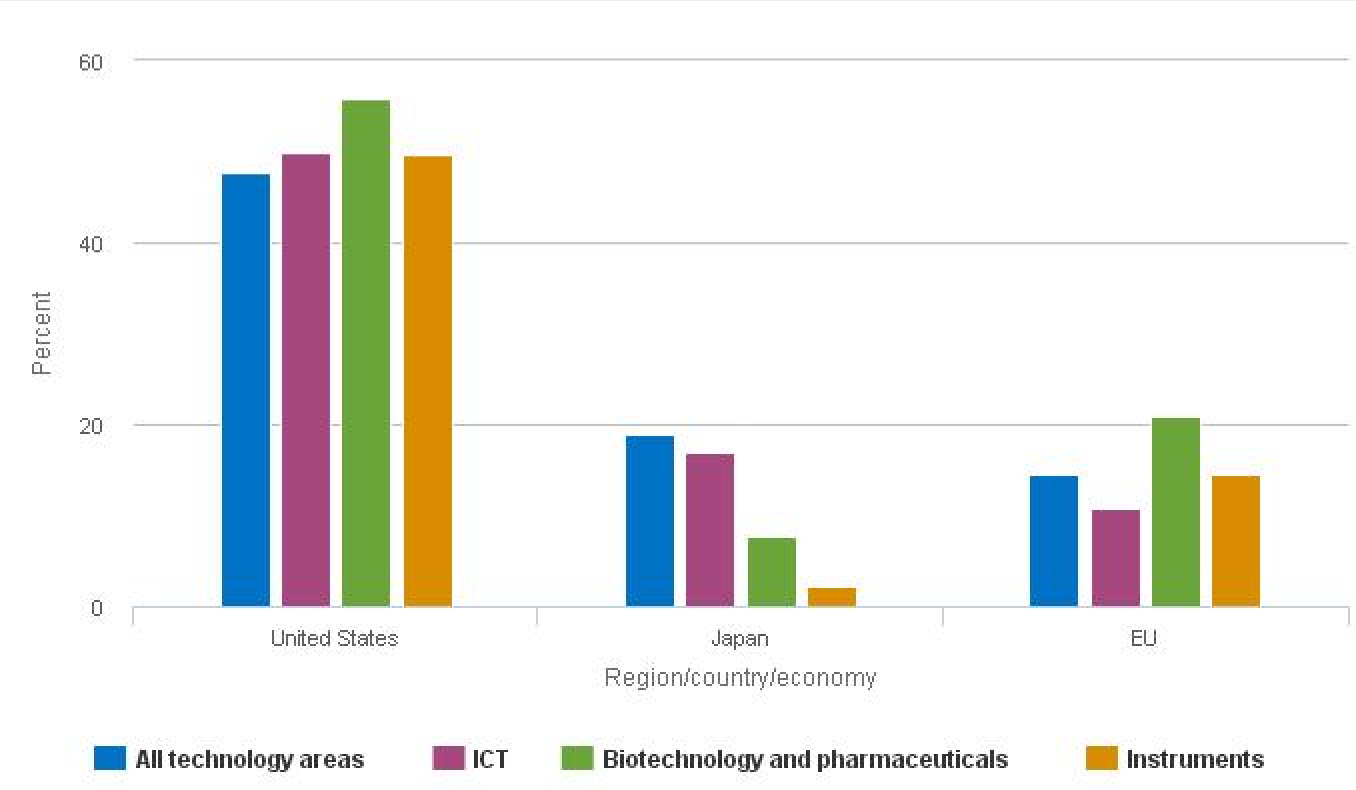
Research in biological and medical sciences and patenting, as well as venture capital and production activity in life sciences, represents global activity related to health. These activities are also spread broadly across the world with a similar degree of specialization between research and production. Research publications reflect contributions to knowledge devoted to health; S&E publications in the United States and the EU are more focused in biological, medical, and other life sciences than the rest of the world. Almost half (48.7%) of the United States' publications are in these areas. Health-related research is an important focus in parts of the developing world as well; India shares the distinction with the United States of having the highest concentration of publications in biological sciences.

Patents are an indicator of the translation of research and other inventive activity into potentially useful innovations. With respect to patenting data from USPTO, the United States and the EU both have greater-than-average patenting activity in biotechnology and pharmaceuticals (Figure O-23), and the EU has an additional concentration in biological materials (see Chapter 6 for detailed data).

Overview

Figure O-23

USPTO patents granted, by selected technology areas for selected region/country/economy of inventor: 2012–14



EU = European Union; ICT = information and communications technologies; USPTO = U.S. Patent and Trademark Office.

NOTES: Technologies are classified by the World Intellectual Property Organization. Patents are fractionally allocated among countries on the basis of the proportion of the residences of all named inventors. ICT consists of computer, semiconductors, telecommunications, digital communications, basic communication processes, and information technology method management. Instruments consists of the following categories: analysis of biological materials, control, measurement, medical technology, and optics.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; USPTO. See appendix tables 6-34–6-49.

Science and Engineering Indicators 2016

However, in terms of production activity, China is now the leader in pharmaceutical manufacturing in terms of quantity of output, and this activity is also growing rapidly in India. The growth in China represents both Chinese firms and outsourced manufacturing by multinational corporations focused primarily on generics. Pharmaceutical manufacturing in India is conducted primarily by domestic firms and also includes the production of generic drugs (Greene 2007).

Summary and Conclusions

The global S&E landscape has experienced dramatic shifts. Over time, the cumulative effect of different growth rates in S&E investment and of different areas of S&E concentration across the globe has led to two outcomes: the "catching up" in particular indicators of S&E activity in parts of the developing world, and the specialized concentrations of global preeminence for developed nations that historically led the global efforts in S&E. As a result, a multipolar world for S&E has emerged after many decades of leadership by the developed world. These developments have taken place in the context of an increasingly interconnected world for S&E activity. Capacity building around the world in R&D and human capital infrastructure, along with improvements in communications technology, has facilitated the interconnected nature and greater international collaboration in S&E activities.

Academic institutions in the developed world continue to be centers of excellence, conducting high-impact S&E research and providing graduate education in S&E to students from across the world. The United States continues to lead in the production of advanced degrees in S&E, while several northern European countries have emerged as centers of high-impact public research, as evidenced by shares of highly cited publications. The impact of S&E research in the relatively new members of the EU has also been growing in recent years, as demonstrated by increased citations from Hungary, Poland, Romania, Slovakia, and Slovenia.

Academic institutions in the developing world have increased their production of graduates with S&E degrees, with China leading the growth in the number of these graduates. R&D expenditures in Asia have also grown rapidly, particularly in China and South Korea. In the United States and the EU, growth has continued but at a slower rate. As a result, China's R&D expenditures are now second only to those of the United States in annual magnitude. China's rapid growth in R&D expenditures and in S&E degrees (both at the bachelor's-degree and doctoral-degree levels) spurred growth in S&E publications.

R&D concentration and intellectual property–related activity are increasingly multipolar; several relatively small economies appear to be specializing in S&E, as evidenced by high rates of R&D intensity in countries such as Israel, South Korea, Taiwan, and Singapore. Commercial S&E activity has a large concentration in parts of East and Southeast Asia; although Japan has been declining in some measures of S&E activities related to knowledge creation (such as shares of S&E publications), the country still rates highly in terms of patents granted. South Korea and Taiwan have experienced rapid growth in patenting and in intellectual property exports.

KTI production and trade account for increasing shares of global output and are closely related to country and regional investment in S&E education and in R&D activity. Production and assembly of high-tech goods have emerged in the developing world, particularly in China, where ICT and pharmaceutical manufacturing have become large shares of global production. Exports of high-technology products are centered in Asia, where China accounts for one-quarter of all such exports, but smaller nations such as Vietnam are expanding rapidly. This production activity, however, often represents the final phase of the global supply chain, where components designed or produced in other countries are transformed into final products.

The developed world, particularly the economies of the United States, the EU, and Japan, maintains the bulk of KI commercial services production and exports, the assignment of patents, and receipts for the use of intellectual property. Intellectual property activities in particular are concentrated in developed economies, both large and small. These developments reflect S&E components of the global value chain, where different regions contribute to global activity based on relative strengths.

This overview has attempted to provide a dynamic summary of the world of S&T as it currently exists and how it has developed over the past decade or more. It has identified some trends that keep working in the direction of

Overview

changing some of the major patterns. Because of the inherent lag associated with the collection and dissemination of high-quality data, the full degree and future direction of such changes become more apparent with the arrival of newer data. As such, the current state of the world depicted in this overview should not be seen as static but rather should be interpreted in the context of a dynamic and integrated world, tied together by global infrastructures and interdependent processes that continue to unfold.

Overview

Glossary

Applied research: The objective of applied research is to gain knowledge or understanding to meet a specific, recognized need. In industry, applied research includes investigations to discover new scientific knowledge that has specific commercial objectives with respect to products, processes, or services (OECD 2002).

Basic research: The objective of basic research is to gain more comprehensive knowledge or understanding of the subject under study without specific applications in mind. Although basic research may not have specific applications as its goal, it can be directed in fields of present or potential interest. This is often the case with basic research performed by industry or by mission-driven federal agencies (OECD 2002).

Development: Development is the systematic use of the knowledge or understanding gained from research directed toward the production of useful materials, devices, systems, or methods, including the design and development of prototypes and processes (OECD 2002).

European Union (EU): As of September 2015, the EU comprised 28 member nations: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom. Unless otherwise noted, Organisation for Economic Co-operation and Development data on the EU include all of these 28 members.

Knowledge- and technology-intensive (KTI) industries: Industries that have a particularly strong link to science and technology. These industries include **high-technology (HT) manufacturing and knowledge-intensive (KI) service industries**. **HT manufacturing industries** include those that spend a relatively high proportion of their revenue on R&D, consisting of aerospace, pharmaceuticals, computers and office machinery, semiconductors and communications equipment, and scientific (medical, precision, and optical) instruments (see http://www.oecd.org/sti/ind/48350231.pdf, accessed 25 August 2015). **KI service industries** include those that incorporate science, engineering, and technology into their services or the delivery of their services, consisting of business, information, education, financial, and health services. **Commercial KI services** are generally privately owned and compete in the marketplace without public support. These services are business, information, and financial services.

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Infographic: Overview of the Global S&E Landscape

An infographic visually exploring data from the Overview is available at https://www.nsf.gov/nsb/sei/infographic1/index.html.

Chapter 1.

Elementary and Secondary Mathematics and Science Education

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Highlights

Student Learning in Mathematics and Science

The National Assessment of Educational Progress (NAEP) mathematics assessment results show that average mathematics scores for fourth and eighth graders improved slightly in 2013, continuing a pattern of small but consistent increases since 2000.

- The average mathematics score of U.S. fourth graders increased by 14 points from 2000 to 2007, leveled off between 2007 and 2009, and then rose by 2 points from 2009 to 2013.
- Among U.S. eighth graders, the average mathematics score increased continually from 2000 to 2013, with a total gain of 12 points over the period.

Overall mathematics scores for twelfth graders improved slightly between 2005 and 2013.

- Between 2005 and 2013, the average mathematics score for students in grade 12 increased by 3 points.

Although the percentage of fourth, eighth, and twelfth grade students achieving a level of proficient or higher on NAEP mathematics assessments increased between 2000 and 2013, those percentages stayed well below the 50% mark.

- The percentage of students in grade 4 achieving a level of proficient or higher increased from 24% in 2000 to 42% in 2013.
- The share of grade 8 students at or above the proficient level rose by 10 percentage points to 36% from 2000 to 2013.
- The percentage of all students in grade 12 who were at or above the proficient level in 2013 stood at 26%.

Between-group differences in mathematics NAEP performance based on parent education and race or ethnicity have persisted over time but narrowed slightly since NAEP testing began in 1978.

- The average score for 9-year-old students in 2012 was 252 for white students, 226 for black students, and 234 for Hispanic students.
- The average score for 13-year-old students with at least one parent who graduated from high school was 270 in 2012, compared with a score of 296 for students with at least one parent who graduated from college.
- For 13-year-olds, the gap between black and white students narrowed by 13 points between 1978 and 2012.

Overall, students from disadvantaged backgrounds continue to lag behind their more advantaged peers, with these disparities starting as early as kindergarten.

- Scores on the Early Childhood Longitudinal Study, Kindergarten Class of 2010–11 (ECLS-K:2011), mathematics assessment show that students with parents who did not graduate high school scored 21, compared with 36 for students with at least one parent with a graduate degree.
- Students whose family income was at or below the Federal Poverty Level averaged a score of 24, whereas students whose family income was at or above 200% of the poverty line had an average score of 33.

- At the high school level, the percentage of students who were proficient at level-5 mathematics skills increased by 5 points from grade 9 to grade 11 among students whose parents graduated from high school, with gains of 7, 16, and 23 points for students whose parents had an associate's, bachelor's, or advanced degree, respectively.

In the international arena, the Program for International Student Assessment data show that the U.S. average mathematics and science literacy scores are below the average scores for all developed countries, and the United States has substantially fewer high scores and more low scores than other developed countries.

- U.S. students' average mathematics score of 481 in 2012 was lower than the average score for all developed countries, 501.
- The average science literacy score for U.S. students in 2012 was 497, lower than the average science score of 511 for all developed countries.
- The United States appreciably underproduces students in the highest levels of mathematics achievement relative to other developed countries.
- The United States also moderately underproduces students in the highest levels of science achievement and, to an extent, overproduces students in the lowest levels of mathematics and science achievement.

High School Coursetaking in Mathematics and Science

The majority of high school students are on track to finish algebra 2 and basic science courses by the end of eleventh grade.

- As of 2012, 69% of current eleventh graders (who were ninth graders in 2009) were enrolled in algebra 2 or a more advanced mathematics course.
- In 2009, 39% of ninth graders enrolled in biology. In 2012, 41% of these students, now in grade 11, were enrolled in another basic science course, chemistry, or physics.

The number of students who take Advanced Placement (AP) courses in mathematics and science continues to rise.

- The number of students who took an AP exam in mathematics or science rose from 273,000 in 2003 to 527,000 in 2013.
- Despite these increases, only 17% of high school graduates took an AP mathematics or science exam, and 10% passed.

Teachers of Mathematics and Science

The majority of K−12 mathematics and science teachers held a teaching certificate and had taught their subjects for 3 years or more.

- In 2011, the vast majority of public middle and high school mathematics and science teachers (91% and 92%, respectively) were fully certified (i.e., held regular or advanced state certification).
- Fully certified mathematics and science teachers were less prevalent in high-minority and high-poverty schools when compared with schools with more advantaged students. For example, 88% of mathematics teachers in high-poverty schools were fully certified, compared with 95% of those in low-poverty schools.

- In 2011, some 85% of public middle and high school mathematics teachers and 90% of science teachers had more than 3 years of experience.

Fully certified, well-prepared, and experienced teachers were not evenly distributed across schools or classes.

- In 2011, for example, 75% of middle school mathematics teachers in low-poverty schools had in-field degrees, compared with 63% of teachers at high-poverty schools.
- At the high school level, 95% of mathematics teachers at low-poverty schools had in-field degrees, compared with 87% at high-poverty schools.

Working conditions were also not evenly distributed across schools.

- Fully 60% of mathematics teachers at high-poverty schools reported student misbehavior interfering with teaching, compared with just over one-third in low-poverty schools.
- For example, about 55% of mathematics and science teachers at high-poverty schools reported that students' tardiness and class cutting interfered with teaching, compared with 37% of teachers at low-poverty schools.

Instructional Technology and Digital Learning

The use of instructional technology in K−12 classrooms has been growing at a rapid pace, but teachers report that resources are still not adequate.

- In 2009, 97% of K–12 public school teachers reported that they had one or more computers in their classroom, and 69% said that they or their students often or sometimes used computers during class time.
- In 2012, 55% of K–12 teachers reported that there were not enough computers for student use in their classes.

The number of students participating in online learning is also rising.

- Full-time enrollment in online schools has grown from approximately 200,000 students in 2009–10 to more than 315,000 in 2013–14.
- In 2009–10, there were an estimated 1,816,400 enrollments in distance-education courses in K–12 public school districts, representing a 473% increase from 317,100 distance-education enrollments in the 2002–03 school year.

Transition to Higher Education

Since 2006, U.S. on-time high school graduation rates have improved steadily.

- In 2006, 73% of public high school students graduated on time with a regular diploma; by 2012, the figure had climbed to 81%.
- Black and Hispanic students had the highest gains, from 61% to 76% for Hispanic students and from 59% to 68% for black students.

Significant racial and ethnic and sex differences persisted, however, with white, Asian or Pacific Islander, and female students having higher graduation rates than their counterparts.

- In 2012, the on-time graduation rate for male students lagged behind that for female students by 7 percentage points (78% versus 85%).
- In 2012, the on-time high school graduation rates for Asian or Pacific Islander and white students were 93% and 85%, respectively; both of these figures surpassed those of black, Hispanic, and American Indian or Alaska Native students (68%–76%).

Immediate college enrollment rates have increased for all students from 1975 to 2013, though differences remain for demographic groups.

- Between 1975 and 2013, the percentage of high school graduates making an immediate transition to college increased from 51% to 66%.
- In 2013, the immediate college enrollment rate of students from low-income families was 33 percentage points lower than the rate of those from high-income families (46% versus 79%).
- Enrollment rates also varied widely with parental education, ranging in 2013 from 43% for students whose parents had less than a high school education to 83% for students whose parents had a bachelor's or higher degree.

American college enrollment rates are higher than the average rate for college enrollment internationally.

- The percentage of American young adults enrolling in university-level education for the first time was 71% in 2012, surpassing the Organisation for Economic Co-operation and Development (OECD) average of 58%.
- The United States ranked eighth out of the 33 countries that participated in the OECD study in 2012.

Introduction

Chapter Overview

Concern about the ability of the United States to compete in the global economy has lent urgency to calls for reform of science, technology, engineering, and mathematics (STEM) education. Federal and state policymakers and legislators have called for national efforts to develop strong STEM pathways from high schools to colleges that eventually will expand the STEM-capable workforce in the United States. At the K–12 level, reform efforts to improve mathematics and science learning have included increasing advanced coursetaking in these areas, promoting early participation in gatekeeper courses such as algebra 1, recruiting and training more mathematics and science teachers, and expanding secondary education programs that prepare students to enter STEM fields in college.

Educators have joined in a state-led effort to develop common national K–12 mathematics and science standards, as well as assessments and indicators for monitoring progress in K–12 mathematics and science teaching and learning. So far, a majority of states have adopted and are implementing the Common Core State Standards, whereas 12 states have adopted the Next Generation Science Standards (see sidebar The Context and Content of National K-12 Mathematics and Science Standards). Considerable attention is being paid to ensure that career and college readiness standards include a strong focus on STEM education (Achieve Inc. 2013; NCEE 2013; Pellegrino and Hilton 2012), and a recent National Research Council report established 14 progress indicators that can be used to monitor STEM progress in the K-12 education system and inform decisions about improving it (NRC 2013). [i]

Following a 2011 report by the National Research Council (NRC) on successful K–12 education in STEM fields, Congress asked the National Science Foundation (NSF) to identify methods for tracking progress toward the report's recommendations. In response, a committee convened by the NRC authored a second report describing a set of 14 progress indicators related to students' access to quality learning, educators' capacity, and policy and funding initiatives in STEM. This second NRC report *Monitoring Progress Toward Successful K-12 STEM Education* (2013), addresses the need for research and data that can be used to monitor progress in the K–12 STEM education system and for making informed decisions about improving it. The recommended indicators provide a framework for Congress and relevant federal agencies to create and implement a national-level monitoring and reporting system that could support progress towards the NRC's three goals for U.S. K-12 education in the STEM disciplines. More information about the indicators can be found at http://stemindicators.org.

The Context and Content of National K-12 Mathematics and Science Standards

The Common Core State Standards (CCSS) and Next Generation Science Standards (NGSS) are the latest developments in a tradition of standards-based education reform that has become a focal point of education reform in the United States. This reform tradition can be traced back to *A Nation at Risk*, which argued that student achievement in the United States was falling behind that of other nations because of inadequacies in its education system (Gardner 1983). President George H.W. Bush convened the first national education summit in Charlottesville, Virginia, in 1989, an event that led to the articulation of six long-term reform goals (Klein 2014). The Charlottesville summit inspired each successive president to promote the development and adoption of standards and assessments through national legislation: President Clinton with the Goals 2000: Educate America Act and the Improving America's Schools Act of 1994, President George W. Bush with the No Child Left Behind Act of 2001, and President Barack Obama with the Race to the Top Fund initiated in 2009 (Klein 2014).

Independent national organizations of educators developed their own sets of standards for science and math education, beginning with the influential *Curriculum and Evaluation Standards for School Mathematics* published by the National Council of Teachers of Mathematics in 1989 (AAAS 1993; NCTM 1989, 2000; NRC 1996). Standards for learning in science and other subjects followed. Many states have used these national standards as models in developing their own standards, although their implementation has varied substantially among states (Shepard, Hannaway, and Baker 2009; Weiss 2000).

In 2009, the National Governors Association Center for Best Practices, the Council of Chief State School Officers, and Achieve Inc. coordinated an effort to develop CCSS in English language arts and mathematics. Since their 2010 release, the CCSS have received acclaim and criticism from educators, policymakers, and education advocates. Although nearly every state signed on to the CCSS initially, support has declined as implementation has progressed (Rentner and Kober 2014). In 2013, Indiana, South Carolina, and Oklahoma reversed their Common Core adoptions, and several other states are reviewing and possibly repealing the Common Core standards (Salazar and Christie 2014; Ujifusa 2014).

The status of CCSS-aligned assessments is even less certain. In 2010, the U.S. Department of Education funded two consortia of states, the Smarter Balanced Assessment Consortium and the Partnership for Assessment of Readiness for College and Careers, to create assessments aligned with the CCSS. States with voting power in the consortia had to agree to implement the assessments by the 2014–15 school year. In addition to federally funded efforts, states such as Kentucky and New York have sought to develop their own CCSS-aligned assessments, as have commercial testing corporations. Many states have experienced difficulties in implementing CCSS-aligned assessments.

The NGSS, released in 2013, were developed by Achieve Inc., the National Research Council, the National Science Teachers Association, and the American Association for the Advancement of Science in conjunction with 26 states. The NGSS have stirred less controversy than the CCSS but have been adopted by fewer states (Heitin 2014b). States have reported that they are too busy implementing CCSS to implement the new science standards simultaneously (Heitin 2014a). In addition, adoption and implementation of NGSS have not been tied to financial incentives as they have been for CCSS (Heitin 2014a).

Chapter Organization

To provide a portrait of K−12 STEM education in the United States, including comparisons of U.S. student performance with that of other nations, this chapter compiles indicators of precollege mathematics and science teaching and learning based mainly on data from the National Center for Education Statistics (NCES) of the U.S. Department of Education, supplemented by other public sources. Table 1-1 contains an overview of the topics covered in this chapter and the indicators used to address them.

Table 1-1 **Indicators of elementary and secondary school mathematics and science education**

Chapter 1. **Elementary and Secondary Mathematics and Science Education**

Topic	Indicator
Student learning in mathematics and science	• Mathematics and science performance of first-time kindergarten students in the 2010−11 and 2011−12 school years • Trends in fourth, eighth, and twelfth graders' mathematics performance through 2013 • Algebra performance of 2009 ninth graders when they were in ninth and eleventh grades (2009 and 2012) • International comparisons of 15-year-olds' mathematics and science literacy in 2012
Student coursetaking in mathematics and science	• Highest mathematics and science course enrollment of eleventh graders in 2012 • Trends in participation and performance in Advanced Placement program from 2003 to 2013
Teachers of mathematics and science	• Degrees, certification, subject-matter preparation, and experience of mathematics and science teachers in 2012 • Professional development of mathematics and science teachers in 2012 • Salaries and working conditions of mathematics and science teachers in 2012
Instructional technology and digital learning	• Review of emerging practices of instructional technology and distance education and their effects on student learning
Transitions to higher education	• Trends in on-time high school graduation rates from 2006 to 2012 • International comparisons of secondary school graduation rates in 2012 • Immediate college enrollment from 1975 to 2013 • Choice of STEM majors among U.S. undergraduate students in the 2011−12 academic year • International comparisons of college enrollment rates in 2012

STEM = science, technology, engineering, and mathematics.

Science and Engineering Indicators 2016

This chapter is organized into five sections. The first section presents indicators of U.S. students' performance in STEM subjects in elementary and secondary school. It begins with a review of national trends in scores on mathematics and science assessments in grades 4, 8, and 12. Next, it presents data from two longitudinal studies that track individual students' growth in mathematics and science knowledge over time: the Early Childhood Longitudinal Study, Kindergarten Class of 2010–11 (ECLS-K:2011), and the High School Longitudinal Study of 2009 (HSLS:09). The section ends by placing U.S. student performance in an international context, comparing the mathematics and science literacy of U.S. 15-year-olds with that of their peers in other countries.

The second section focuses on mathematics and science coursetaking in high school. Using data from HSLS:09, data from the College Board's Advanced Placement (AP) program, and data collected by the U.S. Department of Education's Office of Civil Rights (OCR), it examines high school students' participation in mathematics and science courses.

The third section turns to U.S. elementary, middle, and high school mathematics and science teachers, examining their experience, licensure, subject-matter preparation, professional development, salaries, and working conditions. All teacher indicators in this section use the latest available data, derived from the NCES 2011–12 Schools and Staffing Survey (SASS).

The fourth section examines how technology is used in K−12 education. The section begins by presenting the latest national data on the availability or use of various technological devices in classrooms, Internet access in schools, and the prevalence of online learning among K–12 students. It then provides a review of research on the effectiveness of technology as an instructional tool to improve student learning outcomes.

The fifth section focuses on indicators related to U.S. students' transitions from high school to postsecondary education. It presents national data for on-time high school graduation rates, long-term trends in immediate college enrollment after high school, transition to STEM fields at the postsecondary level, and academic preparation for college. This section also examines the high school graduation and postsecondary entry rates of U.S. students relative to those of their peers in other countries. Together, these indicators present a broad picture of the transition of U.S. students from high school to postsecondary education, the topic of chapter 2.

This chapter focuses on overall patterns and also reports variation in access to educational resources by schools' minority concentrations and poverty levels and in student performance by sex, race or ethnicity, and family and school characteristics. Whenever a comparative statistic is cited in this chapter, it is statistically significant at the 0.05 probability level.

Student Learning in Mathematics and Science

Increasing academic achievement for *all* students—with an emphasis on improving the performance of low-achieving students—is a critical goal of education reform in the United States. Many educators and policymakers focus on improving student learning in STEM subjects because workers' proficiency in STEM fields is considered vital to the health of the economy (Atkinson and Mayo 2010; PCAST 2012). This section presents indicators of U.S. students' performance in STEM subjects in elementary and secondary school. It begins with a review of national trends in scores on mathematics assessments, using data from the National Assessment of Educational Progress (NAEP). Next, it presents data from two longitudinal studies that track individual students' growth in mathematics and science knowledge over time: ECLS-K:2011 and HSLS:09. The section ends by placing U.S. student performance in an international context, comparing the mathematics and science literacy of U.S. 15-year-olds with that of their peers in other countries.

The data from these various sources reveal several key findings. Students' scores on mathematics assessments show some small improvements, continuing a pattern of small but consistent increases over time. Proficiency levels have also improved but remain below 50% for all age groups. Data for the nation's elementary and high school students reveal that achievement gaps in mathematics continue to persist for students from disadvantaged backgrounds, and international assessments reveal that the United States lags behind other developed countries in average mathematics and science literacy scores.

National Trends

This subsection looks at trends in U.S. students' achievement in mathematics over time, presenting estimates from the NAEP. Two NAEP data collections contribute to this discussion: data from the main NAEP demonstrate changes since 1990 in the mathematics performance of students in grades 4, 8, and 12, whereas NAEP long-term trend (LTT) data allow examination of the mathematics performance of 9-, 13-, and 17-year-old students since 1973. This section's analysis includes new mathematics data from the main NAEP 2013 and the NAEP LTT 2012. New science data were not available for analysis in this edition. The most recent available findings based on NAEP science data have been reported in previous editions of *Science and Engineering Indicators* (NSB 2012, 2014).

Although the main NAEP and the NAEP LTT both assess mathematics, there are several differences between them, particularly in the content assessed, how often the assessment is administered, and how the results are reported. These and other differences mean that results from the main NAEP and the NAEP LTT cannot be compared directly. The main NAEP content frameworks and assessments are updated periodically to reflect changes in contemporary curriculum standards, whereas the NAEP LTT content frameworks in science and mathematics have remained the same since about 1970.[i] The following analyses of national trends used cross-sectional data from the main NAEP to examine recent performance and from the NAEP LTT to examine trends going back to 1978.

Reporting Results for the Main NAEP

The main NAEP reports student performance in two ways: scale scores and student achievement levels. Scale scores, designed to measure student mathematics learning, range from 0 to 500 for grades 4 and 8 and from 0 to 300 for grade 12. Student achievement levels developed by the National Assessment Governing Board, with broad input from the public, educators, and policymakers, indicate the extent of students' actual achievement expected for a particular grade level. The three grade-specific achievement levels for mathematics (NAGB 2010) are the following:

- *Basic:* partial mastery of materials
- *Proficient:* solid academic performance
- *Advanced:* superior academic performance

Mathematics Performance of Students in Grades 4 and 8 from 2000 to 2013

Average score. The average mathematics score of U.S. fourth graders increased by 14 points from 2000 to 2007, leveled off between 2007 and 2009, and then rose by 2 points from 2009 to 2013 (Figure 1-1). This overall trend was reflected in almost all demographic groups. For example, from 2000 to 2007, the fourth grade average mathematics score increased by 14 points for white students, 19 points for black students, 19 points for Hispanic students, and 20 points for American Indian or Alaska Native students (Appendix Table 1-1). Average scores for these racial and ethnic groups generally remained unchanged between 2007 and 2009 and then increased by 2 to 4 points from 2009 to 2013.

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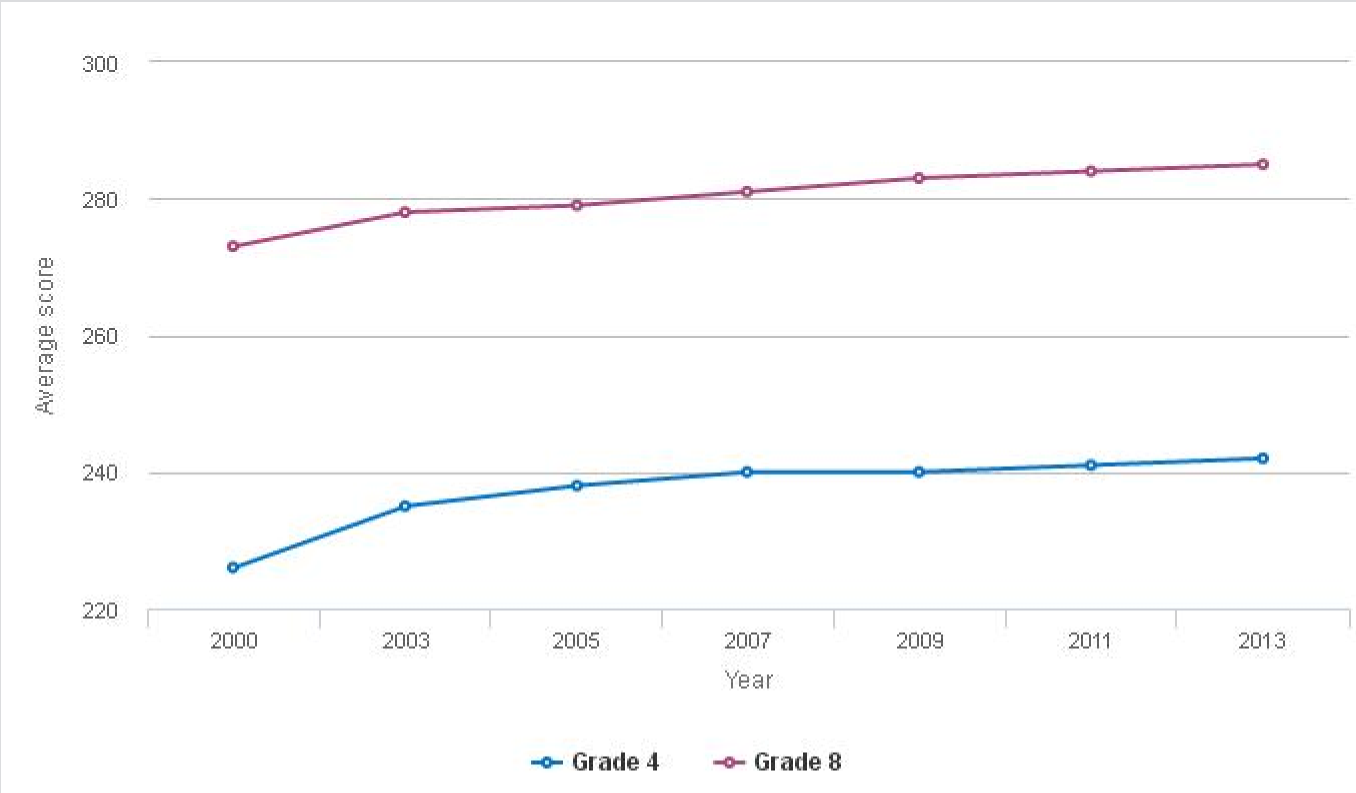
[i] The science framework was established in 1969, and the mathematics framework was created in 1973.

Figure 1-1

Average NAEP mathematics scores of students in grades 4 and 8: 2000–13



NAEP = National Assessment of Educational Progress.

NOTE: NAEP mathematics assessment scores range from 0 to 500 for grades 4 and 8.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of NAEP 2000, 2003, 2005, 2007, 2009, 2011, and 2013 mathematics assessments, National Center for Education Statistics. See appendix table 1-1.

Science and Engineering Indicators 2016

Among U.S. eighth graders, the average mathematics score increased continually from 2000 to 2013, with a total gain of 12 points over the period (Figure 1-1). Continual improvement was seen in almost all demographic groups. Gains were particularly apparent for several groups, including blacks, Hispanics, and Asians or Pacific Islanders, with score increases of 18–19 points from 2000 to 2013 (Appendix Table 1-1).

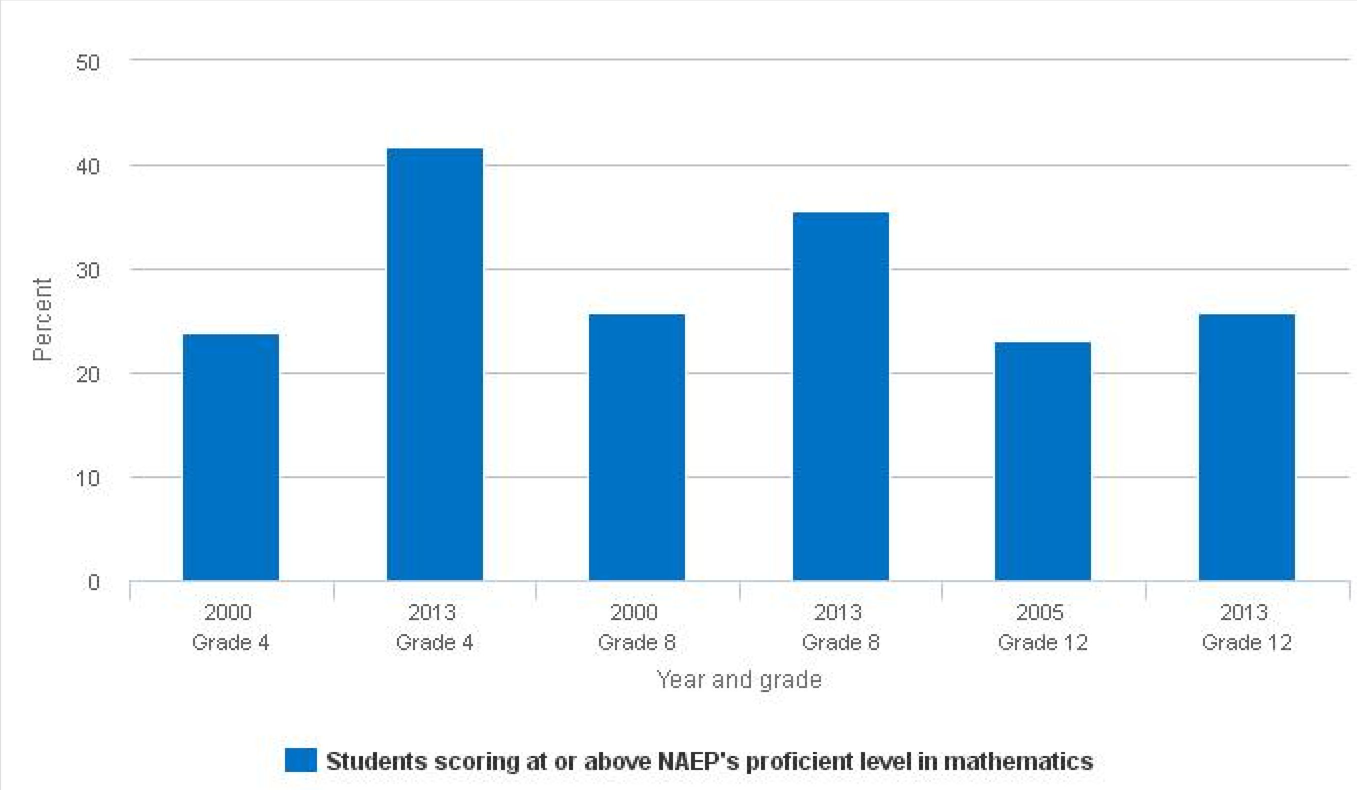
For grade 12, only 2005, 2009, and 2013 results are examined here. Substantial revisions of the mathematics framework for the 2005 assessment made comparison with earlier assessments impossible. Between 2005 and 2013, the average mathematics score for students in grade 12 increased by 3 points (Appendix Table 1-1). Improvement occurred in many groups during this period, ranging from 5 points among several groups to 9 points for Asian or Pacific Islander students and 13 points for those of two or more races. Only English language learners' scores decreased during the period, dropping by 11 points.

Proficiency level. Increases in the percentages of students in grade 4 who achieved a level of proficient or higher in mathematics parallel the average scale score improvements (Appendix Table 1-2). Although the percentage of grade 4 students reaching proficiency or better did increase, it stayed well below the 50% targeted by the standards. Specifically, 42% of students in grade 4 achieved a level of proficient or advanced in 2013, up from 24%

in 2000 (Figure 1-2). In 2013, white and Asian or Pacific Islander students scored above the 50% mark, at 54% and 64%, respectively. Scores for students in other demographic groups were much lower, with just 18% of black students, 26% of Hispanic students, 24% of American Indian or Alaska Native students, 26% of students eligible for free/reduced-price lunch, and 14% of English language learners performing at or above the proficient level (Appendix Table 1-2).

Figure 1-2

Students in grades 4, 8, and 12 scoring at or above NAEP's proficient level in mathematics for their grade: 2000, 2005, and 2013



NAEP = National Assessment of Educational Progress.

NOTE: Grade 12 mathematics data are presented for 2005 and 2013 because the mathematics framework was substantially revised in 2005, making prior assessment results not comparable with those in or after 2005.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of NAEP 2000, 2005, and 2011 mathematics assessments, National Center for Education Statistics. See appendix table 1-2.

Science and Engineering Indicators 2016

The share of grade 8 students at or above the proficient level rose by 10 percentage points, to 36%, from 2000 to 2013 (Figure 1-2). Changes between 2000 and 2013 for most groups were in the range of 8–13 percentage points; however, Asians or Pacific Islanders gained 19 percentage points, and 60% of them performed at or above the proficient level in 2013. English language learners gained just 3 percentage points, with only 5% reaching the proficient level in 2013 (Appendix Table 1-2).

The percentage of all students in grade 12 who were at or above the proficient level in 2013 stood at 26%, below that of eighth graders (36%) and fourth graders (42%) (Figure 1-2). Changes between 2005 and 2013 were generally in the range of 2–4 percentage points, and only Asians or Pacific Islanders were moderately near the 50% mark (Appendix Table 1-2).

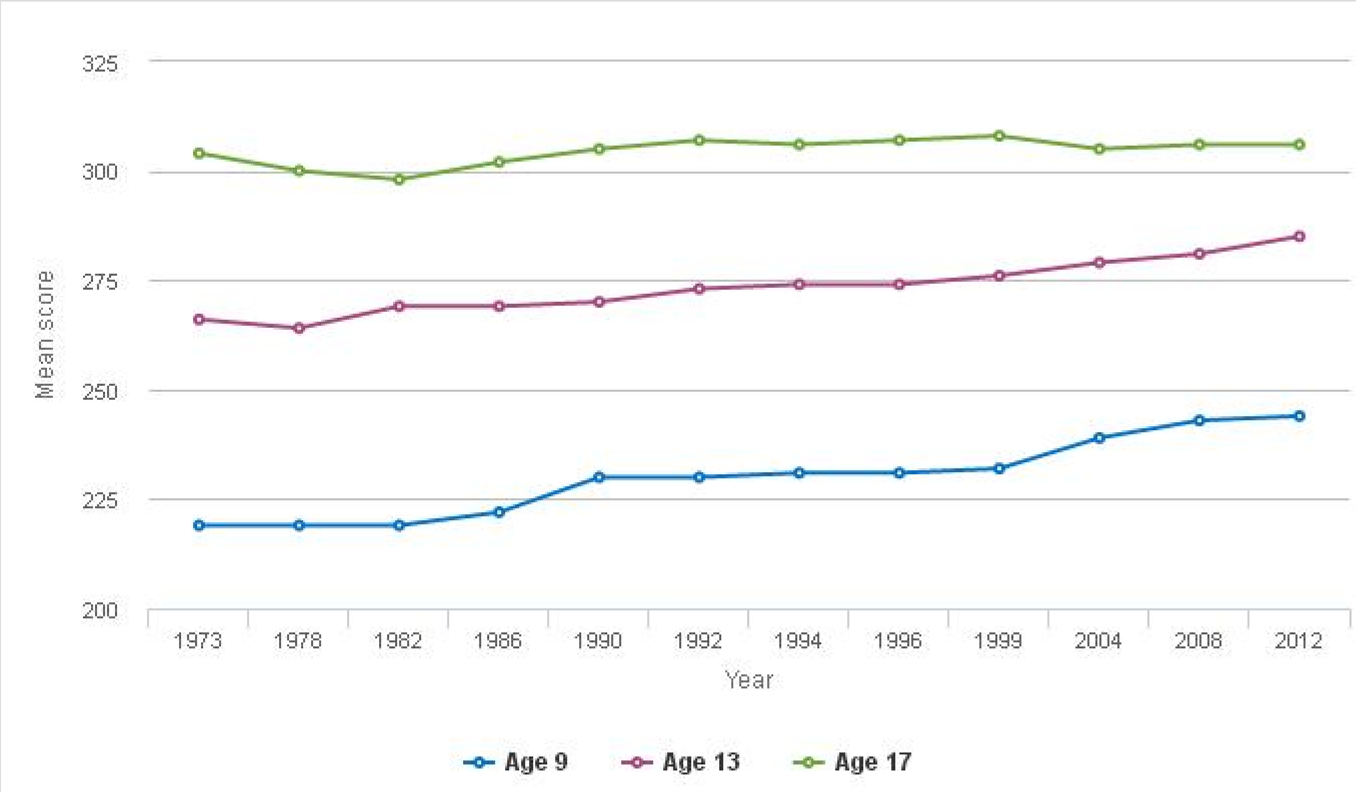
Trends in Mathematics Performance since 1973

NAEP LTT data provide comparable average scores in mathematics for students ages 9, 13, and 17 beginning in 1973.[ii] This section discusses mathematics results from two points in time—1973 and 1978. Although the first LTT mathematics assessment was administered in 1973, very few of the items were included in subsequent assessments. Thus, 1978 is the primary start of the LTT assessment in mathematics. However, NCES was able to extrapolate data to compare the average scores of the 1973 assessment with later assessments, so some comparisons can be made to 1973. NAEP LTT scores range from 0 to 500. The scores exhibit different patterns for each age group. For 9-year-olds, the scores are flat in the 1970s, rise through the late 1980s, remain flat through the 1990s, and then rise again. The scores of 13-year-olds increased at a gradual pace over that same time, but those of 17-year-olds went flat after about 1990 and remained unchanged (Figure 1-3). The 2012 mathematics average for 9-year-old students (244) was 25 points higher than that in 1978; 13-year-old students gained 21 points, to 285, in the same period. The score trends for different demographic groups closely followed these same patterns.

[ii] Estimates for 1973 were extrapolated.

Figure 1-3

Average NAEP LTT mathematics assessment scores of students ages 9, 13, and 17: 1973–2012



NAEP = National Assessment of Educational Progress; LTT = long-term trend.

NOTE: NAEP LTT mathematics assessment score ranges from 0 to 500 for students in all ages.

SOURCES: Rampey B, Dion G, Donahue P, *NAEP 2008 Trends in Academic Progress*, NCES 2009-479 (2009), figures 10–12; National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of NAEP LTT 2012 mathematics assessments, National Center for Education Statistics. See appendix table 1-3.

Science and Engineering Indicators 2016

As shown in Appendix Table 1-3, students in demographic groups identified by sex, highest level of parent education, and race or ethnicity also improved their performance over time. Between 1978 and 2012, the average score for 9-year-old male students increased from 217 to 244, and the average score for 9-year-old female students increased from 220 to 244. The average score for 9-year-old students increased from 224 to 252 for white students, from 192 to 226 for black students, from 203 to 234 for Hispanic students, and from 229 to 265 for Asian or Pacific Islander students. The average score for 13-year-old students with at least one parent who graduated from high school was 263 in 1978 and 270 in 2012. The average score for 13-year-old students with at least one parent who graduated from college was 284 in 1978 and 296 in 2012. Average scores for 17-year-old students changed moderately for all groups, with the exception of Hispanic and black students, whose scores increased by 18 and 20 points, respectively, between 1978 and 2012.

Performance gaps. NAEP LTT data indicate that, although between-group differences in mathematics performance observed in 1978 have persisted, many of these gaps were significantly smaller in 2012 than in 1978 (Table 1-2). The gap between black students and white students at age 9 was 6 points narrower in 2012 than in 1978. All other gaps in mathematics performance at age 9 by race and ethnicity were the same in 2012 as in 1978. For

13-year-olds, the gap between black students and white students narrowed by 13 points, and the gap between Hispanic students and white students narrowed by 12 points. For 17-year-olds, the gap in mathematics scores between black students and white students narrowed by 12 points and the gap between Hispanic students and white students was reduced by 10 points.

Table 1-2 **Magnitude of changes in NAEP LTT mathematics assessment score gaps, by race or ethnicity and parents' highest education: 1978–2012**

Score gap	Age 9	Age 13	Age 17
Race or ethnicity			
Blacks and whites	-6	-13	-12
Hispanics and whites	≈	-12	-10
Asians and whites	≈	16	≈
Asians and blacks	≈	≈	-15
Asians and Hispanics	≈	≈	-13
Parents' highest education			
Did not finish high school and graduated from high school	NA	-14	-13
Did not finish high school and had some college	NA	-8	-9
Did not finish high school and graduated from college	NA	-9	-10
Graduated from high school and had some college	NA	6	4
Graduated from high school and graduated from college	NA	5	≈
Had some college and graduated from college	NA	≈	≈

≈ = no change; NA = not available.

NAEP = National Assessment of Educational Progress; LTT = long-term trend.

NOTES: Hispanic may be any race. Asian, black or African American, and white refer to individuals who are not of Hispanic origin. NAEP LTT mathematics assessment scores range from 0 to 500 for students of all ages.

SOURCES: Rampey B, Dion G, Donahue P, *NAEP 2008 Trends in Academic Progress*, NCES 2009-479 (2009), figures 10–12; National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of NAEP LTT 2012 mathematics assessments, National Center for Education Statistics. See appendix table 1-3.

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Gender gaps. Between 1978 and 2012, there was no consistent gap between the mathematics scores of male and female students at either age 9 or age 13 (Appendix Table 1-3). Among 17-year-old students, however, the NAEP LTT data suggest the existence of a small gap between male and female students in most years between 1978 and 2012, a gap that was not significantly different in 2012 from what it was in 1978. The average scores in 1978 for male and female students were 304 and 297, respectively. In 2012, the average scores for male and female 17-year-old students were 308 and 304, respectively.

Student Development over Time: Longitudinal Data

The national trend data discussed thus far indicate how the performance of the nation's students at specific ages or education levels has changed over time. This section presents data from two nationally representative surveys that track individual students' growth in mathematics and science knowledge, assessing the same students' performance over time rather than querying successive different cohorts. ECLS-K:2011 data provide a look at young children's understanding of mathematics and science and how it changes in the first years of formal schooling. HSLS:09 data indicate how students' understanding of mathematics develops in the first 3 years of high school.

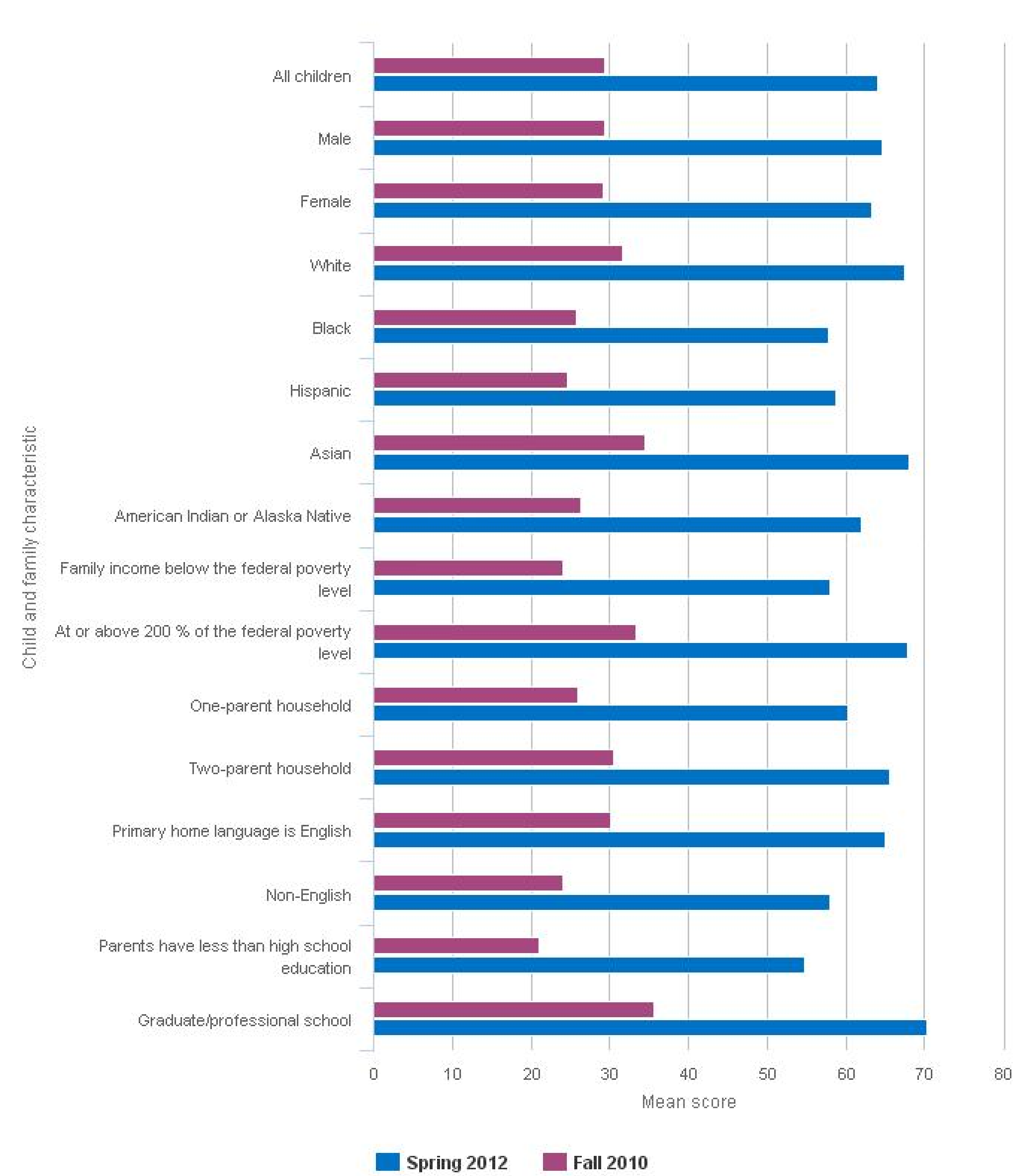
Mathematics and Science Knowledge in Early Childhood

ECLS-K:2011 is a nationally representative, longitudinal study of children's development, early learning, and school progress (Mulligan, Hastedt, and McCarroll 2012). Data for the ECLS-K:2011 study were first collected in fall 2010 from approximately 18,200 kindergarten students. ECLS-K:2011 will follow and test the same student sample each year until spring 2016, when most students will be in fifth grade. This section provides a snapshot of the children in the ECLS-K:2011 cohort who were in kindergarten for the first time in the 2010–11 school year and advanced to first grade in the following year. It compares students' mathematics scores from the beginning of kindergarten to the end of first grade. Science assessment results are only from the beginning and end of first grade, a shorter assessment period. Students' mathematics and science assessment results cannot be compared with each other because scales are developed independently for each subject. Both mathematics and science results show that students enter school with different levels of preparation and that those differences persist for students of different racial, ethnic, and socioeconomic groups, a finding that is supported in the research literature (Loeb and Bassok 2007; Magnuson and Duncan 2006).

Kindergarten performance on the ECLS-K mathematics assessment in fall 2010 varied by demographic characteristics (Figure 1-4). Boys' and girls' mathematics scores did not differ, with both scoring an average of 29. Among racial or ethnic groups, black and Hispanic students scored the lowest (26 and 25, respectively), and Asian students scored the highest (35). Students whose family income was at or below the Federal Poverty Level (FPL) scored 9 points lower than students whose family income was at or above 200% of the poverty line (24 versus 33). Score differences also existed between students from one- and two-parent homes (26 versus 31, respectively), students whose families spoke English at home or not (30 versus 24, respectively), and students whose parents had not graduated from high school and those whose parents had received a graduate-level degree (21 versus 36, respectively).

Figure 1-4

Average mathematics assessment test scores of children who were in kindergarten for the first time during the 2010-11 school year and in first grade during the 2011-12 school year, by child and family characteristics: Fall 2010 and spring 2012



NOTES: Hispanic may be any race. American Indian or Alaska Native, Asian, black or African American, and white refer to individuals who are not of Hispanic origin. Mathematics assessment scores range from 0 to 75 for kindergarteners and from 0 to 96 for first graders.

SOURCES: Mulligan GM, Hastedt S, McCarroll JC, *First-Time Kindergartners in 2010–11: First Findings From the Kindergarten Rounds of the Early Childhood Longitudinal Study, Kindergarten Class of 2010–11 (ECLS-K:2011)*, NCES 2012-049 (2012); Mulligan GM, McCarroll JC, Flanagan KD, Potter D, *Findings From the First-Grade Rounds of the Early Childhood Longitudinal Study, Kindergarten Class of 2010–11 (ECLS-K:2011)*, NCES 2015-109 (2014). See appendix table 1-4.

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Assessment scores for these students in spring 2012 show that the same performance gaps evident at kindergarten entrance persisted into the end of first grade. For example, the difference in scores between white and black students was 6 points in fall 2010 and 10 points in spring 2012; for Hispanic and white students, the gap was 7 points in fall 2010 and 9 points in spring 2012 (Appendix Table 1-4). Schooling did not close the achievement gap. The average mathematics assessment score for first graders was 64. Black and Hispanic students scored the lowest (58 and 59, respectively) compared to other racial or ethnic groups. Students with family incomes below the FPL, students from one-parent homes, students from non-English-speaking homes, and students whose parents had less than a high school education all scored lower than their counterparts.

ECLS-K:2011 collected first grade science assessment data in fall 2011 and spring 2012.[i] The first grade science assessment included items about physical sciences, life science, environmental sciences, and scientific inquiry. First grade students' average score was 24 points on a 47-point scale in fall 2011 and 27 points in spring 2012 (Figure 1-5). Science assessment scores show the same pattern as mathematics scores, with achievement gaps evident at the beginning of first grade not closing by the end of the school year. Students from non-English-speaking homes, students with family income below the FPL, and students with parents with less than a high school education posted the lowest scores (Appendix Table 1-5).

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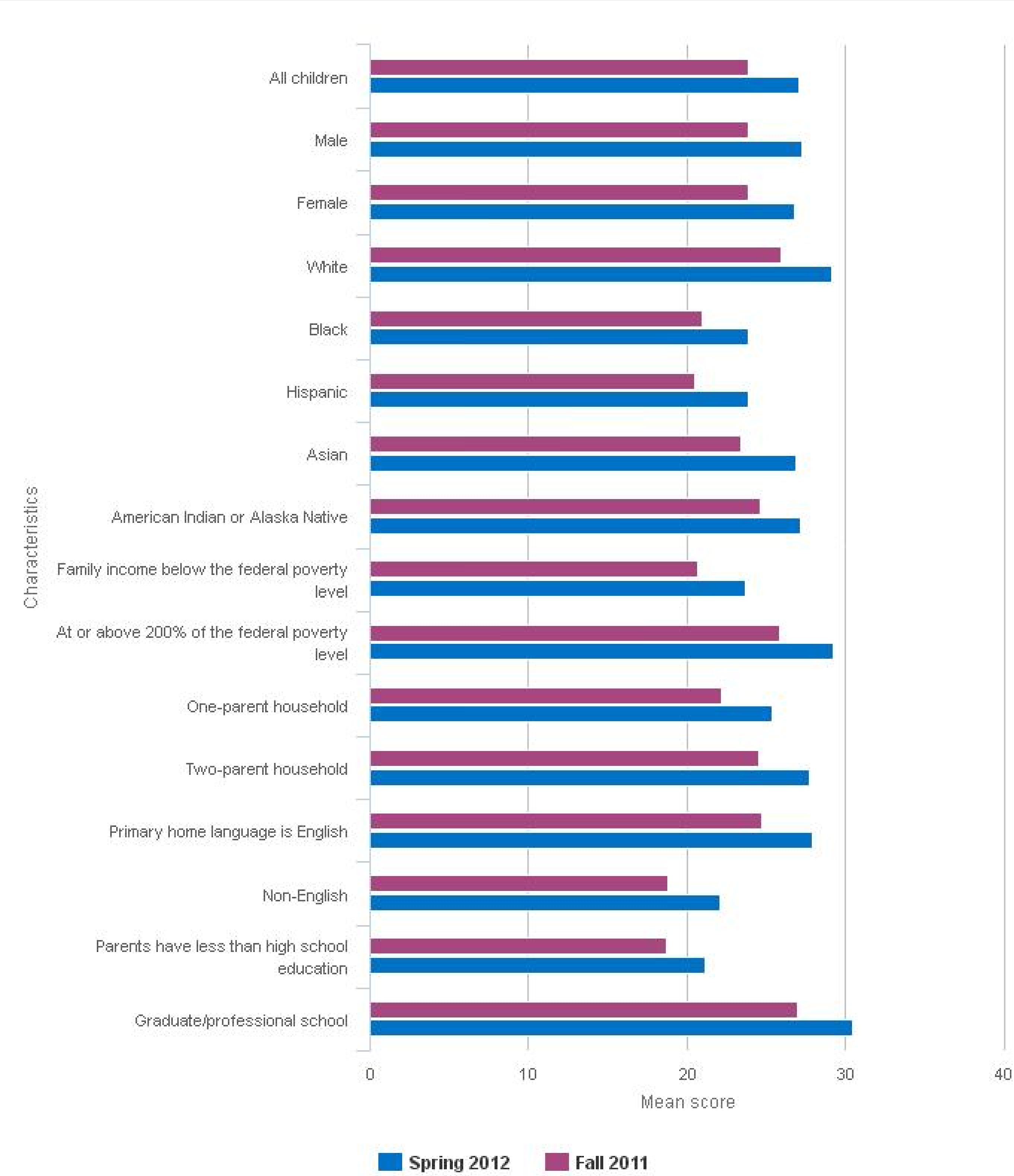
[i] This analysis does not include results from the spring 2011 science assessment because they have not been reported by NCES (i.e., the ECLS-K:2011 First Look report did not include results from the kindergarten science assessment).

Figure 1-5

Average science assessment test scores of children who were in kindergarten for the first time during the 2010–11 school year and in first grade during the 2011–12 school year, by child and family characteristics: Fall 2011 and spring 2012



NOTES: Hispanic may be any race. American Indian or Alaska Native, Asian, black or African American, and white refer to individuals who are not of Hispanic origin. Science assessment score ranges from 0 to 47.

SOURCES: Mulligan GM, Hastedt S, McCarroll JC, *First-Time Kindergartners in 2010–11: First Findings From the Kindergarten Rounds of the Early Childhood Longitudinal Study, Kindergarten Class of 2010–11 (ECLS-K:2011)*, NCES 2012-049 (2012); Mulligan GM, McCarroll JC, Flanagan KD, Potter D, *Findings From the First-Grade Rounds of the Early Childhood Longitudinal Study, Kindergarten Class of 2010–11 (ECLS-K:2011)*, NCES 2015-109 (2014). See appendix table 1-5.

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Developing Algebra Skills in High School

Mastering the mathematics concepts and skills taught in the typical algebra 1 course allows high school students to take higher-level mathematics and more challenging college preparatory courses. Taking higher-level mathematics courses, in turn, is associated with positive academic outcomes beyond high school such as college attendance, college graduation, job readiness, and higher earnings (Achieve Inc. 2008; Adelman 2008; Bozick and Lauff 2007; Byun, Irvin, and Bell 2014; Gaertner et al. 2014; Gamoran and Hannigan 2000; Long, Conger, and Iatarola 2012; Nord et al. 2011). This discussion uses data from HSLS:09 to measure the development of students' understanding and skills in algebra as they move through high school.

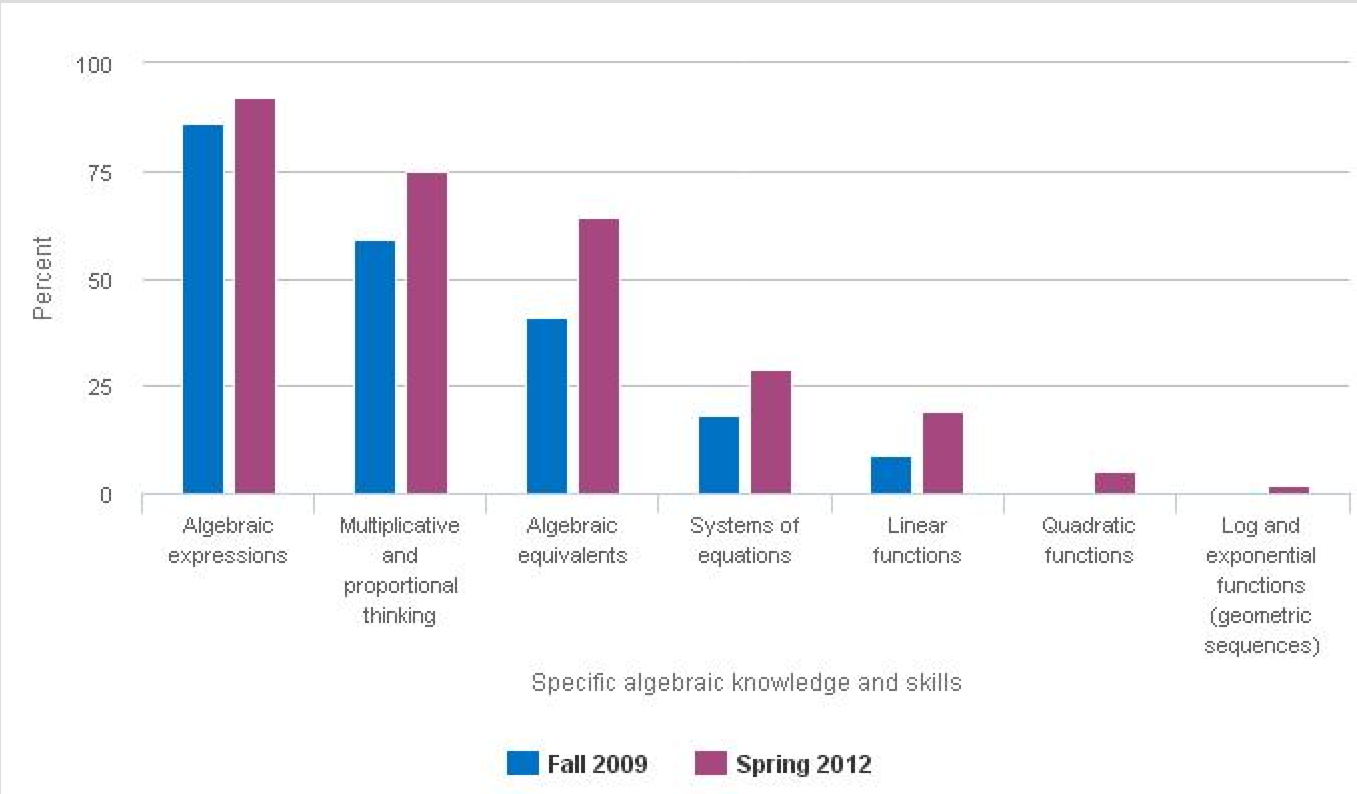
HSLS:09, a nationally representative longitudinal study, focuses on understanding students' trajectories from the beginning of high school into higher education and the workforce (Ingels et al. 2011). HSLS:09 pays particular attention to high school–level math and science education, the high school environment, and postsecondary education. The HSLS:09 sample of approximately 24,000 students was drawn from students who were in grade 9 in 944 schools across the United States during the 2008–09 academic year. Students were interviewed for the first follow-up survey more than 2 years later, when most were in eleventh grade. During both the base-year and first follow-up data collections, students completed a mathematics assessment of algebraic reasoning and problem solving. Science was not assessed, so it is not discussed in this section. The mathematics assessment provided indicators of the students' proficiency in hierarchical performance levels; that is, students proficient at any given level are considered proficient at all lower levels. The base-year algebra assessment included the following five algebraic proficiency levels:

- Level 1: The student understands algebra basics, including evaluating simple algebraic expressions and translating between verbal and symbolic representations of expressions.
- Level 2: The student understands proportions and multiplicative situations and can solve situation word problems involving proportions, find the percentage of a number, and identify equivalent algebraic expressions for multiplicative situations.
- Level 3: The student understands algebraic equivalents and can link equivalent tabular and symbolic representations of linear equations, identify equivalent lines, and find the sum of variable expressions.
- Level 4: The student understands systems of linear equations, can solve such systems algebraically and graphically, and can characterize the lines (parallel, intersecting, collinear) represented by a system of linear equations.
- Level 5: The student understands linear functions and can find and use slopes and intercepts of lines and functional notation.

HSLS:09 students were first assessed in ninth grade in fall 2009 and again at the end of eleventh grade in spring 2012. The percentage of students reaching proficiency at each of the five levels increased in 2012. Constrained by a ceiling effect, the smallest gain occurred in the percentage of students who were proficient at level 1, which increased from 86% in 2009 to 92% in 2012 (Figure 1-6). In 2012, three-fourths of students were proficient at multiplicative and proportional thinking, nearly two-thirds understood algebraic equivalents, almost 30% grasped systems equations, and about a fifth comprehended linear functions. These shares rose by 10–23 percentage points over the 3 years between 2009 and 2012. Although algebraic proficiency levels of male and female students progressed broadly in parallel, this was not the case for students from different demographic backgrounds. Socioeconomic status (SES), parental education level, and private school attendance were associated with greater proficiency gains (Appendix Table 1-6). For example, the percentage of students who were proficient at level 5 increased by 5 points among students whose parents graduated from high school, with gains of 7, 16, and 23 points for students whose parents had an associate's, bachelor's, or advanced degree, respectively. High SES and private-school attendance provided a similar advantage in level-5 proficiency score gains.

Figure 1-6

Fall 2009 students in grade 9 who were proficient in specific algebraic knowledge and skills in fall 2009 and spring 2012



NA = not available; quadratic functions and log and exponential functions were not tested in fall 2009.

SOURCES: Ingels SJ, Dalton B, Holder TE, Lauff E, Burns LJ, *High School Longitudinal Study of 2009 (HSLS:09): A First Look at Fall 2009 Ninth-Graders*, NCES 2011-327 (2011); Ingels SJ, Dalton B, *High School Longitudinal Study of 2009 (HSLS:09) First Follow-up: A First Look at Fall 2009 Ninth-Graders in 2012*, NCES 2014-360 (2013). See appendix table 1-6.

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The HSLS:09 assessed two proficiency levels that ninth graders were not expected to reach but that at least some eleventh graders students were expected to attain (Ingels and Dalton 2013):

- Level 6: The student understands quadratic functions and the relationship between roots and the discriminant and can solve quadratic equations and inequalities.
- Level 7: The student understands exponential and log functions, including geometric sequences, and can identify inverses of log and exponential functions and when geometric sequences converge.

In 2012, approximately 5% of students were proficient at level 6, and approximately 2% were proficient at level 7 (Figure 1-6; Appendix Table 1-6). These numbers were substantially higher for Asian or Pacific Islander students than for any other group: 17% and 8%, respectively, more than triple the average (Appendix Table 1-6). Approximately 6% of male students and 5% of female students were proficient at level 6, a small but statistically significant difference. Student SES, parental education, race or ethnicity, and school type all influenced student scores. The patterns were broadly similar for level-7 proficiency.

International Comparisons of Mathematics and Science Performance

Chapter 1. **Elementary and Secondary Mathematics and Science Education**

Governments are increasingly viewing their population's education levels and performance as national resources and are assessing their education status in a broader international context. The Organisation for Economic Co-operation and Development (OECD) has conducted a triennial Program for International Student Assessment (PISA) study since 2000 that allows comparisons of mathematics and science performance of 15-year-olds in the United States with that of their peers in other nations.[i] In addition to analyzing students' average performance among countries and trends over time, and new to this edition of *Science and Engineering Indicators*, this section examines variations in students' scores in different countries—that is, how tightly students' scores in any country cluster around that country's mean score.

Science and Engineering Indicators 2014 examined data from another international assessment, the Trends in International Mathematics and Sciences Study (TIMSS) (NSB 2014). TIMSS and PISA are different in design and goals and do not allow direct side-by-side comparison. The present analysis presents new PISA data from 2012 and looks at trends since 2003.

Principal differences between TIMSS and PISA are the following:[ii]

- **Grade level and scope.** TIMSS conducts mathematics and science assessments of students in grades 4 and 8. PISA, on the other hand, assesses the mathematics, science, and reading performance of 15-year-old students.[iii]
- **Knowledge and skills versus application of knowledge.** TIMSS assessments are designed to measure students' knowledge in the mathematics and science curricula of participating countries. PISA assessments are designed to measure students' ability to apply mathematics and science knowledge to real-world applications.
- **Country participation.** Although some of the same countries participate in both TIMSS and PISA, many countries participate in only one or the other.

PISA's focus is on the application of school knowledge to real-life situations. For example, students may be asked to estimate an area, identify the best price for a product, or interpret statistics in a news report (see sidebar, Sample Items from the Program for International Student Assessment Mathematics and Science Assessments).

Trends in Mathematics and Science Knowledge among 15-Year-Old Students in the United States

Figure 1-7 shows the average mathematics and science literacy scores for 15-year-old students in the United States between 2003 and 2012.[iv] Students in the United States had an average mathematics literacy score of 483 in 2003, 474 in 2006, 487 in 2009, and 481 in 2012. The average science literacy scores for U.S. students were 489 in 2006, 502 in 2009, and 497 in 2012. The average mathematics literacy scores for male students and female students did not change significantly from 2003 to 2012, nor did the science literacy scores change significantly from 2006 to 2012 (Table 1-3).

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[i] OECD is an intergovernmental organization with membership of 34 advanced economies and 6 partner nations.

[ii] See the TIMMS website (https://nces.ed.gov/TIMSS/faq.asp?FAQType=8).

[iii] Schools in each country are randomly selected by the international contractor for participation in PISA. At these schools, the test is given to students who are between age 15 years 3 months and age 16 years 2 months at the time of the test, rather than to students in a specific year of school. This average age of 15 was chosen because at

this age young people in most OECD countries are nearing the end of compulsory education (http://www.oecd.org/pisa/aboutpisa/pisafaq.htm).

[iv]The PISA mathematics assessment was also conducted in 2000 but, because the framework for the mathematics assessment was revised in 2003, it is not appropriate to compare results from the 2000 assessment to subsequent PISA mathematics assessments. Similarly, the framework for the PISA science assessment was changed in 2000 and in 2003, preventing comparisons of results in either 2000 or 2003 with science literacy scores from subsequent years.

Sample Items from the Program for International Student Assessment Mathematics and Science Assessments

Sample Items from the 2012 Program for International Student Assessment (PISA) Mathematics Assessment

1. *Peter's bicycle has a wheel circumference of 96 cm (or 0.96 m). It is a three-speed bicycle with a low, a middle, and a high gear. The gear ratios of Peter's bicycle are:*

   Low 3:1 Middle 6:5 High 1:2

   How many pedal turns would Peter take to travel 960 m in middle gear? Show your work.
   NOTE: A gear ratio of 3:1 means 3 complete pedal turns yields 1 complete wheel turn.

   Correct answer: 1,200 pedal turns, with a fully correct method.

3. *One advantage of using a kite sail is that it flies at a height of 150 m. There, the wind speed is approximately 25% higher than down on the deck of the ship. At what approximate speed does the wind blow into a kite sail when a wind speed of 24 km/h is measured on the deck of the ship?*
   a. *6 km/h*
   b. *18 km/h*
   c. *25 km/h*
   d. *30 km/h*
   e. *49 km/h*

   Correct answer: D

Sample Items from the 2012 PISA Science Assessment

1. *Fevers that are difficult to cure are still a problem in hospitals. Many routine measures serve to control this problem. Among those measures are washing sheets at high temperatures.*

   Explain why high temperature (while washing sheets) helps to reduce the risk that patients will contract a fever.

   Correct answer: Answers that refer to the killing or removal of bacteria, microorganisms, germs, or viruses, or to the sterilization of the sheets.

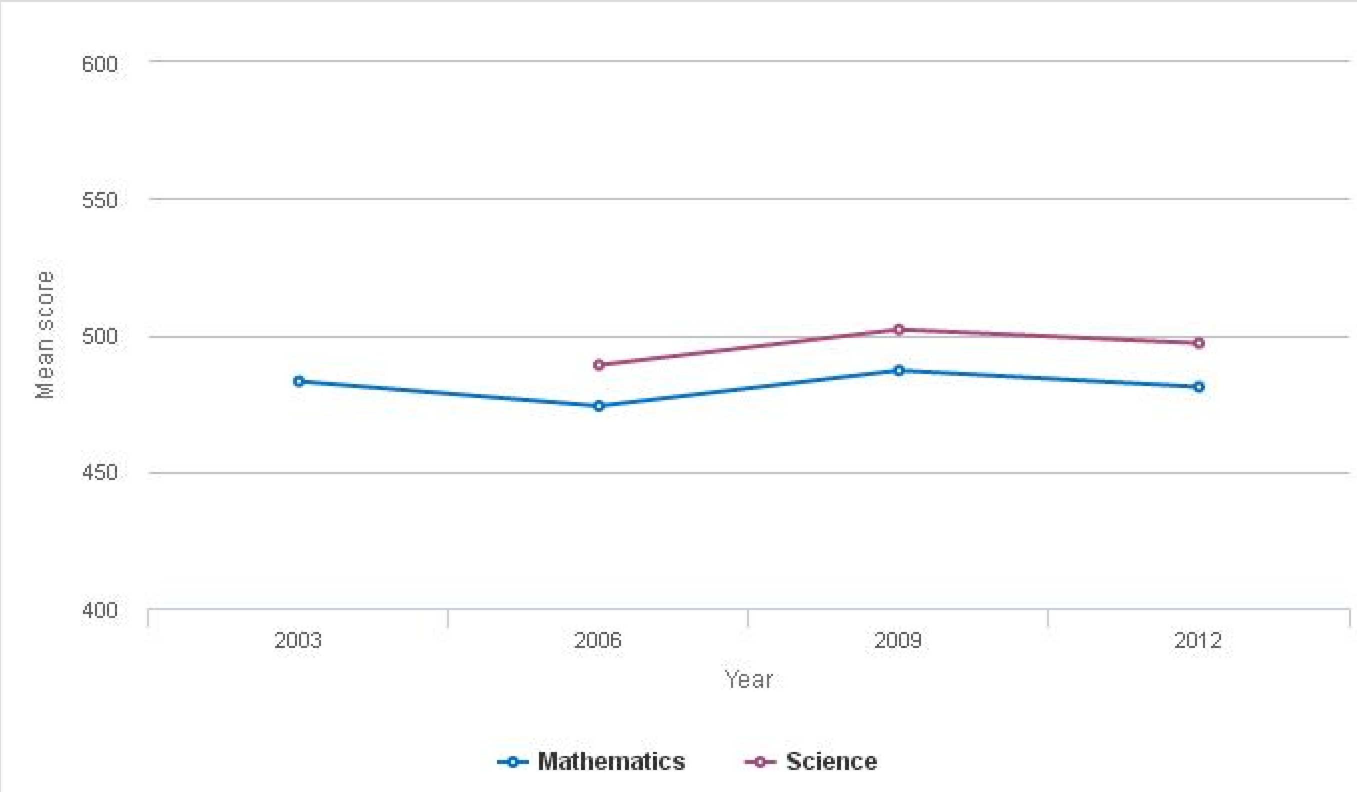
3. *The temperature in the Grand Canyon ranges from below 0 degrees C to over 40 degrees C. Although it is a desert area, cracks in the rocks sometimes contain water. How do these temperature changes and the water in rock cracks help to speed up the breakdown of rocks?*
    a. *Freezing water dissolves warm rocks.*
    b. *Water cements rocks together.*
    c. *Ice smooths the surface of rocks.*
    d. *Freezing water expands in the rock cracks.*

Correct answer: D. Freezing water expands rock cracks.

Additional sample questions: http://nces.ed.gov/surveys/pisa/pdf/items_math2012.pdf (for mathematics) and http://nces.ed.gov/surveys/pisa/pdf/items_science.pdf (for science).

Figure 1-7

Mean mathematics and science literacy assessment scores of 15-year-old students in the United States: 2003–12



NA = not available; science literacy assessment was not administered in 2003.

NOTE: The mathematics and science literacy assessment scores range from 0 to 1,000.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the Program for International Student Assessment 2003, 2006, 2009, and 2012 mathematics and science literacy assessments, National Center for Education Statistics.

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Table 1-3 Mean mathematics and science literacy assessment scores of 15-year-old students in the United States, by sex: 2003–12

	Mathematics		Science	
Year	Male	Female	Male	Female
2003	486	480	NA	NA
2006	479	470	489	489
2009	497	477	509	495
2012	484	479	497	498

NA = not available.

NOTES:	The mathematics and science literacy assessment scores range from 0 to 1,000. Science literacy assessment was not administered in 2003.
SOURCE:	National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the Program for International Student Assessment 2003, 2006, 2009, and 2012 mathematics and science literacy assessments, National Center for Education Statistics.
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Mathematics Literacy among U.S. 15-Year-Olds

U.S. students' average mathematics score of 481 in 2012 was lower than the average score for all developed countries, 501. It was also lower than the scores of students from two-thirds of all developed countries (Appendix Table 1-7). Among developed countries, students from Singapore had the highest literacy score at 574 (Table 1-4). Other developed countries with average scores that were significantly higher than that of U.S. students included Switzerland (531), Finland (519), Germany (514), Slovenia (501), and Iceland (493). The U.S. students' average mathematics score was also lower than that of two developing countries, Vietnam (511) and the Russian Federation (482). Overall, U.S. students performed relatively well on PISA items that required only lower-level skills—reading and simple handling of data directly from tables and diagrams, handling easily manageable formulas—but they struggled with tasks involving creating, using, and interpreting models of real-world situations and using mathematical reasoning (OECD 2015).

Table 1-4 **Mean mathematics literacy assessment scores of 15-year-old students in developed countries, by country: 2012**

Grouping and country	Score
Score higher than United States' score of 481	
Singapore	574
South Korea	554
Japan	536
Switzerland	531
Netherlands	523
Estonia	521
Finland	519
Canada	518
Poland	518
Belgium	515
Germany	514
Austria	506
Australia	504
Ireland	502
Slovenia	501
Denmark	500
New Zealand	500

Grouping and country	Score
Czech Republic	499
France	495
United Kingdom	494
Iceland	493
Latvia	491
Luxembourg	490
Score not statistically different from United States' score of 481	
Norway	489
Portugal	487
Italy	485
Spain	484
Slovakia	482
United States	481
Sweden	478
Score lower than United States' score of 481	
Israel	467
Greece	453

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the Program for International Student Assessment 2012 mathematics literacy assessment, National Center for Education Statistics. See appendix table 1-7.

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Science Literacy among U.S. 15-Year-Olds

The average science literacy score for U.S. students in 2012 was 497, lower than the average science score of 511 for all developed countries (Appendix Table 1-8). Among developed countries, Singapore had the highest score at 552 (Table 1-5). Other developed countries with science literacy scores that were significantly higher than that of U.S. students included Japan (547), South Korea (538), Germany (524), and the United Kingdom (514).

Table 1-5 **Mean science literacy assessment scores of 15-year-old students in developed countries, by country: 2012**

Grouping and country	Score
Score higher than United States' score of 497	
Singapore	552
Japan	547
Finland	545
Estonia	541

Grouping and country	Score
South Korea	538
Poland	526
Canada	525
Germany	524
Ireland	522
Netherlands	522
Australia	522
New Zealand	516
Switzerland	515
Slovenia	514
United Kingdom	514
Czech Republic	508
Score not statistically different from United States' score of 497	
Austria	506
Belgium	505
Latvia	502
France	499
Denmark	498
United States	497
Spain	496
Norway	495
Italy	494
Luxembourg	491
Portugal	489
Score lower than United States' score of 497	
Sweden	485
Iceland	478
Slovakia	471
Israel	470
Greece	467

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the Program for International Student Assessment 2012 science literacy assessment, National Center for Education Statistics. See appendix table 1-8.

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Variability in Mathematics and Science Achievement across Countries

Chapter 1. **Elementary and Secondary Mathematics and Science Education**

The data in this chapter primarily include mean student achievement scores in mathematics and science in the United States and other countries. The variability of student scores on a mathematics or a science test may provide additional insights into the well-being of K–12 STEM education in the United States. For instance, if the United States has higher overall variability in achievement than other countries, this may indicate that educational outcomes are more unequal in the United States. Also, the percentage of U.S. students scoring at very high values relative to those of other countries may provide insights on how well the United States fares in preparing students to be STEM innovators. The percentage scoring at very low values may indicate education system shortcomings.

This section will present information on overall variability, measured as the average distance of students' scores from the mean of those scores. This is the *mean deviation*. A mean deviation of 75, to take a value typical of developed countries, indicates that, on average, students are 75 points from the mean in either direction. For a country with a bell-shaped distribution of student achievement, which is approximately the case for many countries, a 75-point mean deviation would also mean that 90% of students would fall within 184 points from the mean, in both directions. This section will also examine how different countries compare in the highest and lowest percentiles of achievement. All data in this section are from the 2012 PISA.

The United States is quite typical, among 32 developed countries, in terms of overall variability and has lower variability than several Nordic countries noted for their egalitarianism. With a mean deviation of 76 for science achievement, the United States is very near the median score of 77 for the developed countries in the data (Table 1-6).[v] The United States has a lower mean deviation for science achievement than Norway, Sweden, and Iceland.[vi] In addition, these countries do not have a higher *average* for science achievement than the United States. On the other hand, South Korea and Estonia have higher average scores than the United States and also have mean deviations about 10 points or more below that of the United States.

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[v]PISA contains data on a few country regions such as particular U.S. states, the Perm region of Russia, and Chinese cities. These are not included in analyses in the text of these sections, in which only whole countries are considered. Developed and developing status are defined by the International Monetary Fund's classification of countries into advanced and emerging economies (https://www.imf.org/external/pubs/cat/longres.aspx?sk=24628.0).

[vi]All scores and comparisons in this section were calculated in accordance with the formulae presented in the *PISA Data Analysis Manual: SAS®* (OECD 2009).

Table 1-6 **Mean deviation of science literacy assessment scores of 15-year-old students in developed countries, by country: 2012**

Grouping and country	Score
Mean deviation higher than United States' mean deviation of 76	
Israel	87
New Zealand	85
Singapore	85
Luxembourg	84
Belgium	81

Grouping and country	Score
Slovakia	81
Australia	81
France	80
United Kingdom	80
Sweden	80
Norway	80
Iceland	80
Mean deviation not statistically different from United States' mean deviation of 76	
Netherlands	77
Germany	77
Japan	76
United States	76
Austria	75
Italy	75
Denmark	74
Finland	74
Slovenia	73
Switzerland	73
Ireland	73
Canada	72
Mean deviation lower than United States' mean deviation of 76	
Czech Republic	72
Portugal	71
Greece	71
Poland	69
Spain	69
South Korea	65
Estonia	64
Latvia	63

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the Program for International Student Assessment 2012 science literacy assessment, National Center for Education Statistics. See appendix table 1-8.

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The lower mean deviation for the United States in contrast to the Nordic countries, despite the generally recognized greater ethnic diversity of the United States, suggests that mean deviation does not merely reflect diversity. If mean deviation is a summary of inequalities from all sources that affect achievement, the poorer mean deviations of Nordic countries with respect to science achievement scores might reflect sources of inequality such as less integrated immigrant populations or educational tracks.

The United States produces more students at or below the 10% mark for all developed countries in science. Almost 12% of American students are at or below the science achievement score defining the bottom 10% of students for all developed countries (Appendix Table 1-8). Compared with all developed countries, 17% more U.S. students are at or below the 10% threshold. This takes into account the size of the United States population. Additionally, the United States produces fewer students above the scores that define the 90th, 95th, and 99th percentiles across all developed countries. The United States has about 23% fewer students in each of these high-score groups.

Finland is at times cited as an exemplary educational system. With variability for science achievement that is practically identical to that of the United States, Finland's advantage is in higher average science achievement. Another Baltic country that stands out more sharply than Finland in the PISA data is Estonia. Estonia shows that it is possible both to have a better average science score than the United States and to maintain lower variability and better percentile values (Appendix Table 1-8). Mean deviations sharply lower than those of the United States could be due to policy, sociostructural, or cultural reasons that may or may not be duplicable in the United States.

The 27 developing countries in the PISA data have, typically, lower variation in achievement than in developed countries. Because these countries select themselves for inclusion in PISA, it is not possible to generalize to all developing countries. Nevertheless, these countries can serve as a contrast to developed countries. Half of these countries have a mean deviation for science achievement of 64.7 or lower. In short, these mean deviations for self-selected developing countries are shifted down by about 10 points from those of developed countries. These developing countries also, however, have a lower median value of average science scores, 438 (versus 525 for developed countries).

The 2012 PISA survey also provides data regarding mathematics achievement. The findings are broadly similar to those for science achievement. With a mean deviation of 73 for mathematics achievement, the United States has the tenth-largest variability of 32 developed countries—moderately near the median score of 78 (Table 1-7). The United States has about the same variability for mathematics achievement as Norway, Sweden, and Iceland. Additionally, differences among these countries in mean scores are small. On the other hand, a number of countries do somewhat better than the United States both in terms of mean and mean deviation in mathematics, particularly Estonia, Latvia, Denmark, and Finland. The first two of these countries also had appreciably lower mean deviations for science achievement.

Table 1-7 **Mean deviation of mathematics literacy assessment scores of 15-year-old students in developed countries, by country: 2012**

Grouping and country	Score
Mean deviation higher than United States' mean deviation of 73	
Singapore	86
Israel	85
Belgium	83
Slovakia	81
New Zealand	81
South Korea	80

Grouping and country	Score
France	79
Germany	78
Luxembourg	78
Australia	78
Czech Republic	77
Portugal	77
United Kingdom	76
Switzerland	76
Mean deviation not statistically different from United States' mean deviation of 73	
Austria	75
Japan	75
Netherlands	75
Slovenia	75
Italy	75
Sweden	74
Iceland	74
Poland	73
United States	73
Norway	73
Canada	72
Spain	71
Greece	71
Mean deviation lower than United States' deviation of 73	
Finland	68
Ireland	68
Denmark	66
Latvia	66
Estonia	65

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the Program for International Student Assessment 2012 mathematics literacy assessment, National Center for Education Statistics. See appendix table 1-7.

Science and Engineering Indicators 2016

The United States falls particularly short with respect to students in the highest percentiles of mathematics achievement. If the United States was doing as well as other developed countries, then 1% of U.S. students would be at or above the score that defines the 99th percentile of students across all developed countries. Instead, only about 0.4% of U.S. students have a score at or above that 99th percentile score for developed countries, with the result that the United States has 61% fewer students in this group than the average for developed countries (Appendix Table 1-7). Similarly, the United States has 42% and 45% fewer students compared with all developed countries above the scores that define, respectively, the 90th and 95th percentiles of students across all developed countries. In addition, the United States has values for mathematics achievement in two of the lower ranges of percentiles that are worse than for all developed countries: the United States has 24% more students below the international 10% score, and it has 18% more students below the international 5% score.

As with science scores, the mean deviations for developing countries are shifted down about 10 points from those of developed countries. The average of mean mathematics scores for developing countries, however, is 439, in contrast with 520 for developed countries.

High School Coursetaking in Mathematics and Science

To understand students' achievement in mathematics or science, it helps to understand what courses they have taken. This section examines high school students' participation in mathematics and science courses using data from HSLS:09, the College Board's AP program, and data collected from OCR. HSLS:09 data describe the breadth of mathematics and science coursetaking from the ninth through eleventh grades, as reported by students. AP data describe students' success in mastering the material taught in college-level mathematics and science courses while in high school as measured by AP test scores. OCR data provide enrollments in high school science and mathematics courses nationwide by sex, race, and ethnicity. The main findings in this section are that the United States is making progress in increasing advanced coursetaking, though the overall percentage of students taking mathematics and science AP tests remains small, and wide gaps persist in advanced coursetaking among students from different socioeconomic backgrounds.

Eleventh Grade Mathematics and Science Coursetaking

In addition to the algebra achievement data discussed above, HSLS:09 provides detailed data about high school students' coursetaking in mathematics and science and the high school and personal factors that lead students into and out of STEM fields of study and related careers.[i] Although subsequent follow-ups include collection and coding of high school transcripts in 2013, as well as a second follow-up survey to be conducted in 2016, the coursetaking data reported here are drawn from students' responses to questions about the courses in which they were enrolled in the 2008–09 and 2011–12 academic years.[ii] Future transcript data will examine directly which courses students attempted and passed.

Science and Engineering Indicators 2014 (NSB 2014) presented data about the mathematics and science courses that ninth graders enrolled in and about variations in their coursetaking by such factors as race and ethnicity, parental education level, and SES. Algebra 1 and biology 1 were the most common courses for ninth graders. Students who had a parent with a master's degree or higher were more likely to report enrollment in a mathematics course above algebra 1, and students in the lowest SES category were more likely to report no enrollment in science or mathematics. This section examines the mathematics and science coursetaking patterns of these students when most of them were in the spring of their eleventh grade year.

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[i] NCES established the Secondary Longitudinal Studies Program (SLSP) to study the educational, vocational, and personal development of young people beginning with their high school years and following them over time into adult roles and responsibilities. Thus far, the SLSP consists of five major studies: the National Longitudinal Study of the High School Class of 1972 (NLS:72); the High School and Beyond (HS&B) survey; the National Education Longitudinal Study of 1988 (NELS:88); the Education Longitudinal Study of 2002 (ELS:2002); and the High School Longitudinal Study of 2009 (HSLS:09). More information about each of these studies is available at http://nces.ed.gov/surveys/slsp.

[ii] Additional follow-ups by NCES are currently planned to at least age 26.

Mathematics Coursetaking

Completing algebra 2 (or an equivalent course) is a high school graduation requirement under the "college- and career-ready" graduation requirements that 25 states have adopted (Achieve Inc. 2013). As of 2012, 69% of current eleventh graders (who were ninth graders in 2009) were enrolled in algebra 2 or a more advanced mathematics course (Table 1-8).[iii] Among the remaining students, 12% were taking geometry 1, 8% were taking algebra 1 or more basic mathematics, and 11% were not enrolled in any mathematics course. Substantial demographic disparities exist: 56% of students from the bottom SES quintile were taking algebra 2 or higher, compared to 83% of students from the top SES quintile (Appendix Table 1-9). Nonetheless, substantial percentages of students were enrolled in algebra 2 or higher across most demographic categories: 51% of students whose parents never completed high school, 54% of those who entered high school expecting to complete high school or less, 45% of students in the lowest quintile of prior mathematics achievement,[iv] and 56% of students from the bottom SES quintile. Across racial or ethnic groups, the percentage of students who took algebra 2 or higher ranged from 62% among Hispanic students to 86% among Asian or Pacific Islander students.

[iii] Population statistics derived from HSLS:09 are derived using the appropriate sample weights.

[iv] The prior mathematics achievement quintile score is a norm-referenced measure of achievement. The quintile score divides the weighted (population estimate) achievement distributions into five equal groups, based on mathematics score. See chapter 2 of the *HSLS:09 Base-Year Data File Documentation* for more information on the derivation of the mathematics quintile score (Ingels et al. 2011).

Table 1-8 **Highest-level mathematics course in which students in grade 11 enrolled, by student and family characteristics: 2012**

(Percentage distribution)

Student and family characteristic	No mathematics	Basic math and algebra 1	Geometry 1	Algebra 2	Trigonometry, calculus, and other advanced math[a]
All students	11.3	7.7	12.1	33.5	35.4
Sex					
Male	11.5	8.4	13.5	32.7	34.0
Female	11.2	7.0	10.7	34.4	36.8
Race or ethnicity					
White	10.6	7.2	10.1	32.8	39.3
Black	15.7	8.2	11.3	35.1	29.7
Hispanic[b]	11.0	8.5	18.2	34.3	27.9
Asian	5.9	3.1	5.3	22.4	63.5
Other	11.9	9.5	12.8	38.4	27.6
Parents' highest education[c]					
Less than high school	15.1	16.5	17.8	26.6	24.0
High school diploma or equivalent	14.5	10.1	14.7	34.3	26.3
Associate's degree	12.1	8.7	16.5	34.6	28.0

Student and family characteristic	No mathematics	Basic math and algebra 1	Geometry 1	Algebra 2	Trigonometry, calculus, and other advanced math[a]
Bachelor's degree	10.6	6.7	12.4	37.1	33.2
Master's degree or higher	7.9	4.6	6.5	27.8	53.1
Highest mathematics course in grade 9					
No mathematics	20.0	10.8	12.9	29.6	26.8
Basic math/pre-algebra	13.4	16.9	27.6	25.4	16.7
Algebra 1	9.9	7.2	14.5	49.3	19.0
Above algebra 1	10.0	4.7	2.2	10.2	73.0
Students' educational expectations in grade 9					
High school or less	14.0	12.6	19.8	35.7	18.0
Some college	13.7	11.6	14.8	38.0	21.8
Bachelor's degree	9.8	6.6	10.3	36.2	37.0
Graduate/professional degree	10.1	4.9	7.2	30.6	47.1
Don't know	11.9	9.3	16.6	36.3	26.1
Control of school in grade 12					
Public	11.6	7.7	12.5	33.6	34.6
Private	2.5	3.5	5.6	36.1	52.2
Socioeconomic status in grade 12[d]					
Lowest fifth	15.7	12.0	16.3	32.8	23.3
Middle three-fifths	11.3	7.8	12.7	36.0	32.3
Highest fifth	7.4	3.4	6.5	27.2	55.6

[a] Includes probability and statistics, trigonometry and pre-calculus, analytic geometry and calculus, and other advanced math.

[b] Hispanic may be any race. Asian, black or African American, white, and other races refer to individuals who are not of Hispanic origin.

[c] The highest level of education achieved by either parent.

[d] Socioeconomic status (SES) is a composite variable derived from parental education level, parental occupation, and family income. The quintile measure divides the SES distribution into five equal quintile groups. Quintile 1 corresponds to the lowest one-fifth of the population, and quintile 5 corresponds to the highest. For this report, the middle three quintiles are combined into one category.

NOTE: Percentages may not add to total because of rounding.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of High School Longitudinal Study of 2009 (HSLS:09), National Center for Education Statistics. See appendix table 1-9.

The HSLS:09 data show that the proportion of students reporting enrollment in courses above algebra 2 varies by demographic characteristics. Overall, 35% of all students took courses beyond algebra 2. The proportion of Asian or Pacific Islander students (64%) reporting enrollment in such courses, however, is more than twice as large as the proportion of black (30%), Hispanic (28%), or other nonwhite and not Hispanic (28%) students reporting enrollment. Additionally, the proportion who took such courses was more than twice as high for students whose highest educated parent had a master's degree or higher (53%) than for those whose parents had a high school diploma (26%) or did not finish high school (24%). Students from the highest SES quintile (56%) took these courses at twice the rate of students from the lowest SES quintile (23%).

Data from HSLS:09 confirm that prior academic performance strongly predicts later coursetaking (Conger, Long, and Iatarola 2009; Zietz and Joshi 2005). Seventy-one percent of students in the top quintile of prior mathematics achievement (determined from a measure of students' mathematics achievement as they entered ninth grade in fall 2009) took trigonometry, calculus, and other advanced mathematics courses, compared with 30% of students in the middle three quintiles and 15% in the bottom quintile (Figure 1-8). Similarly, 73% of students who had taken a class above algebra 1 in their freshman year had moved beyond algebra 2 by their junior year, whereas only 19% of 2009 freshman who had taken algebra 1 had done so.[v]

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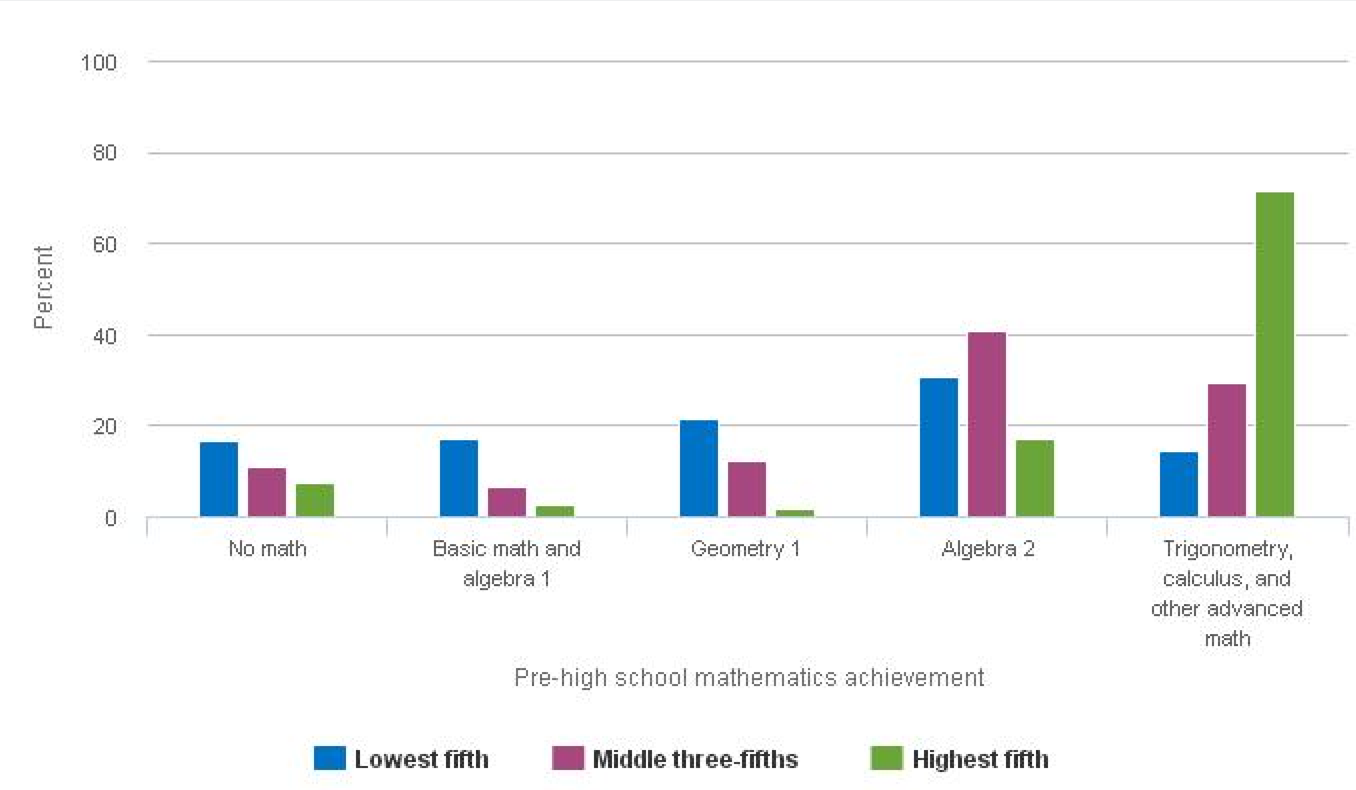
[v] Freshman year coursetaking data come from *Science and Engineering Indicators 2014* (NSB 2014). Overall, 10% of freshmen were not enrolled in a mathematics course, 9% were enrolled in basic mathematics or pre-algebra, 52% were enrolled in algebra 1, and 29% were enrolled in a more advanced course.

Figure 1-8

Highest-level mathematics course enrollment of students in grade 11, by pre-high school mathematics achievement: 2012



NOTE: Other advanced math includes probability and statistics, trigonometry and pre-calculus, analytic geometry and calculus, and other advanced math.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of High School Longitudinal Study of 2009 (HSLS:09), National Center for Education Statistics. See appendix table 1-9.

Science and Engineering Indicators 2016

Science Coursetaking

Biology 1 was the most prevalent science course among ninth graders in 2009, with 39% of students enrolled (NSB 2014). Three years later, in 2012, 41% of this cohort (most of whom were in their second semester of eleventh grade) had enrolled in the other level-1 science courses, chemistry 1 or physics 1 (Table 1-9). Moreover, across demographic groups defined by sex and by race or ethnicity, students enrolled in other level-1 courses at comparable rates: 40% of male students and 42% of female students; 43% of Asian or Pacific Islander students, 42% of white students, 41% of black students, and 40% of Hispanic students. Larger differences were observed across the spectra of parental education and SES: 32% of students whose parents had less than a high school education, for example, enrolled in chemistry 1 or physics 1, compared to 43% of students whose highest-educated parent had a bachelor's degree. Similarly, 35% of students from the bottom SES quintile enrolled in these courses, compared with 46% of students from the top quintile.

Table 1-9 **Highest-level science course enrollment of students in grade 11, by student and family characteristics: 2012**

(Percentage distribution)

Student and family characteristic	No science	General, basic, earth /environmental, physical science	Biology 1	Chemistry 1 or physics 1	Advanced science[a]
All students	19.9	8.6	10.6	40.8	20.1
Sex					
Male	21.1	9.9	11.3	39.6	18.2
Female	18.7	7.3	9.9	42.1	22.0
Race or ethnicity					
White	18.4	8.7	9.4	41.9	21.7
Black	23.7	9.2	11.6	40.8	14.8
Hispanic[b]	22.2	8.2	12.7	39.8	17.1
Asian	8.6	3.8	7.1	43.2	37.3
Other	22.2	10.9	12.5	36.0	18.5
Parents' highest education[c]					
Less than high school	32.6	10.1	11.1	31.5	14.7
High school diploma or equivalent	20.8	10.6	13.2	39.3	16.2
Associate's degree	26.6	10.8	14.0	33.6	15.1
Bachelor's degree	18.8	10.2	10.0	43.3	17.6
Master's degree or higher	12.8	6.7	6.9	44.8	28.9
Highest science course in grade 9					
No science	33.0	10.1	13.1	29.8	14.0
General science	19.6	9.5	18.7	37.7	14.5

Student and family characteristic	No science	General, basic, earth /environmental, physical science	Biology 1	Chemistry 1 or physics 1	Advanced science[a]
Earth/environmental/physical science	18.1	9.4	9.7	46.2	16.7
Biology 1	15.5	8.0	8.2	43.0	25.2
Above biology 1	16.7	3.6	17.5	36.5	25.7
Students' educational expectations in grade 9					
High school or less	29.1	12.0	17.1	28.6	13.3
Some college	22.7	12.8	11.1	38.8	14.6
Bachelor's degree	17.9	7.2	8.7	47.2	19.0
Graduate/professional degree	15.9	6.1	7.7	44.0	26.3
Don't know	21.6	11.1	13.1	38.8	15.4
Control of school in grade 12					
Public	20.1	8.8	10.8	40.4	19.8
Private	7.5	4.5	6.3	55.2	26.5
Socioeconomic status in grade 12[d]					
Lowest fifth	25.9	9.7	14.6	34.6	15.1
Middle three-fifths	20.5	9.3	10.8	41.1	18.3
Highest fifth	12.8	5.6	6.4	45.6	29.7

[a] Includes biology 2, chemistry 2, physics 2, and other advanced science.

[b] Hispanic may be any race. Asian, black or African American, white, and other races refer to individuals who are not of Hispanic origin.

[c] The highest level of education achieved by either parent.

[d] Socioeconomic status (SES) is a composite variable derived from parental education level, parental occupation, and family income. The quintile measure divides the SES distribution into five equal quintile groups. Quintile 1 corresponds to the lowest one-fifth of the population, and quintile 5 corresponds to the highest. For this report, the middle three quintiles are combined into one category.

NOTE: Percentages may not add to total because of rounding.

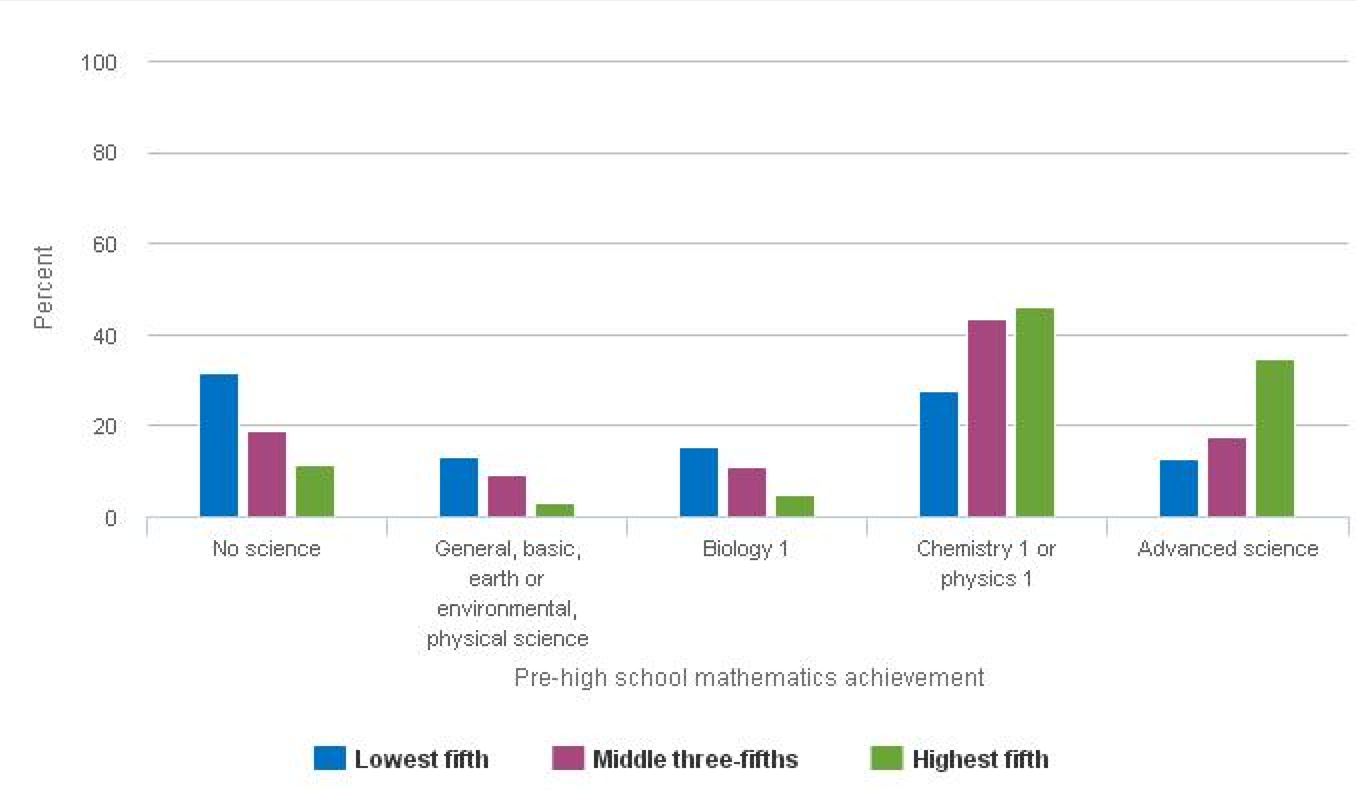
SOURCE:	National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of High School Longitudinal Study of 2009 (HSLS:09), National Center for Education Statistics. See appendix table 1-10. *Science and Engineering Indicators 2016*

The pattern in level-1 chemistry or physics coursetaking varied appreciably by prior mathematics achievement,[vi] with 28% of students from the bottom achievement quintile enrolling in these classes versus 46% of those in the top achievement quintile (Figure 1-9). There were also large differences by educational expectations, with 29% enrollment in chemistry 1 or physics 1 among students anticipating a high school diploma or less, compared with 47% of students anticipating a bachelor's degree and 44% of students anticipating a graduate or professional degree (Table 1-9).

[vi] Prior science achievement was not measured in HSLS:09.

Figure 1-9

Highest-level science course enrollment of students in grade 11, by pre-high school mathematics achievement: 2012



NOTE: Advanced science includes biology 2, chemistry 2, physics 2, and other advanced science.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of High School Longitudinal Study of 2009 (HSLS:09), National Center for Education Statistics. See appendix table 1-10.

Science and Engineering Indicators 2016

As with mathematics, taking advanced science courses in high school allows students to move through college science curricula quickly. For example, advanced science coursetaking in high school has been associated with better performance in introductory college biology, a prerequisite for more advanced study in biology and health-related fields (Loehr et al. 2012). Similarly, enrollment and performance in advanced physics and calculus courses during high school are also positively associated with performance in college physics and calculus courses (Tyson 2011).

Disparities in advanced science coursetaking, therefore, have consequences, and the HSLS:09 data reveal that, as with mathematics, the percentage of students taking more advanced science courses (i.e., level-2 sciences and similar) varied with some demographic characteristics. Overall, 20% of students took advanced science courses in spring 2012, with young women slightly more likely than young men to do so (22% versus 18%) (Table 1-9). But whereas 15% and 17% of black and Hispanic students took these courses, respectively, more than twice as many Asian or Pacific Islander students did (37%). The ratio was similar across other demographic categories as well:

- Fifteen percent of students whose most-educated parent had less than a high school education took advanced science, compared with 29% of those whose most-educated parent had at least a master's degree.

- Thirteen percent of students in the lowest quintile of mathematics achievement took advanced science, compared with 35% of those in the highest achievement quintile (Appendix Table 1-10).
- Thirteen percent of students anticipating completing at most a high school education took advanced science, compared to 26% of those anticipating completing a graduate degree.
- Fifteen percent of students in the lowest SES quintile took advanced science, compared to 30% of those in the highest SES quintile.

Computer Science and Engineering Coursetaking

Computer science and coding skills are widely recognized as a valuable asset in the current and projected job market (Zinth 2015). The Bureau of Labor Statistics projects 37.6% growth from 2012 to 2022 in the computer systems design and related services industry—from 1,620,300 jobs in 2012 to a projected 2,229,000 jobs in 2022 (U.S. DOL/BLS 2013). The percentages of U.S. students taking computer science and engineering courses in high school are quite low, however, and vary by sex and other demographic characteristics. A recent survey of high school administrators indicates that most schools offer computer science, but most of these schools count computer science as an elective rather than a requirement, which may contribute to a low percentage of students taking such courses (CSTA 2014). To encourage districts to offer computer science courses—and to encourage students to complete these classes—14 states have amended high school graduation requirements either to allow or require computer science to fulfill math, science, or foreign language course requirements (Zinth 2015). Several states also have begun to require computer science courses to fulfill requirements for a specialized diploma or an endorsement to the standard high school diploma.

HSLS:09 data show that a quite small proportion of students take computer science or engineering courses, with 6% of second-semester eleventh graders taking computer science classes and 2% taking engineering classes in 2012 (Table 1-10). Male students were more likely to take both types of courses. About 3% of male students took engineering courses, compared with less than 1% of female students (Appendix Table 1-11). In computer science, it was 7% of male students, compared with 4% of female students. This gender disparity is also apparent in AP courses, with courses such as computer science A made up of 81% male students and just 19% of female students (Figure 1-10).

Table 1-10 **Engineering and computer/information science course enrollment of students in grade 11, by student and family characteristics: 2012**

(Percent)

Student and family characteristic	Engineering	Computer/ information science
All students	2.0	5.7
Sex		
Male	3.3	7.2
Female	0.7	4.2
Race or ethnicity		
White	2.1	5.5
Black	1.9	5.6
Hispanic[a]	1.6	6.2
Asian	1.9	6.9

Student and family characteristic	Engineering	Computer/ information science
Other	2.1	5.7
Parents' highest education[b]		
Less than high school	1.4	8.1
High school diploma or equivalent	1.2	7.7
Associate's degree	2.4	4.2
Bachelor's degree	1.5	4.7
Master's degree or higher	2.6	5.6
Highest mathematics course in grade 9		
No math	2.3	6.4
Basic math/pre-algebra	1.5	4.0
Algebra 1	1.7	5.5
Above algebra 1	2.4	6.4
Students' educational expectations in grade 9		
High school or less	1.9	5.3
Some college	1.8	4.6
Bachelor's degree	2.3	6.4
Graduate/professional degree	2.1	5.9
Don't know	1.7	5.7
Control of school in grade 12		
Public	2.1	5.8
Private	1.0	4.0
Socioeconomic status in grade 12[c]		
Lowest fifth	1.4	7.8
Middle three-fifths	2.1	5.1
Highest fifth	2.2	5.6

[a] Hispanic may be any race. Asian, black or African American, white, and other races refer to individuals who are not of Hispanic origin.

[b] The highest level of education achieved by either parent.

[c] Socioeconomic status (SES) is a composite variable derived from parental education level, parental occupation, and family income. The quintile measure divides the SES distribution into five equal quintile groups. Quintile 1 corresponds to the lowest one-fifth of the population, and quintile 5 corresponds to the highest. For this report, the middle three quintiles are combined into one category.

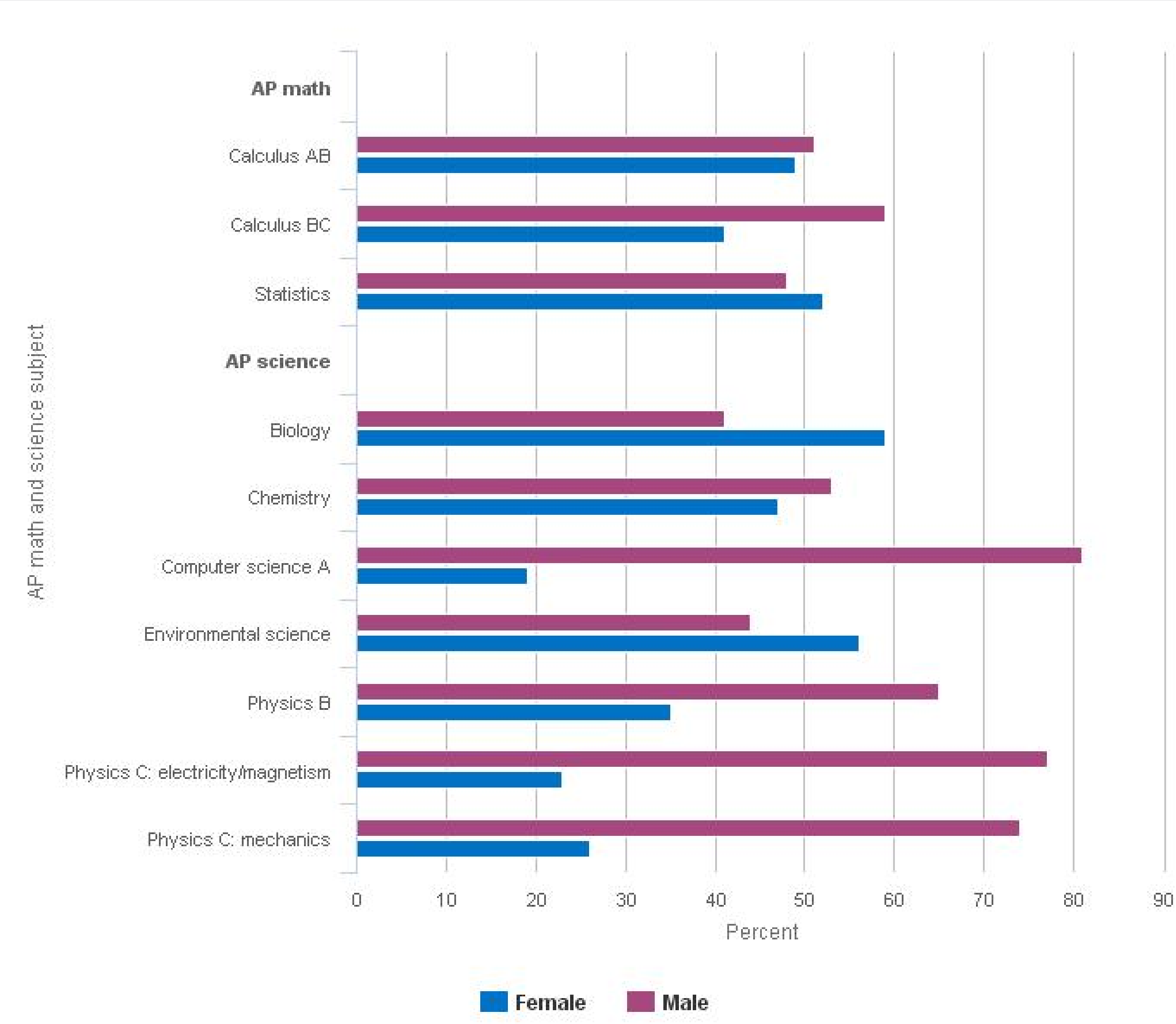
NOTE: Percentages may not add to total because of rounding.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of High School Longitudinal Study of 2009 (HSLS:09), National Center for Education Statistics. See appendix table 1-11.

Science and Engineering Indicators 2016

Figure 1-10

Public school students in graduating class of 2013 who took AP exams in mathematics and science in high school, by sex



AP = Advanced Placement.

NOTES: The College Board reports AP results by graduating class rather than by calendar year. Results include exams taken by graduates throughout their high school career.

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Science and Engineering Indicators 2016

Participation and Performance in the Advanced Placement Program

The AP program is one of the largest and most well-known programs offering high school students the opportunity to earn college credit. Other opportunities include the International Baccalaureate program, which also offers college credit for high school courses, and dual enrollment, where students enroll in college courses while still in high school (Thomas et al. 2013).

Administered by the College Board, a nonprofit organization, the AP program offers college-level courses in 34 different subjects in students' high schools, enabling students to earn credit toward both high school diplomas and college degrees simultaneously. The College Board also administers exams that test students' mastery of course material. Students who earn a passing score (3 or higher out of 5) on an AP exam may be eligible to earn college credits, placement into more advanced college courses, or both, depending on the policy of the postsecondary institution they attend.

AP Exam Taking and Performance among All Students

About one-third of 2013 high school graduates took an AP exam in any subject, and about one-fifth of all students passed the exam. Seventeen percent of students took an AP mathematics or science exam, and 10% passed (Table 1-11). Among mathematics and science exams, calculus AB has been the most popular, followed by biology; both remained so in 2013, when approximately 223,000 students took the calculus AB exam and 162,000 took the biology exam. Fewer students took more advanced exams (e.g., calculus BC, taken by about 78,000 students). Physics C: electricity and magnetism was the least popular exam among 2013 graduates, taken by approximately 14,000 students (Table 1-12).

Table 1-11 **Public school students who took or passed an AP exam as a proportion of overall student population, by subject: Graduating classes 2003, 2008, and 2013**

(Percent)

	Students who took an AP exam			Students who passed an AP exam[a]		
Subject	2003	2008	2013	2003	2008	2013
Any subject	18.9	25.2	33.2	12.2	15.4	20.1
Mathematics or science[b]	10.0	13.2	17.4	6.1	7.4	9.7

AP = Advanced Placement.

[a] Students scoring 3, 4, or 5 on a scale of 1–5 for an AP exam.

[b] Includes calculus AB, calculus BC, statistics, biology, chemistry, environmental science, computer science A, physics B, physics C: electricity/magnetism, and physics C: mechanics.

NOTES: The College Board reports AP results by graduating class rather than by calendar year. Results include exams taken by graduates throughout their high school career.

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Science and Engineering Indicators 2016

Table 1-12 **Public school students who took or passed an AP exam in high school, by subject: Graduating classes 2003, 2008, and 2013**

	Students who took an AP exam (number)			Students who passed an AP exam (number)[a]			Students who passed an AP exam (%)[a]		
Subject	2003	2008	2013	2003	2008	2013	2003	2008	2013
Any AP exam	514,163	756,708	1,003,430	331,734	460,785	607,505	64.5	60.9	60.5
Any AP mathematics or science exam	272,580	396,232	527,001	166,582	222,931	291,946	61.1	56.3	55.4
AP mathematics exam									
Calculus AB	131,951	176,864	223,444	86,048	104,722	128,940	65.2	59.2	57.7
Calculus BC	36,619	55,323	78,291	29,252	43,769	62,965	79.9	79.1	80.4
Statistics	48,345	92,692	141,335	28,967	53,581	80,529	59.9	57.8	57.0
AP science exam									
Biology	80,000	121,554	162,381	47,544	64,718	90,198	59.4	53.2	55.5
Chemistry	51,105	79,242	107,431	29,469	42,685	58,536	57.7	53.9	54.5
Environmental science	22,039	50,118	97,918	10,896	25,860	46,733	49.4	51.6	47.7
Computer science A	12,090	12,258	22,273	7,551	7,003	14,293	62.5	57.1	64.2
Physics B	31,650	46,009	68,802	18,412	26,555	41,278	58.2	57.7	60.0
Physics C: electricity /magnetism	7,581	9,349	14,045	4,941	6,387	9,458	65.2	68.3	67.3
Physics C: mechanics	16,042	21,994	31,959	11,322	15,789	23,472	70.6	71.8	73.4

AP = Advanced Placement.

[a] Students scoring 3, 4, or 5 on a scale of 1–5 for an AP exam.

NOTES: The College Board reports AP results by graduating class rather than by calendar year. Results include exams taken by graduates throughout their high school career.

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The number of high school graduates who take at least one AP exam doubled in the 10 years from 2003 to 2013. In contrast, the overall high school population increased by just 9% between 2001 and 2013 (U.S. DOE 2015). In 2013, just over 1 million students took one or more AP exams in any subject, almost twice the 514,000 students who took an AP exam in 2003. Similarly, the number of students who took an AP exam in mathematics or science rose from 273,000 in 2003 to 527,000 in 2013. The AP statistics exam continued to grow in popularity, with 141,000 students taking the exam in 2013, compared with 48,000 in 2003. Though still representing a small proportion of overall AP exams, the computer science A exam has also grown over the past 10 years, with 22,000 students taking the exam in 2013, compared with 12,000 in 2003 and 2008.

The growing number of students taking AP exams over the past decade was accompanied by a decline in the overall passing rate, even as rates for some individual exams have risen or remained steady. In 2013, 61% of students who took one or more AP exams had passed at least one exam, compared with 65% in 2003. For mathematics and science exams, the passing rate was 55%; the corresponding 2003 passing rate was 61%.

Passing rates were highest for the more advanced exams. In 2013, the passing rate for calculus BC was 80% (the highest of any exam), compared with 58% for calculus AB. The passing rate was 73% for physics C: mechanics, 67% for physics C: electricity and magnetism, but 60% for physics B. The lowest passing rate for any AP mathematics or science exam was 48% for the environmental science exam. Despite the growth in the number of AP test takers, the College Board estimates that 60% of students who have the potential to succeed in AP coursework (based on performance on sections of the Preliminary SAT/National Merit Scholarship Qualifying Test) do not participate in AP courses (College Board 2014).

AP Exam Taking and Performance by Sex and Race or Ethnicity

Mathematics and science AP exam taking at the most advanced levels varies with students' sex and race or ethnicity. Although the students who took calculus AB, statistics, and chemistry exams were roughly evenly split by sex, at advanced levels male students predominated, representing 59% of all calculus BC takers, 65% of physics B, 77% of physics C: electricity and magnetism, and 74% of physics C: mechanics (Figure 1-10).

In addition, black and Hispanic students are underrepresented among AP exam takers, particularly among more advanced mathematics and science courses (College Board 2014). Black students made up 15% of 2013 high school graduates but only 3% of students who took the calculus BC or either physics C exam (Appendix Table 1-12). Hispanic students made up 19% of graduates but less than 10% of exam takers in calculus BC (8%), physics C: electricity and magnetism (7%), and physics C: mechanics (9%). On the other hand, Asians or Pacific Islanders were overrepresented among AP exam takers, accounting for 6% of graduates but about 30% of exam takers in physics C: electricity and magnetism and in calculus BC.

Racial and Ethnic Differences in Advanced Mathematics and Science Coursetaking: Civil Rights Data

OCR collects data from U.S. primary and secondary schools about students' demographics and access to high school–level mathematics and science courses. These data provide an additional look at racial and ethnic differences in high school mathematics and science coursetaking. In the most recent academic year with data available, 2009–10, enrollments in lower-level courses such as geometry and biology show little differentiation across racial and ethnic and groups (Appendix Table 1-13). For example, 22% of all students were enrolled in geometry, including 22% of white students, 22% of Hispanic students, 23% of Asian or Pacific Islander students, and 20% of American Indian or Alaska Native students.[i] However, in high-level courses such as calculus, fewer black and Hispanic students were enrolled relative to Asian or Pacific Islander and white students: 3% of all students were enrolled in calculus, including 4% of white students, 9% of Asian or Pacific Islander students, 2% of black students, and 1% each among Hispanic and American Indian or Alaska Native students.

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[i] No estimate was available for black students.

Teachers of Mathematics and Science

Students' achievement in mathematics and science depends not only on the courses they take but also, in large part, on their access to high-quality instruction. Many factors affect teacher quality, including qualifications, subject-matter knowledge, ongoing professional development, access to instructional coaches, and working conditions (Campbell and Malkus 2011; Creemers, Kryiakides, and Antoniou 2013; DeMonte 2013; Eckert 2013; Johnson, Kraft, and Papay 2012; Schmidt et al. 2008; Shober 2012; Wilson 2011). This section presents various indicators of public school mathematics and science teachers' quality, including educational attainment, professional certification, participation in student teaching, self-assessment of preparation, and years of experience. The section also examines school factors, such as salary and working conditions, that contribute to teacher effectiveness. It focuses on middle and high school teachers because mathematics and science teachers are more common and more easily identified at these levels than at the elementary level.[i] The main finding in this section is that highly qualified teachers, as measured by any of the indicators presented here, are less prevalent at high-poverty and high-minority schools.

The primary data source is the 2011−12 SASS, a national survey designed to provide descriptive data on elementary and secondary education across a wide range of topics, including teacher demand, teacher and principal characteristics, general conditions in schools, principals' and teachers' perceptions of their school climate and problems in their schools, teacher compensation, and district hiring and retention practices. Comparable data from earlier SASS collections in 2003−04 and 2007−08 are also used to examine changes over time. In this section, 2003, 2007, and 2011 refer to the academic years 2003−04, 2007−08, and 2011−12. When possible, measures are analyzed separately for schools with differing concentrations of minority and low-income students.[ii]

To provide context, the total number of U.S. public school teachers was about 3.4 million in 2011 (Appendix Table 1-14), a 13% increase over the approximately 3.0 million teachers employed in 1999 (Gruber, Wiley, and Broughman 2002). In 2011, approximately 509,000 taught mathematics or science in public schools, accounting for 15% of the public school teaching force nationwide. Most subject-specific mathematics and science teachers (approximately 415,000, or 82%) taught at the middle and high school levels. The number of elementary teachers at public schools in 2011 was approximately 1.8 million, and the majority of those teachers taught mathematics and science in addition to other subjects.

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[i] Middle and high school teachers included in this section are identified using an NCES Schools and Staffing Survey (SASS) variable that indicates the level of the school at which teachers are employed. Middle schools are defined as those with no grade lower than 5 and no grade higher than 8; high schools are defined as those with no grade lower than 7 and at least one grade higher than 8. Elementary school teachers, not included in these indicators, typically teach multiple subjects, and most of them hold a certification in general education.

[ii] Based on the percentage of students in school qualifying for free/reduced-price lunch.

Characteristics of High-Quality Teachers

The effects of good teachers on student achievement have been well documented (Boonen, Van Damme, and Onghena 2014; Hanushek 2011; Harris and Sass 2011; Jackson, Rockoff, and Staiger 2014; Stronge, Ward, and Grant 2011), but the specific teacher characteristics that contribute to student success remain less clear. Some studies have cast doubt on whether commonly measured indicators, such as teachers' licensure scores or the selectivity of their undergraduate institutions, are related to teaching effectiveness (Boyd et al. 2006; Buddin and Zamarro 2009a, 2009b; Hanushek and Rivkin 2006). This section reports on indicators such as public school mathematics and science teachers' educational attainment, professional certification, participation in student teaching, self-assessment of preparation, and years of experience. Other less easily observed characteristics may also contribute to teacher effectiveness, including teachers' abilities to motivate students, engage students in learning, maximize instruction time, and diagnose and overcome students' learning difficulties. However, these characteristics are often difficult and costly to measure and therefore are rarely included in nationally representative surveys.

Highest Degree Attained

Although teachers with master's degrees typically earn additional salary or stipends, research suggests that these degrees are not associated with improved student achievement (Harris and Sass 2007; Leak and Farkas 2011). There are studies, however, that suggest that master's degrees in math and science are associated with a positive effect on student achievement in those subjects (Miller and Roza 2012). The data available from SASS do not break advanced degrees down by subject area, but available data are reported here because of general interest in teacher qualifications. Virtually all mathematics and science teachers at public middle and high schools in 2011 held at least a bachelor's degree, and more than half had earned an additional degree (e.g., master's degree, education specialist, certificate of advanced graduate studies, doctorate, professional degree) (Figure 1-11). The proportion of middle and high school mathematics and science teachers with a master's degree or higher has increased since 2003, from 48% to 56% in 2011 for mathematics teachers and from 52% to 61% for science teachers (Appendix Table 1-15). But teachers with master's degrees were not evenly distributed across schools. For example, in 2011, 71% of science teachers in low-poverty schools had earned a master's or higher degree, compared with 52% of those in high-poverty schools (Table 1-13).[i]

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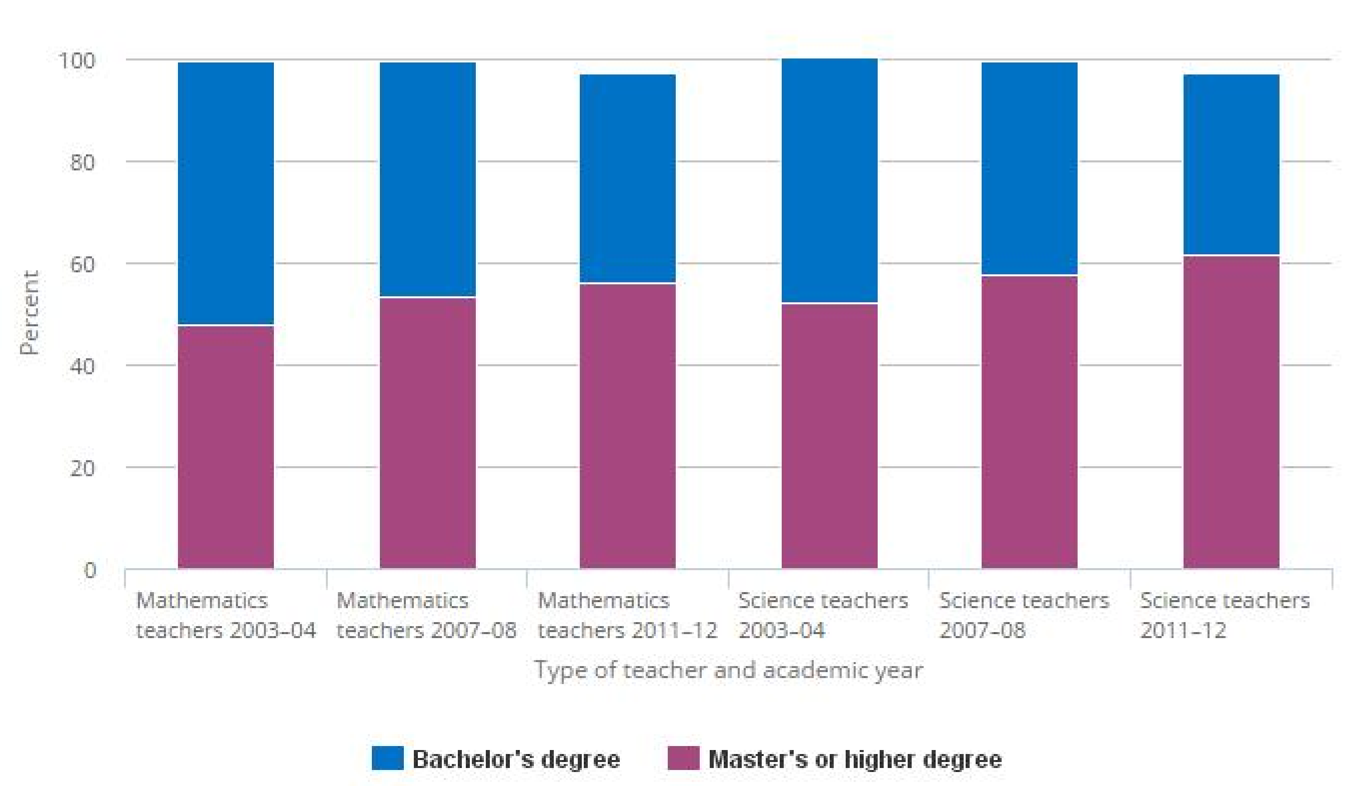
[i] To simplify the discussion, schools in which 10% or fewer of the students are eligible for the federal free /reduced-price lunch program are called *low-poverty schools,* and schools in which more than 50% of the students are eligible are called *high-poverty schools.* Similarly, *low-minority schools* are those in which 5% or fewer of the students are members of a minority, and *high-minority schools* are those in which more than 45% of the students are members of a minority.

Figure 1-11

Public middle and high school mathematics and science teachers who had a bachelor's or higher degree: Academic years 2003–04, 2007–08, and 2011–12



SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of 2003–04, 2007–08, and 2011–12 Schools and Staffing Survey, National Center for Education Statistics. See appendix table 1-15.

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Table 1-13 Public middle and high school mathematics and science teachers with a master's or higher degree, by minority enrollment and school poverty level: Academic year 2011–12

(Percent)

School characteristic	Mathematics teachers	Science teachers
Minority enrollment (%)		
0–5	58.2	63.7
> 5–45	57.6	67.1
> 45	54.0	54.6
School poverty level (%)[a]		
0–10	62.3	71.1
> 10–50	54.9	65.9
> 50	55.0	52.1

	[a] School poverty level is percentage of students in school qualifying for free/reduced-price lunch.
SOURCE:	National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of 2011–12 Schools and Staffing Survey, National Center for Education Statistics. See appendix table 1-15.
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Certification and Entry into the Profession

All public school teachers must have some type of state certification to teach. The traditional path to becoming a teacher begins in an undergraduate education program, where future teachers earn a bachelor's or master's degree and full teaching certification prior to beginning to teach. In recent years, a growing proportion of new teachers have entered the profession through an alternative pathway that typically involves a program that recruits college graduates from other fields or midcareer professionals in nonteaching positions. These teachers often begin to teach with probationary or temporary certification while they work toward regular certification during the first few years of their teaching careers.[ii]

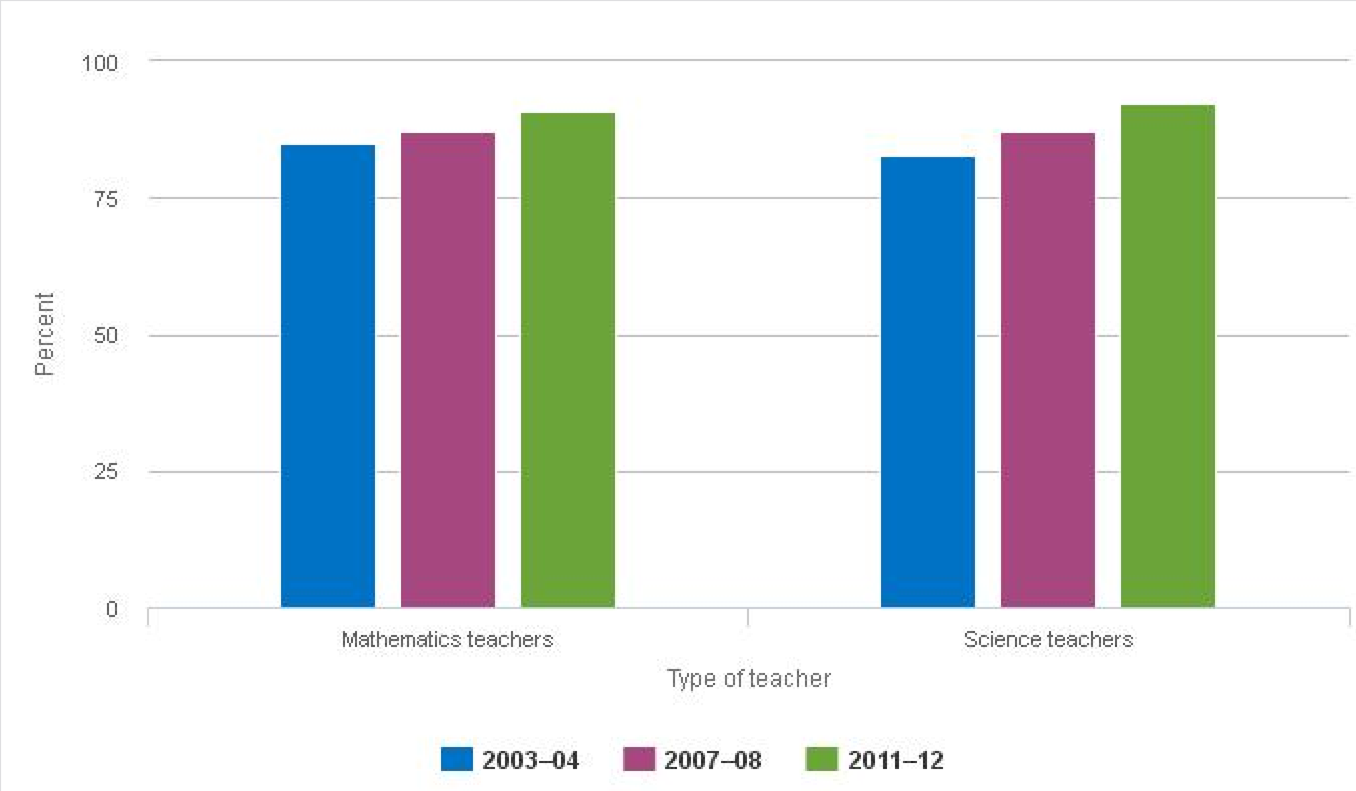
State certification. Each state requires public school teachers to earn a certificate that licenses them to teach. States set criteria for various types of certification; usually, a full certification entails a combination of passing scores on tests, a bachelor's degree with a specified number of credits in education and in the discipline taught, and supervised student teaching experience (NCTQ 2013). In 2011, 25 states required prospective teachers to have a major in a content-specific subject area for at least one initial credential at the secondary level, whereas 20 states had the same requirement at the middle school level and 13 at the elementary level (U.S. Department of Education 2013b). Differences in state standards and requirements for certification complicate measurement of the effect of teachers' credentials on student outcomes; this may have contributed to the research finding that teacher certification has mixed effects on student achievement (Guarino et al. 2013; Jacob 2012; Leak and Farkas 2011; Mo, Singh, and Chang 2013).

In 2011, the vast majority of public middle and high school mathematics and science teachers (91% and 92%, respectively) were fully certified (i.e., held regular or advanced state certification) (Figure 1-12). The percentage of mathematics and science teachers with full state certification has increased by 6 percentage points and 9 percentage points, respectively, from 2003 to 2011. The increase was seen in many types of schools but was more apparent among science teachers in high-minority schools (from 79% in 2003 to 90% in 2011) and high-poverty schools (from 80% to 91%) (Appendix Table 1-16).

[ii]Probationary certification generally is awarded to those who have completed all requirements except for a probationary teaching period. Provisional or temporary certification is awarded to those who still have requirements to meet. States also issue emergency certification to those with insufficient teacher preparation who must complete a regular certification program to continue teaching. Teachers' type of certification differs from their pathway into the profession: teachers from both traditional and alternative programs may have any type of state certification enabling them to teach. Alternative-pathway teachers, however, are more likely to begin teaching with a provisional or temporary certification.

Figure 1-12

Public middle and high school mathematics and science teachers who held a regular or advanced certification: Academic years 2003–04, 2007–08, and 2011–12



SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of 2003–04, 2007–08, and 2011–12 Schools and Staffing Survey, National Center for Education Statistics. See appendix table 1-16.

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Despite these increases, fully certified mathematics and science teachers were still less prevalent in high-minority and high-poverty schools when compared with schools with more advantaged students. For example, 88% of mathematics teachers in high-poverty schools were fully certified, compared with 95% of those in low-poverty schools (Table 1-14). The share of fully certified science teachers was 91% in high-minority schools, slightly lower than the 95% in low-minority schools.

Table 1-14 Public middle and high school mathematics and science teachers with a regular or advanced certification, by minority enrollment and school poverty level: Academic year 2011–12

(Percent)

School characteristic	Mathematics teachers	Science teachers
Minority enrollment (%)		
0–5	94.4	94.8
> 5–45	92.5	94.5

School characteristic	Mathematics teachers	Science teachers
> 45	88.6	89.5
School poverty level (%)[a]		
0–10	95.2	95.0
> 10–50	91.9	92.8
> 50	88.2	90.6

[a] School poverty level is percentage of students in school qualifying for free/reduced-price lunch.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of 2011–12 Schools and Staffing Survey, National Center for Education Statistics. See appendix table 1-16.

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Alternative entry into the teaching profession. Rather than completing traditional undergraduate programs in education, some teachers enter teaching through alternative programs such as Teach for America, The New Teacher Project (TNTP), and other programs administered by states, districts, universities, and other organizations to expedite the transition of nonteachers into teaching. Some alternative entry programs place recruits in *high-need schools*—generally, those with high levels of student poverty and low levels of student achievement. According to its website, TNTP has recruited or trained nearly 50,000 teachers for high-need locations since 1997; Teach for America's annual placement of teachers in high-need schools has grown from about 900 to more than 10,000 between 1995 and 2013 (Teach for America 2013). Although data are not available on the number of mathematics and science teachers placed by these programs, the goals of both TNTP and Teach for America include increasing the supply of teachers in those subject areas.[iii]

Researchers have observed few systematic differences in the training received by aspiring teachers in traditional versus alternative pathways (Henry et al. 2014; Linek et al. 2012; Sass 2011).[iv] Much of the formal training for teachers in both traditional and alternative programs takes place in schools of education at universities (Walsh and Jacobs 2007). Although SASS data show that a smaller proportion of alternative-pathway teachers participated in student teaching before beginning teaching (see the "Student Teaching" section), research has generally found few clear effects of teachers' pathways into the profession on students' achievement (Gansle, Noell, and Burns 2012; Goldhaber, Liddle, and Theobald 2013; Harris and Sass 2011). Some studies have found that teachers from particular programs, such as Teach for America, may be more effective in teaching STEM subjects than teachers with other types of preparation (Henry et al. 2014).

SASS asked teachers whether they entered the teaching profession through an alternative certification program designed to expedite the transition of nonteachers to a teaching career (e.g., a state, district, or university alternative certification program). In 2011, 18% of public middle and high school mathematics teachers and 26% of science teachers had entered the profession through an alternative certification program, compared with 17% of teachers in other fields (Table 1-15). The number of science teachers who had entered the profession through this pathway has risen somewhat in recent years, from 22% in 2007 to 26% in 2011 (Appendix Table 1-17).

[iii] In 2011, states reported 439 alternative-route teacher programs offered at postsecondary institutions (U.S. Department of Education 2013b). Some programs, such as Teach for America, receive direct federal support, and others are themselves federal programs, such as the U.S. Department of Defense's Troops to Teachers program, which facilitates the entry of military personnel into teaching careers. Race to the Top, a federal competitive grant

program encouraging certain education reforms, awarded points to applicant states for providing high-quality alternative pathways for aspiring teachers. More information about these programs is available at https://www.teachforamerica.org/about-us/our-initiatives/stem-initiative and http://blowmindsteachstem.com/. Information about the Troops to Teachers program is available at http://www2.ed.gov/programs/troops/index.html.

[iv] Large variation has been observed between programs within each pathway (Boyd et al. 2008).

Table 1-15 **Public middle and high school mathematics, science, and other teachers who entered teaching through an alternative certification program, by minority enrollment and school poverty level: Academic year 2011–12**

(Percent)

School characteristic	Mathematics teachers	Science teachers	Other teachers
All schools	17.8	25.6	16.9
Minority enrollment (%)			
0–5	8.9	14.8	10.6
> 5–45	12.3	21.4	13.4
> 45	24.3	32.0	21.8
School poverty level (%)[a]			
0–10	11.6	19.0	11.5
> 10–50	14.6	22.9	13.7
> 50	23.2	31.2	22.2

[a] School poverty level is percentage of students in school qualifying for free/reduced-price lunch.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of 2011–12 Schools and Staffing Survey, National Center for Education Statistics. See appendix table 1-17.

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Teachers who had entered through alternative programs were more concentrated in schools with high rates of minority enrollment and school poverty, reflecting the recruiting priority that these programs place on high-need schools. For example, 23% of mathematics teachers in high-poverty schools had entered teaching through an alternative program, compared with 12% of those in low-poverty schools (Table 1-15). The percentage of science teachers in high-poverty schools who had entered teaching through an alternative program was 31%, compared with 19% of science teachers in low-poverty schools. Although the supply of mathematics and science teachers generally has been adequate to fill vacancies due to retirement of mathematics teachers, many schools find it difficult to fill their mathematics and science teaching positions due to preretirement teacher turnover (Goldhaber et al. 2014; Ingersoll 2011; Ingersoll and May 2012). Teacher shortages in these subjects are not distributed evenly across schools. High-poverty and high-minority schools in urban areas tend to have the highest rates of teacher turnover. The resulting shortages may contribute to schools' decisions to hire teachers from alternative entry programs.

Student Teaching

Student teaching offers prospective teachers hands-on classroom experience to help them transfer what they learn from coursework into classroom teaching. Practical experience in the classroom may also affect student achievement once teachers enter the classroom (Ronfeldt 2012; Ronfeldt and Reininger 2012).[v] According to

SASS data, teachers who had participated in student teaching were generally more likely than those who had not to report feeling well, or very well, prepared for various aspects of their first year of teaching (Appendix Table 1-18).

Among public middle and high school mathematics and science teachers with fewer than 5 years of experience in 2011, 85% of mathematics teachers and 75% of science teachers had participated in student teaching (Figure 1-13). The proportion differed by school composition; for example, 94% of new mathematics and 89% of new science teachers in low-poverty schools participated in student teaching, compared with 80% and 73%, respectively, in high-poverty schools (Appendix Table 1-19).

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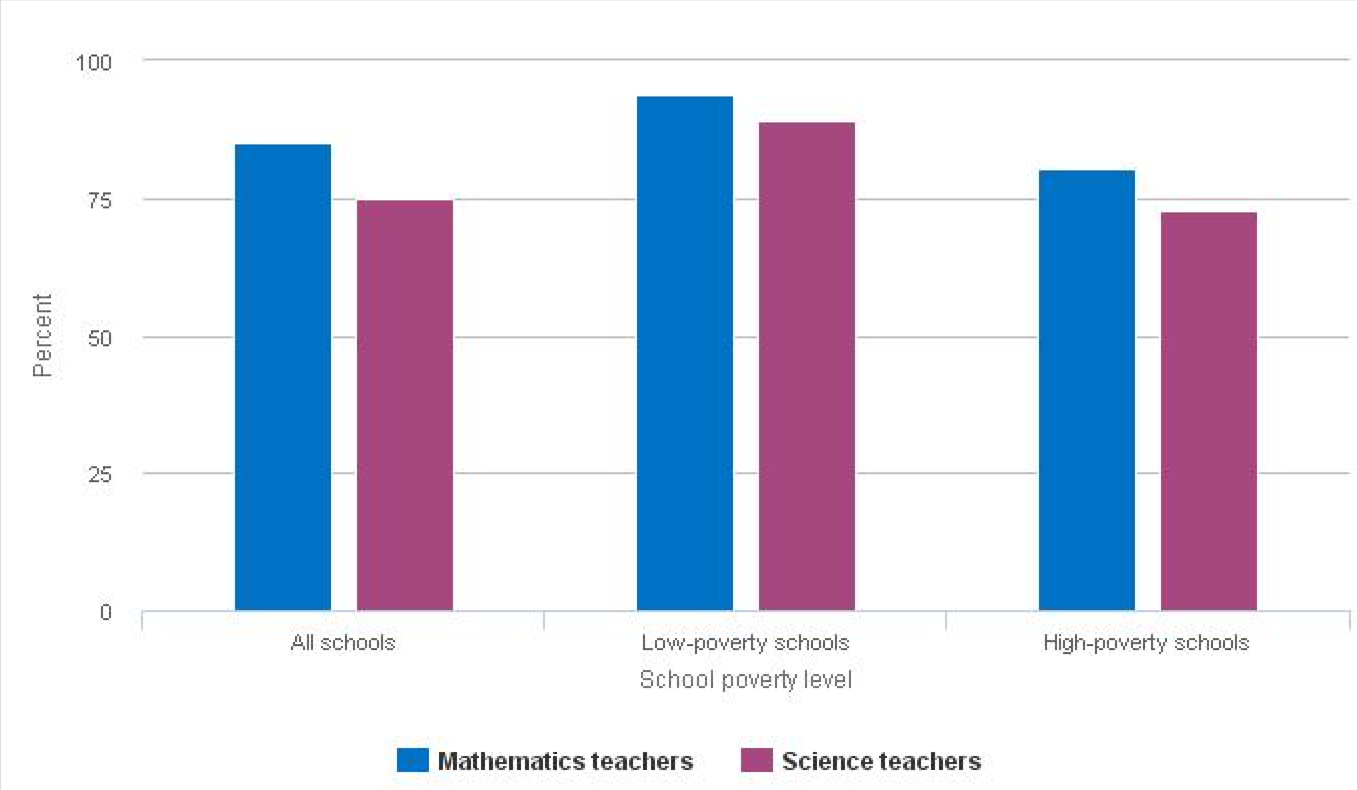
[v] Research suggests that characteristics of the student teaching placement program affect subsequent teacher effectiveness. In New York City, teachers who were placed in easy-to-staff schools during their student teaching were more likely to remain teaching in the district and see gains in student achievement, regardless of the characteristics of the school at which they were ultimately employed (Ronfeldt 2012). Teachers whose preparation programs provided oversight of their student teaching and required a capstone project saw larger student achievement gains during their first year (Boyd et al. 2008).

Figure 1-13

Participation of new public middle and high school mathematics and science teachers in practice teaching, by school poverty level: Academic year 2011–12



NOTES: New teachers refer to teachers with fewer than 5 years of teaching experience. School poverty level is percentage of students in school qualifying for free/reduced-price lunch. Schools with 0%–10% of such students are low-poverty schools, and schools with more than 50% of such students are high-poverty schools.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of 2011–12 Schools and Staffing Survey, National Center for Education Statistics. See appendix table 1-19.

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Although student teaching is prevalent, many teachers who entered the profession through alternative programs report not participating in student teaching. In 2011, 48% of mathematics teachers and 52% of science teachers who entered the profession through an alternative program had not participated in student teaching, lower than the 94% of mathematics and science teachers who entered teaching the traditional way (Appendix Table 1-20). Thirty-nine states require prospective teachers in traditional preparation programs to participate in student teaching, whereas 16 states require that all alternative-route teachers have an opportunity to student teach (NCTQ 2011, 2013).

Self-Assessment of Preparedness

New middle and high school teachers generally reported that they felt well prepared to perform various tasks during their first year of teaching (Appendix Table 1-21). In 2011, 87% of new mathematics teachers and 90% of new science teachers felt prepared to teach their subject matter. Among new science teachers, this represents an increase since 2003, when 79% felt prepared to teach the subject matter. A larger proportion of new science teachers also reported feeling prepared to assess students (70% in 2011 versus 59% in 2003). New teachers' assessments of their preparation were lower in high-minority and high-poverty schools. For example, in 2011, 95% of new mathematics teachers in low-poverty schools felt prepared to teach their subject matter, compared with 83% of their peers in high-poverty schools (Appendix Table 1-21).

Experience

Teachers generally are more effective in helping students learn as they gain years of experience, particularly during their first few years (Harris and Sass 2011; Kraft and Papay 2014; Ladd and Sorensen 2014; Rice 2013; Wiswall 2013). Some studies have shown a positive relationship between student achievement and the number of years of teacher experience (Chingos and Peterson 2011; Ng, Nicholas, and Williams 2010), suggesting that experience may be an important characteristic of effective teachers. Although the percentage of teachers of mathematics with more than 20 years of experience decreased from 29% in 2003 to 23% in 2011, the percentage of teachers with 10–19 years of experience increased from 27% to 33%, and the percentage of teachers with less than 3 years of experience decreased from 19% to 15% (Appendix Table 1-22). The pattern among science teachers was similar. Overall, in 2011, 85% of public middle and high school mathematics teachers and 90% of science teachers had more than 3 years of experience.

Recent studies have found, however, that novice teachers (i.e., teachers with 3 years or fewer of experience) are more likely than experienced teachers to work in high-poverty and high-minority schools, suggesting that students in these schools may have fewer effective teachers (Loeb, Kalogrides, and Béteille 2012; LoGerfo, Christopher, and Flanagan 2012; Sass et al. 2012). In 2011, some 15% of public middle and high school mathematics teachers and 10% of science teachers were novices with 3 years or less of experience (Table 1-16). Proportionally more mathematics teachers in high-minority schools and high-poverty schools were novice teachers than in low-minority schools (19% versus 10%) and low-poverty schools (18% versus 10%). The pattern was similar for science.

Table 1-16 **Public middle and high school mathematics and science teachers with less than 3 years of teaching experience, by minority enrollment and school poverty level: Academic year 2011–12**

(Percent)

School characteristic	Mathematics teachers	Science teachers
All schools	14.9	10.4
Minority enrollment (%)		
0–5	10.2	11.6
> 5–45	11.8	8.2
> 45	18.6	12.7
School poverty level (%)[a]		
0–10	10.3	8.7
> 10–50	13.3	9.0
> 50	18.1	12.9

[a] School poverty level is percentage of students in school qualifying for free/reduced-price lunch.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of 2003–04, 2007–08, and 2011–12 Schools and Staffing Survey, National Center for Education Statistics. See appendix table 1-22.

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School Factors Contributing to Teachers' Effectiveness

Teachers bring a variety of knowledge, skills, and experience into their classrooms, but conditions in their schools and districts also influence their effectiveness in promoting student outcomes and their decisions about remaining in the profession. This section presents indicators of district and school attributes that affect teachers' success, including the assignment of teachers to subjects, initial and ongoing professional development, salaries, and working conditions.

In-Field Teaching

In-field teaching assignment in middle and high schools has been found in some studies to have a positive correlation with teacher knowledge and student mathematics achievement (Lee 2012; Sung and Yang 2013). Its inverse, *out-of-field teaching,* is associated with teacher attrition and lack of content knowledge and may be more prevalent than previously recognized (Hill and Dalton 2013; Hobbs 2015). In recognition of the potential benefits associated with in-field teaching, the No Child Left Behind Act of 2001 (NCLB) mandated that all students have teachers who demonstrate competence in subject knowledge and teaching. NCLB provided specific guidance and criteria for adequate preparation to teach mathematics and science to the states.

To determine whether teachers have subject-specific preparation for the fields they teach, research has focused on matching teachers' formal preparation (as indicated by degree major and certification field) with their teaching field (Hill and Gruber 2011; Morton et al. 2008). Following this line of research, the National Science Board distinguished four levels of formal preparation for teaching mathematics and science at the middle and high school levels (NSB 2010). Mathematics teachers with the most rigorous preparation—that is, those teaching *in field*—had a degree, full certification, or both in mathematics or mathematics education. Similarly, in-field science teachers had a degree, full certification, or both in science or science education.

The push for the highly qualified teachers mandated by NCLB appears to have had a significant effect on the percentage of middle school mathematics and science teachers who meet this rigorous definition of preparation. The percentage of middle school mathematics and science teachers with in-field degrees has increased steadily since 2003 (Table 1-17). In 2011, two-thirds of middle school mathematics teachers and three-quarters of middle school science teachers had in-field degrees. The level of in-field mathematics and science teachers in high schools has not changed significantly since 2003, remaining steady at about 90% for mathematics and biology/life sciences teachers and 80% for physical sciences teachers.

Table 1-17 Preparation of public middle and high school mathematics and science teachers for teaching in their field: Academic years 2003–04, 2007–08, and 2011–12

(Percentage distribution)

	Academic year 2003–04				Academic year 2007–08				Academic year 2011–12			
Teaching level /field	In field [a]	Related field [b]	General education [c]	Other [d]	In field [a]	Related field [b]	General education [c]	Other [d]	In field [a]	Related field [b]	General education [c]	Other [d]
Middle school												
Mathematics	53.5	3.9	37.5	5.1	64.3	1.6	30.6	3.4	66.7	0.7	28.3	4.3
Science	67.0	na	29.2	3.8	69.7	na	27.0	3.3	74.2	na	23.4	2.4
High school												
Mathematics	87.4	2.0	3.1	7.5	88.0	1.2	3.4	7.4	90.1	1.0	4.1	4.8
Biology/life sciences	91.9	3.6	1.3	3.2	93.2	3.9	0.9	2.0	90.0	5.1	2.6	2.3
Physical sciences	78.1	19.6	0.9	1.5	81.6	15.4	1.2	1.8	79.1	16.6	1.0	3.4

na = not applicable.

[a] Mathematics teachers with a degree and/or full certification in mathematics or mathematics education. Science teachers with a degree and/or full certification in science or science education.

[b] Mathematics teachers with a degree and/or full certification in a field related to mathematics (e.g., science, science education, computer sciences, engineering). Science teachers with a degree and/or full certification in a field related to their teaching field (e.g., high school biology teachers with a degree and/or full certification in chemistry). This category is omitted for middle school science teachers because science teachers at this level are usually not distinguished by specific science fields such as physics, chemistry, or biology.

[c] Mathematics and science teachers with a degree and/or full certification in general elementary, middle, or secondary education.

[d] Mathematics and science teachers without a degree or certification in their teaching field, a related field, or general elementary, middle or secondary education.

NOTE: Percentages may not add to total because of rounding.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of 2003–04, 2007–08, and 2011–12 Schools and Staffing Survey, National Center for Education Statistics. See appendix table 1-23.

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The percentage of in-field teachers does vary by school poverty level. In 2011, for example, 75% of middle school mathematics teachers in low-poverty schools had in-field degrees, compared with 63% of teachers at high-poverty schools (Appendix Table 1-23). At the high school level, 95% of mathematics teachers at low-poverty schools had in-field degrees, compared with 87% at high-poverty schools. One notable exception was middle school science teachers, 75% of whom had in-field degrees regardless of the school poverty level.

Professional Development for Mathematics and Science Teachers

Professional development enables teachers to update their knowledge, sharpen their skills, and acquire new teaching techniques, all of which may enhance the quality of teaching and learning (Davis, Petish, and Smithey 2006; Richardson and Placier 2001). Although much of the literature on professional development has found little causal evidence of its effectiveness, some research on the effects of individual programs of professional development for elementary and middle school mathematics and science teachers has found positive effects on student achievement (DeMonte 2013; Gersten et al. 2014; Heller et al. 2012). Two types of professional development are discussed here—new teacher professional development through induction and support programs, and ongoing professional development for more experienced teachers.

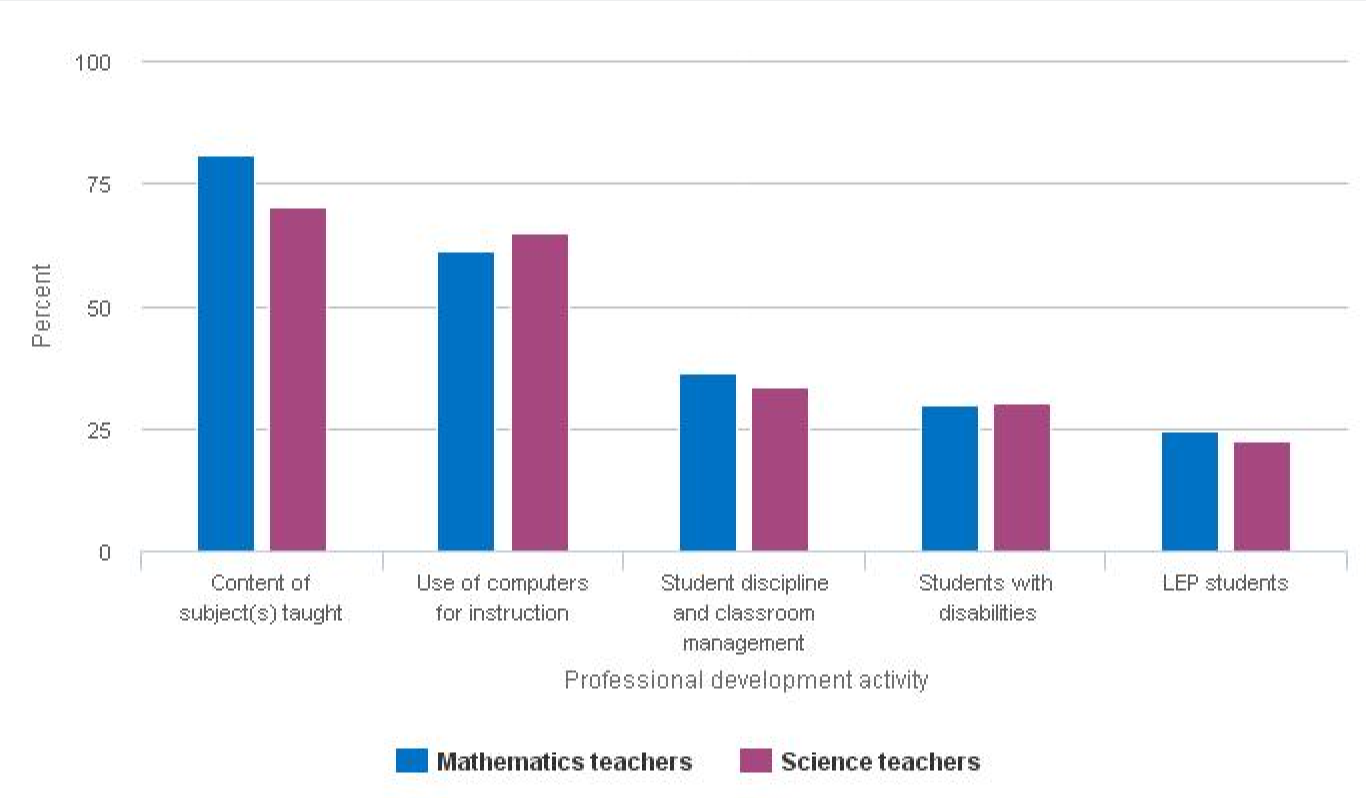
New teacher induction and support. Induction programs for beginning teachers, including support, guidance, and orientation, improve teacher commitment and retention, strengthen teachers' instructional practices, and raise student achievement (Ingersoll and Strong 2011; Wang, Odell, and Clift 2010). Such professional development often begins during a teacher's first year in the classroom, continues in subsequent years, and may prevent early attrition.

Participation in new teacher induction programs has increased markedly since 2003. Among new public middle and high school teachers with fewer than 5 years of experience in 2011, 84% of mathematics and 87% of science teachers had participated in an induction program during their first year, compared with 71% of mathematics teachers and 68% of science teachers in 2003 (Appendix Table 1-24). Teacher participation in induction programs is lower in schools with high concentrations of minority and low-income students, but these gaps have narrowed since 2003. In 2003, 59% of mathematics teachers in high-poverty schools had participated in an induction program, compared with 76% in low-poverty schools, a gap of 17 percentage points. In 2011, that gap was 8 percentage points. The gap narrowed even more in science, with 57% of science teachers in high-poverty schools participating in an induction program in 2003, compared with 77% in low-poverty schools—a gap of 20 percentage points. In 2011, that gap was 8 percentage points. Appendix Table 1-25 shows data on other types of support provided to new teachers when they start their careers.

Ongoing professional development. Ongoing professional development for teachers is often mandated by state regulations and delivered by school districts to teachers throughout their careers. The type of professional development provided for teachers varies substantially, and some types are more effective than others. Simply spending time in professional development activities may not have any effect on student achievement (Garet et al. 2001). The most common types of professional development for mathematics and science teachers in 2011 were subject area instruction and the use of technology in the classroom. In 2011, 81% of mathematics teachers and 70% of science teachers in public middle and high schools received professional development focused on their content area during the preceding 12 months (Figure 1-14). Sixty-one percent of mathematics teachers and 65% of science teachers received professional development in the use of computers for instruction. In comparison, fewer than half received training in classroom discipline or management, teaching students with disabilities, or teaching students with limited English proficiency (Appendix Table 1-26).

Figure 1-14

Participation of public middle and high school teachers in professional development activities during past 12 months, by topic: Academic year 2011–12



LEP = limited English proficiency.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of 2011–12 Schools and Staffing Survey, National Center for Education Statistics. See appendix table 1-26.

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The duration of professional development programs is often shorter than what research suggests may be desirable. More research is needed to establish a threshold; some studies have suggested 80 hours or more of professional development is necessary to affect teacher practice (CCSSO 2009). Among teachers who received professional development in their subject area in 2011, 28% of mathematics and science teachers received 33 hours or more (Figure 1-15).[i]

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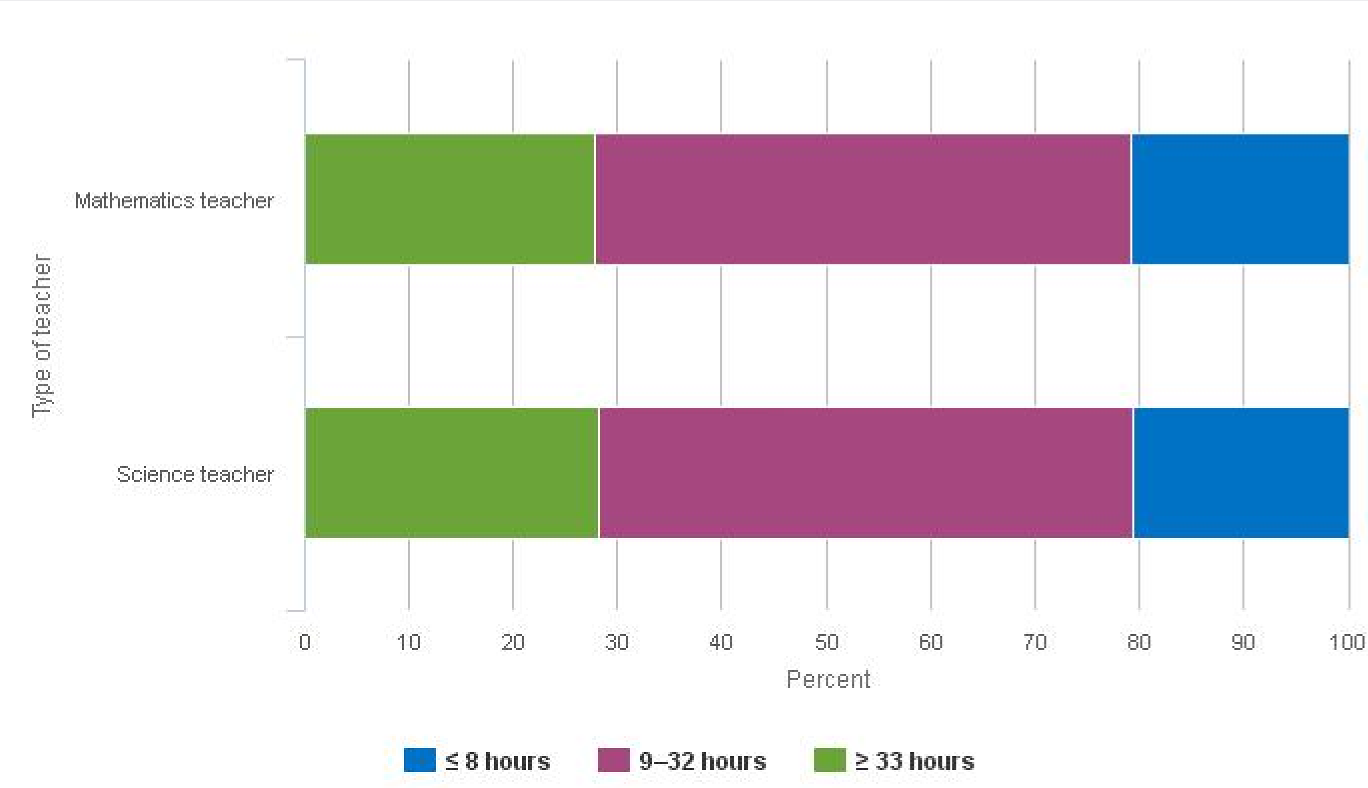
[i] The maximum duration SASS provides as an option in its teacher questionnaire is "33 hours or more," which is reported in this chapter. Research suggests that teachers who receive content-focused professional development already have relatively strong content knowledge (Desimone, Smith, and Ueno 2006).

Figure 1-15

Duration of professional development received by public middle and high school mathematics and science teachers in their subject area during past 12 months: Academic year 2011–12



SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of 2011–12 Schools and Staffing Survey, National Center for Education Statistics. See appendix table 1-26.

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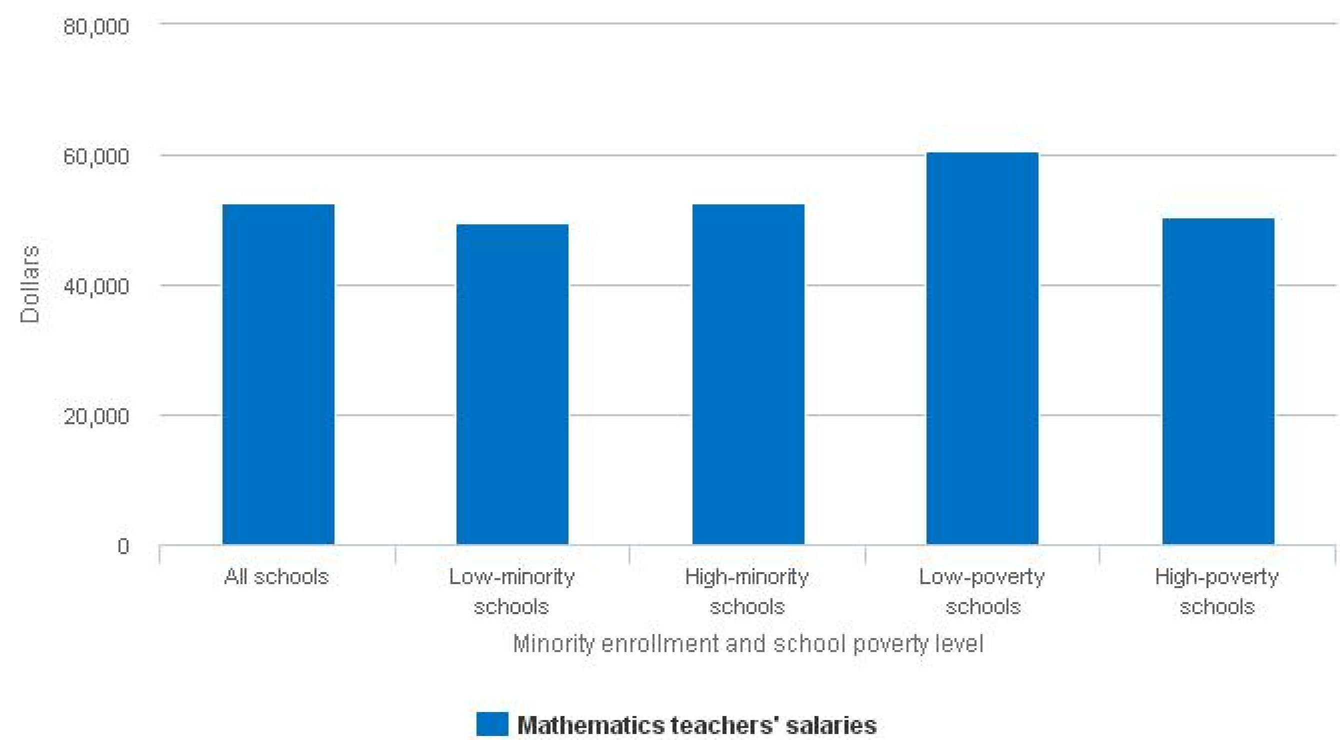
Teacher Salaries

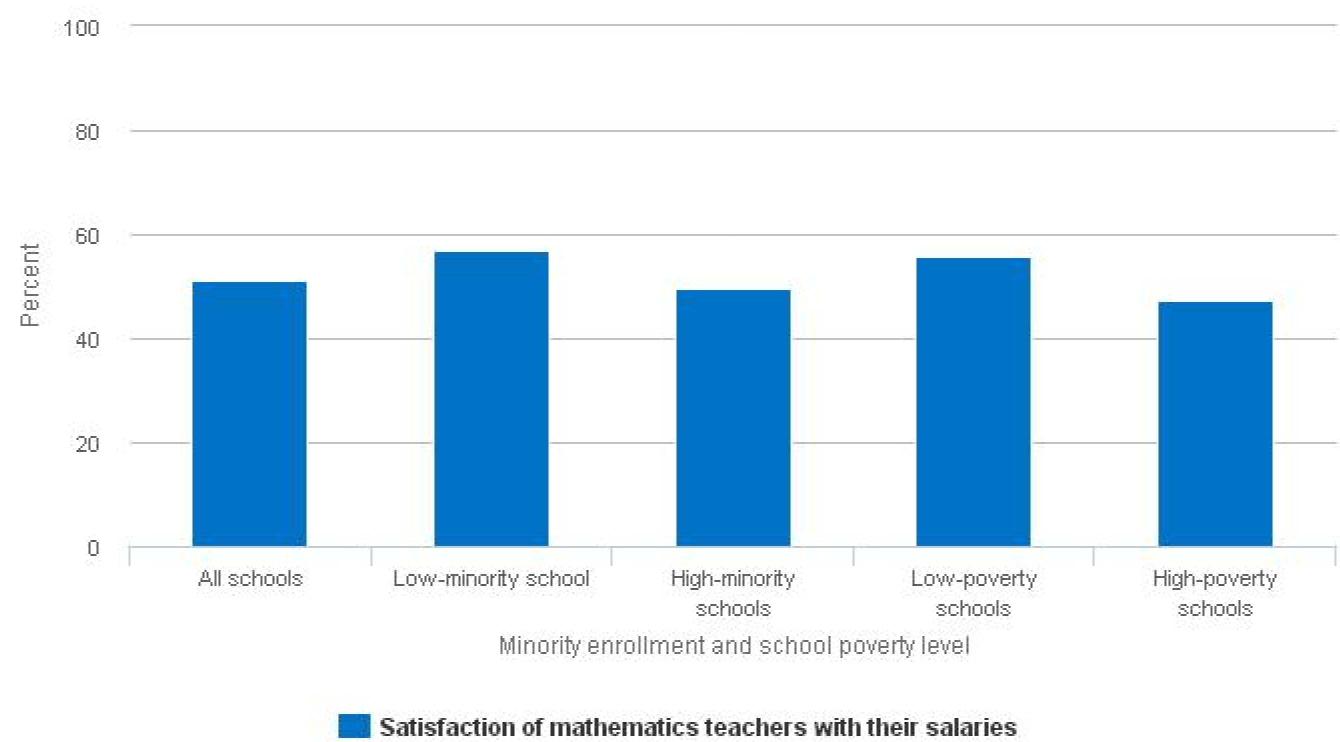
Higher teacher salaries may help keep teachers from leaving the profession (Feng 2014; Gilpin 2012; James et al. 2011; Leigh 2012). In 2007, 15% of school districts offered pay incentives in fields of shortage—usually mathematics, science, and special education—and 10% offered rewards for excellence in teaching (Aritomi and Coopersmith 2009). However, researchers caution that financial incentives may be less effective than factors such as positive working conditions in attracting and retaining high-quality teachers (Berry and Eckert 2012; Rose 2012). Although federal and state strategies have offered financial incentives in an effort to attract quality teachers to hard-to-staff schools, large differences in teacher quality and salary levels persist across and within states (Adamson and Darling-Hammond 2012). Research has indicated that teachers earn less than other professionals with similar levels of education (AFT 2008; Hanushek and Rivkin 2007). The circumstances of employment and the nature of the work differ between teachers and nonteachers, however, and may account for salary differences to some extent. Teachers are more likely than other professionals to work in rural areas, for example, where costs of living and salaries are lower (Taylor 2008). Selecting the appropriate comparison group for teachers also complicates salary comparisons. Some research uses salary data for fields requiring a bachelor's degree (AFT 2008), and at least one study suggests that a smaller set of occupations requiring similar skills may be more appropriate (Milanowski 2008).

In 2011, the average base salary of middle and high school teachers was approximately $53,000 for mathematics teachers and $54,000 for science teachers, based on teachers' reports in SASS (Figure 1-16). Salaries were lowest for mathematics and science teachers at low-minority schools (approximately $50,000 and $49,000 respectively), which may be related to the low number of minority students in rural areas, where teacher pay tends to be lower. Teachers at high-poverty schools earned less than their counterparts at low-poverty schools, with mathematics teachers earning $10,000 less and science teachers earning $13,000 less (Appendix Table 1-27).

Figure 1-16

Average salaries of public middle and high school mathematics teachers and percentage who were satisfied with their salaries, by minority enrollment and school poverty level: Academic year 2011–12





NOTES: Schools with 0%–5% minority enrollment are low-minority schools, and schools with more than 45% minority enrollment are high-minority schools. School poverty level is percentage of students in school qualifying for free/reduced-price lunch. Schools with 0%–10% of such students are low-poverty schools, and schools with more than 50% of such students are high-poverty schools.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of 2011–12 Schools and Staffing Survey, National Center for Education Statistics. See appendix table 1-27.

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When asked to rate their satisfaction with their salaries, slightly more than half of mathematics teachers, and just under half of science teachers, reported being satisfied (Figure 1-16; Appendix Table 1-27). Mathematics teachers in low-poverty and low-minority schools were more likely to be satisfied with their salaries than their colleagues in high-poverty and high-minority schools, even though teachers in high-minority schools earned higher base salaries than those in low-minority schools. Patterns were similar among science teachers.

International comparisons of teacher salaries are not available by specific subject, but general comparisons can be made. Organizations such as OECD generally use purchasing power parity to compare salaries across countries. Purchasing power parity reflects the money needed to purchase the same goods and services across countries. By this metric, the United States ranked 6th in teacher pay internationally in 2011 (UNESCO 2014). According to OECD, the United States ranked 11th among OECD countries in 2011 for salaries of teachers with 15 years of experience (OECD 2014).

On average across OECD countries, primary school teachers earn 85% of the salary of college-educated, 25–64-year-old, full-time, full-year workers, whereas lower secondary teachers earn 88% and upper secondary teachers earn 92% of that benchmark salary. The United States ranks 27th among developed countries by this metric, well below the OECD average (OECD 2014).

Teacher Perceptions of Working Conditions

Like salaries, working conditions play a role in determining the supply of qualified teachers and influencing their decisions about remaining in the profession. Safe environments, strong administrative leadership, cooperation among teachers, high levels of parent involvement, and sufficient learning resources can improve teacher effectiveness, enhance teachers' commitment to their schools, and promote job satisfaction, thereby decreasing rates of teacher turnover (Berry and Eckert 2012; Feng 2014; Johnson, Kraft, and Papay 2012; Ladd 2011; Shen et al. 2012). Other studies suggest that schools that have strong leadership opportunities for teachers have greater teacher retention (Harris and Muijs 2004; Schweig 2014).

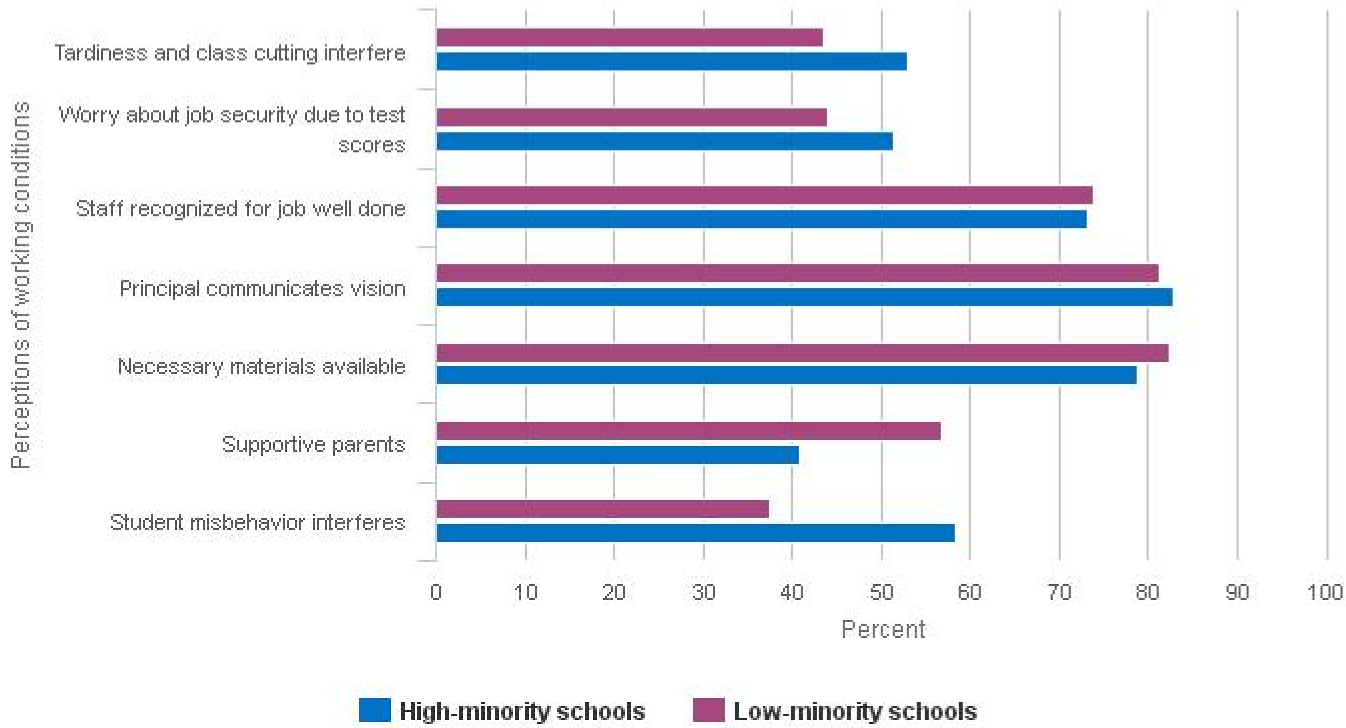
SASS asked teachers at public middle and high schools whether they agreed with several statements about their school environments and working conditions. Majorities of mathematics and science teachers agreed with the following statements in 2011: the school principal knows what kind of school he or she wants and has communicated it to the staff (83% of mathematics and 82% of science teachers); the necessary materials for teaching are available (82% and 77%); and staff are recognized for a job well done (74% and 70%) (Appendix Table 1-28).[ii]

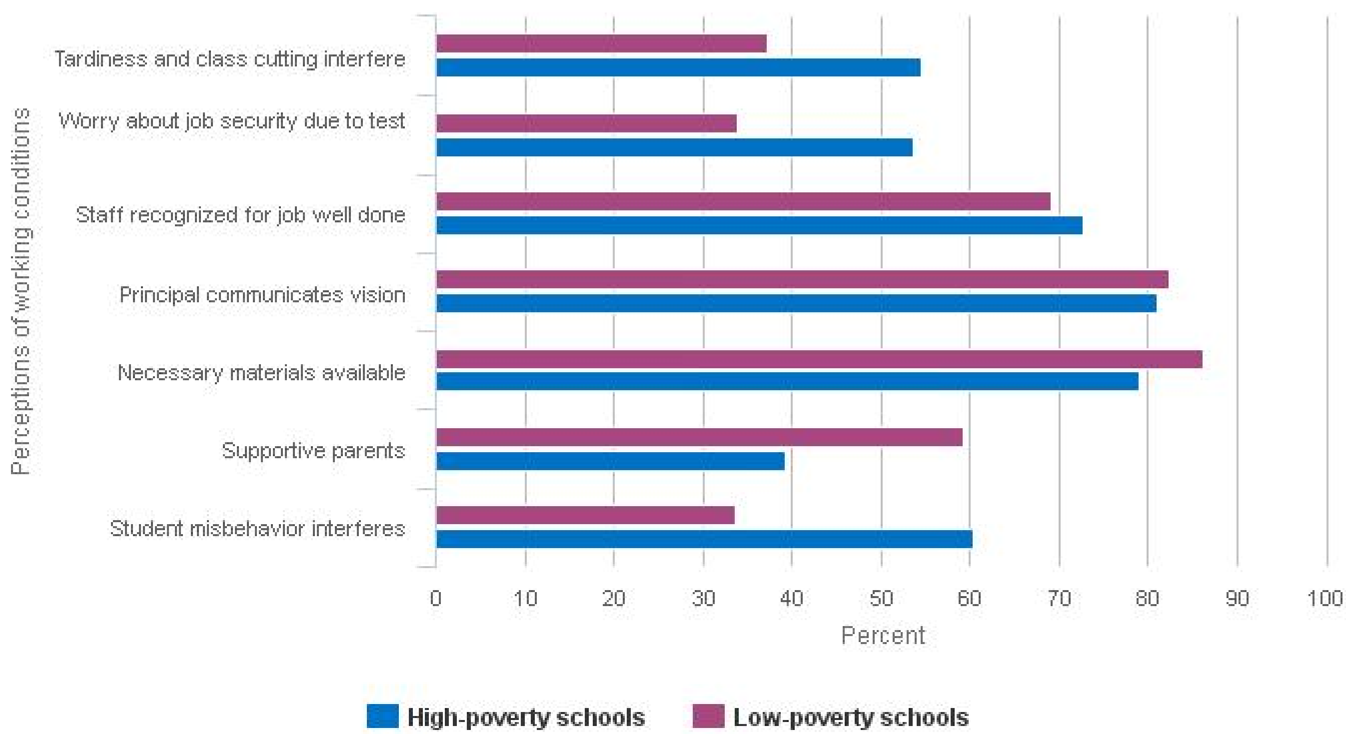
However, responses to some questions—about tardiness, class cutting, misbehavior, and student preparation—revealed differences in school environments between high- and low-poverty schools. For example, about 55% of mathematics and science teachers at high-poverty schools in 2011 reported that students' tardiness and class cutting interfered with teaching, compared with 37% of teachers at low-poverty schools (Figure 1-17; Appendix Table 1-28). Fully 60% of mathematics teachers at high-poverty schools reported student misbehavior interfering with teaching, compared with just over one-third in low-poverty schools.

[ii] The statements about working conditions included in this section represent a selection of those measured in SASS. For a complete list of questions and results for public elementary and secondary teachers, see the *Digest of Education Statistics 2010* (Snyder and Dillow 2011:116, table 76).

Figure 1-17

Perceptions of working conditions of public middle and high school mathematics teachers, by minority enrollment and school poverty level: Academic year 2011–12





NOTES: Teachers were asked to indicate their agreement with various statements about their school conditions. Response categories included Strongly agree, Somewhat agree, Somewhat disagree, and Strongly disagree. Percentages are based on teachers responding Strongly agree or Somewhat agree to various statements. Schools with 0%–5% minority enrollment are low-minority schools, and schools with more than 45% minority enrollment are high-minority schools. School poverty level is percentage of students in school qualifying for free/reduced-price lunch. Schools with 0%–10% of such students are low-poverty schools, and schools with more than 50% of such students are high-poverty schools.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of 2011–12 Schools and Staffing Survey, National Center for Education Statistics. See appendix table 1-28.

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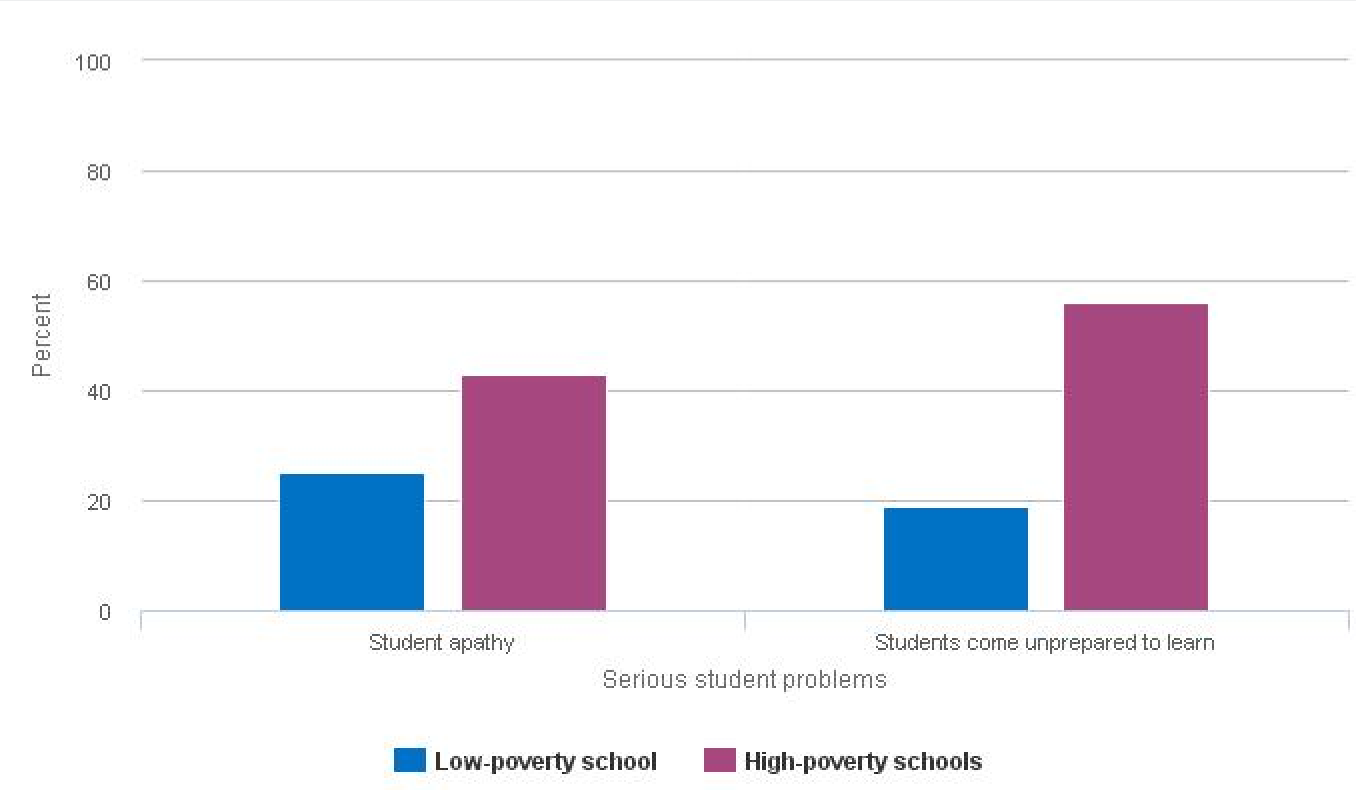
Lack of student preparation was a serious problem for 56% of mathematics teachers at high-poverty schools in 2011, compared with 19% at low-poverty schools—a gap of 37 percentage points (Figure 1-18). Teacher perceptions of student apathy as a serious problem showed a similar pattern, although the gap was not quite as large: 43% at high-poverty schools, compared with 25% at low-poverty schools. Patterns were similar among science teachers (Appendix Table 1-29).

Figure 1-18

Serious student problems reported by public middle and high school mathematics teachers, by school poverty level: Academic year 2011–12



NOTES: Teachers were asked to indicate the seriousness of various student problems in their schools. Response categories included Serious problem, Moderate problem, Minor problem, and Not a problem. Percentages are based on teachers viewing various student problems as Serious. School poverty level is percentage of students in school qualifying for free/reduced-price lunch. Schools with 0%–10% of such students are low-poverty schools, and schools with more than 50% of such students are high-poverty schools.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of 2011–12 Schools and Staffing Survey, National Center for Education Statistics. See appendix table 1-29.

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Some of these problems may be worsening, according to teachers' reports about student apathy and lack of preparation for learning. For example, 34% of all mathematics and 35% of science teachers in 2011 called student apathy a serious problem, compared with 28% and 29%, respectively, in 2007 (Appendix Table 1-29). Again, about 40% of mathematics teachers in 2011, compared with 33% in 2007, identified students' lack of preparation for learning as a serious problem. Similar increases were observed among science teachers.

Instructional Technology and Digital Learning

Over the years, policymakers and researchers have developed a broad consensus that modern technology has great potential to transform education (Duffey and Fox 2012; Johnson et al. 2014; U.S. Department of Education 2010). Support for technology integration in K–12 students' learning has grown and is now widespread. In 2012, 92% of elementary and secondary school principals and 89% of parents of school-aged children reported that technology was so important to student academic success that it should be included in the school's core mission, compared with 77% of school principals and 78% of parents who thought so in 2008 (Project Tomorrow 2013).

Recognizing the potential value of technology, the U.S. federal government has launched a series of initiatives in recent years urging school leaders and educators across the nation to adopt a 21st century model of education that encompasses technology. In 2010, the U.S. Department of Education released a National Education Technology Plan, calling for "revolutionary transformation rather than evolutionary tinkering," leveraging technology to improve teaching, personalize learning, and create engaging learning communities (U.S. Department of Education 2013a:v). In 2013, President Obama announced the ConnectED initiative, pledging to connect 99% of American students to next-generation broadband and high-speed wireless in their schools and libraries within the next 5 years (The White House n.d.). Many states have also joined the federal efforts, taking an active role to build a technology-rich learning environment in their states (Duffey and Fox 2012; NASBE 2012; Watson et al. 2014).

Technology integration in school entails not just providing access to the Internet but also encompasses the strategic use of a broad array of technological tools and practices, including online courses; use of various devices and hardware in classrooms; computer-based assessment; adaptive software for students with special needs; and more. Collectively referred to as *instructional technology,* this wide range of tools and practices involves using and creating appropriate technological processes and resources to facilitate teaching, engage students, and improve learning outcomes (Alliance for Excellent Education 2011; Richey 2008).

This section focuses specifically on the use of technology as an instructional tool in the U.S. K–12 education system. It presents the latest national data on the availability or use of various technological devices in classrooms, Internet access in schools, and the prevalence of online learning among K–12 students. This leads to a review of research on the effectiveness of technology as an instructional tool on student learning outcomes.

Technology as an Instructional Tool

The use of instructional technology—computers, the Internet, mobile devices, interactive whiteboards, and other emerging technologies—in K−12 classrooms has been growing at a rapid pace. Existing national data address the availability or use of technological tools in schools or classrooms, although data and research on the quality and effectiveness of the technologies remain limited (Gray, Thomas, and Lewis 2010a, 2010b; Snyder and Dillow 2013).

Computers and Other Technology Devices

Computers are universally available in U.S. elementary and secondary schools (NSB 2014). As of 2008, all U.S. public K–12 schools had one or more computers for instructional purposes on campus (Gray, Thomas, and Lewis 2010a). Computers are also commonly available in classrooms. In 2009, for example, 97% of K–12 public school teachers reported that they had one or more computers in their classroom, and 69% said that they or their students often or sometimes used computers during class time (Gray, Thomas, and Lewis 2010b). In addition to computers, the majority of teachers reported having the following technology devices either available as needed or in the classroom every day: liquid crystal display (LCD) or digital light processing (DLP) projectors (84%), digital cameras (78%), and interactive whiteboards (51%). Among teachers who reported that these devices were available to them, one-half or more also reported that they used these devices for instruction sometimes or often: 72% of teachers used LCD or DLP projectors, 57% used interactive whiteboards, and 49% used digital cameras.

Despite the widespread access to computers and other devices in classrooms, many teachers still believe they lack technology resources. According to a 2012 national survey conducted by Project Tomorrow, a national education nonprofit organization, 55% of K–12 teachers reported that there were not enough computers for student use in their classes, thus highlighting this deficiency as one of the major obstacles in their use of technology for teaching (Project Tomorrow 2013).

The 2012 National Survey of Science and Mathematics Education sponsored by the National Science Foundation revealed a split between mathematics and science teachers in a nationally representative sample of K–12 teachers about the adequacy of their instructional technology (e.g., computers, calculators, and probes or sensors) (Banilower et al. 2013). Although 69% of high school mathematics teachers indicated that their instructional technology resources were adequate, just 34%–48% of elementary, middle, and high school science teachers indicated the same.

Reported adequacy of technology resources also varied by schools' student achievement levels and composition. Teachers with higher concentrations of low-achieving students, low-income students, and non-Asian minority students had less-positive views on the adequacy of instructional resources. For example, the mean score derived from teachers' responses to the adequacy of instructional resources was 47 for teachers of science classes with mostly low-achieving students, compared with 69 for teachers of science classes with mostly high-achieving students (Table 1-18).

Table 1-18 **Mathematics and science teachers' views of adequacy of instructional resources in class, by class and school characteristics: 2012**

(Mean)

Class and school characteristic	Mathematics teachers	Science teachers
Achievement level of class		
Mostly high achievers	74	69
Average/mixed achievers	70	56
Mostly low achievers	68	47
Percent of non-Asian minority students in class		
Lowest quartile	73	60
Second quartile	71	59
Third quartile	70	58
Highest quartile	69	50
Percent of students eligible for free/reduced-price lunch in school		
Lowest quartile	73	64
Second quartile	71	55
Third quartile	69	54
Highest quartile	68	50

NOTES:	Estimates are class mean scores derived from teachers' evaluation of the adequacy of various instructional resources in class. For mathematics teachers, instructional resources include measurement tools, instructional technology, manipulatives (e.g., pattern blocks), and consumable supplies (e.g., graphing papers). For science teachers, instructional resources include facilities (e.g., lab tables), equipment (e.g., microscopes), consumable supplies (e.g., chemicals), and instructional technology (e.g., computers). Choices of responses range from 1 (not adequate) to 5 (adequate).
SOURCE:	Banilower ER, Smith PS, Weiss IR, Malzahn KA, Campbell KM, Weis AM, *Report of the 2012 National Survey of Science and Mathematics Education*, Horizon Research, Inc. (2013).
	Science and Engineering Indicators 2016

Internet Access and Mobile Devices

Access to the Internet is universal in public K–12 schools in the United States. As of 2008, 100% of public schools had instructional computers with an Internet connection (Gray, Thomas, and Lewis 2010a). In addition, student access to the Internet via instructional computers at school has increased substantially since 2000. In 2008, there were three students per computer with Internet access, compared with seven students per computer with Internet access in 2000 (Gray, Thomas, and Lewis 2010a).

Although Internet access at schools is universal, access with adequate bandwidth and connection speeds remains an area of concern (Fox et al. 2012). In 2010, the Federal Communications Commission (FCC) found that nearly 80% of schools with federal funding for Internet access were not satisfied with their Internet connections (FCC 2010). Slow connection speeds were the primary complaint. In particular, students in high-minority schools were half as likely to have high-speed Internet as students in low-minority schools; low-income students were twice as likely as affluent students to have slow Internet access at their schools; and students in remote rural areas were twice as likely as their urban and suburban peers to have slow Internet access at their schools (Horrigan 2014).

To respond to the federal government's ConnectED initiative for connecting all students to the digital age, in 2014 the FCC dedicated $5 billion in new funds to the existing federal program, the Schools and Libraries program, also known as the E-rate program, to support the construction of high-speed wireless Internet connections on school campuses and library buildings (see sidebar, E-rate Program: Its Purpose and Modernization).

E-rate Program: Its Purpose and Modernization

The Schools and Libraries Program, also known as the E-rate program, is the federal education technology program under the direction of the Federal Communications Commission (FCC). Authorized as part of the Telecommunications Act of 1996, the program was designed to help libraries and K–12 schools in the United States obtain affordable access to the Internet by providing 20%–90% purchase discounts on telecommunications, Internet access, and internal network connections (Jaeger, McClure, and Bertot 2005). For schools, discount rates are based on the percentage of students in the school who are eligible for the National School Lunch Program and by the school's urban-rural classification.

Over the years, the E-rate program has helped U.S. schools and libraries connect to the Internet. When the program was first launched in 1996, only 14% of K–12 classrooms had Internet connections; by 2005, the percentage had risen to 94%. Similarly, just 28% of U.S. public library systems offered Internet access to the public in 1996, but nearly all public libraries around the country (98%) had Internet connections by 2006.*

Despite this growth, the capacity of U.S. K–12 schools and libraries to access Internet content has not kept pace with the latest developments in information and communication technologies. In particular, half of K–12 school buildings have old, slow internal wiring that has difficulty carrying data at today's broadband speeds, and three out of five K–12 schools lack the Wi-Fi needed to access the interactive content of today's Internet (NASBE 2012).

Recognizing these deficiencies, on July 11, 2014, the FCC adopted the E-rate Modernization Order. The order expands funding for Wi-Fi networks and seeks to ensure that the E-rate program meets the broadband needs of schools and libraries in today's world of interactive, individualized digital learning. Through this order, the FCC hopes to accomplish three goals:

- To ensure affordable access to high-speed broadband sufficient to support digital learning in schools and robust connectivity for all libraries
- To maximize the cost-effectiveness of spending for E-rate–supported purchases
- To make the E-rate application and other processes fast, simple, and efficient

Under the E-rate Modernization Order, the FCC has set aside a total of $5 billion in new funding in the next 5 years to support the construction of Wi-Fi services on school campuses and in libraries. More information on the E-rate Modernization Order is available at http://www.fcc.gov/document/fcc-releases-e-rate-modernization-order.

* Data retrieved from the Education and Library Networks Coalition (http://www.edlinc.org/get_facts.html#Is%20the%20E-Rate%20program%20working).

In addition to computers, mobile devices such as laptops, smartphones, and tablets are enhancing students' access to the Internet. Even though these Internet-connected devices have become one of the primary means with which youth interact and learn from each other, little national data are available to describe how and with what frequency these devices are used in day-to-day learning in and out of school (NTIA 2011).

Among high school students in 2013, 89% owned Internet-connected smartphones, 60% had laptops, and 50% had access to tablets (Project Tomorrow 2014). Teacher access to these devices has also risen dramatically: between 2008 and 2012, the percentage of teachers who owned a smartphone jumped from 20% to 67%, and the percentage who owned a tablet rose from 6% to 31% (Project Tomorrow 2013).

Digital Conversion

With the advent of Internet-connected mobile devices, schools and districts are also instigating what is called a *digital conversion* within their classrooms, replacing traditional hard-copy textbooks with interactive, multimedia digital textbooks or e-textbooks that are accessible to students through the Internet. The Speak Up National Survey, conducted by Project Tomorrow in 2012, found that some middle and high school teachers had already started capitalizing on the potential of this digital conversion, supplementing their teaching with videos (47%), digital textbooks (21%), animations (20%), online curricula (21%), simulations (10%), and virtual labs (6%) (Project Tomorrow 2013). The survey also found that mathematics and science teachers took the lead in the adoption of these new teaching strategies. Nevertheless, lacking computers or mobile devices is a major hindrance to digital conversion: 60% of school principals said that the lack of computers or devices with Internet access was a major obstacle to the greater adoption of digital content in their schools (Project Tomorrow 2014).

Distance Education and Online Courses

In addition to its potential for enhancing learning in the classroom, technology can also enable students to receive instruction remotely through distance education or online learning. Distance education may include videoconferencing and televised or audiotaped courses, but Internet courses (commonly referred to as *online learning*) are the most widespread and fastest-growing mode of delivery at the K–12 level. Online learning programs range from programs that are fully online with all instruction occurring via the Internet to hybrid or *blended learning* programs that combine face-to-face teacher instruction with online components (Picciano and Seaman 2009; Staker and Horn 2012; Watson et al. 2014).

During recent years, online learning at the K–12 level has grown rapidly in the United States. Online learning mainly occurred at the high school level; enrollment at this level accounted for 74% of the total K–12 distance-education enrollment in 2009–10. In 2009–10, there were an estimated 1,816,400 enrollments in distance-education courses in K–12 public school districts, representing a 473% increase from 317,100 distance-education enrollments in the 2002–03 school year (Snyder and Dillow 2013). As of 2013–14, a total of 30 states (including the District of Columbia) had statewide full-time online schools (Watson et al. 2014). Full-time enrollment in online schools has grown from approximately 200,000 students in 2009–10 to more than 315,000 in 2013–14 (iNACOL 2013; Watson et al. 2014). In addition, 26 states operated virtual schools in 2013–14, providing supplemental online courses to approximately 740,000 students nationwide (Watson et al. 2014). To put these changes in context, overall K–12 public enrollment increased by 2% in the same period, from 48,183,086 in fall 2002 to 49,360,982 in fall 2009 (Snyder and Dillow 2013).

A nationally representative survey of public school districts conducted by NCES in 2009 found that the top reasons for offering online learning opportunities were to provide courses not otherwise available at their schools (64%) and to give students opportunities to recover course credits from classes missed or failed (57%) (Queen and Lewis 2011). The survey also found that credit recovery was especially important in urban areas, where 81% of school districts indicated this was a very important reason for making online learning opportunities available. Other reasons school districts gave for providing online learning options included offering AP or college-level courses (40%), reducing scheduling conflicts for students (30%), and providing opportunities for homebound students and those with special needs (25%).

Research on Effectiveness of Instructional Technology and Online Learning

Effects of Instructional Technology

Existing research studies about the effects of instructional technology on student learning are not comprehensive enough to address the general question of whether technology yields improved student outcomes (Tamim et al. 2011). Few national studies are available; many of the existing studies were of brief duration or were based on specific products, small and geographically narrow samples, or weak research designs. To address these shortcomings, the Office of Educational Technology has issued a report outlining the problems with current research on digital education and providing a framework for how research evidence can be improved (U.S. Department of Education 2013a).

Nevertheless, several meta-analyses—studies that seek to combine data from nonrepresentative studies into a rigorous statistical design to provide limited but more rigorous findings—have yielded some promising findings. A large-scale meta-analysis summarized a total of 1,055 primary studies from 1967 to 2008 and concluded that the use of computer technologies in classrooms had positive (though small) effects on student achievement (Tamim et al. 2011).

Three meta-analyses that specifically focused on mathematics learning compared the mathematics achievement of students taught in elementary and secondary classes using technology-assisted mathematics programs with that of students in control classes using alternative programs or standard methods (Cheung and Slavin 2011; Li and Ma

2010; Rakes et al. 2010). All three studies found small, positive effects on student achievement when technology was incorporated into mathematics classes. A randomized impact evaluation found that a computer-aided application improved elementary students' mathematics test scores (Carrillo, Onofa, and Ponce 2010).

Cumulative evidence, again based on limited studies, suggests that technology's potential to improve student achievement may depend on how it is incorporated into instruction (Cennamo, Ross, and Ertmer 2013; Ross, Morrison, and Lowther 2010; Tamim et al. 2011). One study found that when computing devices were used as tools to supplement the traditional curriculum, no achievement increase was observed. When computing devices were used as main teaching tools in class, however, there was an increase in student achievement (Norris, Hossain, and Soloway 2012).

Effects of instructional technology may also vary with grade level. One study randomly selected middle and high schools across seven states either to adopt a technology-assisted algebra curriculum or continue with the traditional algebra curriculum (Pane et al. 2013). The study found that, although students in high schools with technology-assisted curricula performed better than their peers in schools with traditional curricula, such differences were not observed among students in middle schools.

Effects of Online Learning

Policymakers and researchers cite numerous potential benefits of online learning, which include increasing access to resources, personalizing learning, and assisting struggling students (Bakia et al. 2012; U.S. Department of Education 2010; Watson et al. 2013). Despite these potential benefits, few rigorous national studies have addressed the effectiveness of online learning compared with that of traditional school models at the K–12 level (Means et al. 2010). One small-scale study with a quasi-experimental design found that students participating in online learning performed as well as their peers in comparable classrooms that used traditional instruction (O'Dwyer, Carey, and Kleiman 2007). A meta-analysis of more than 500 studies addressing the effectiveness of online learning found that interactive distance education provided small and positive effects on student achievement compared to traditional classroom instruction (Bernard et al. 2004). Other recent studies also have observed some positive effects for online learning, but researchers stress that teacher training and the way in which online components are integrated into the curriculum are important variables that could affect outcomes and need to be the subject of more rigorous research (Norris, Hossain, and Soloway 2012; Tamim et al. 2011). The latest research suggests that distance education and online schools are meeting the needs of students who do not have access to adequate physical school and course options. However, research on the effectiveness of online learning is still in a nascent state (Watson et al. 2014).

Transition to Higher Education

One of the most important education goals in the United States is to educate every student to graduate from high school ready for college and a career (Achieve Inc. 2013; NCEE 2013; Pellegrino and Hilton 2012; The White House n.d.). Over the past decades, U.S. high school graduation rates have been rising steadily, surpassing 80% for the first time in U.S. history in 2012 (Balfanz et al. 2014).

High school completion represents a major milestone for adolescents, but skills acquired in high school are often insufficient qualifications for jobs that pay enough to support a family. In today's labor market, most of the fastest-growing, well-paying jobs require at least some postsecondary education (Carnevale, Smith, and Strohl 2010; Hout 2012). Given the competitive pressures associated with an increasingly global economy, young people who do not pursue education beyond high school face fewer job opportunities, lower earnings, and a greater likelihood of being unemployed and underemployed compared with their college-educated peers (Baum, Ma, and Payea 2013; Blossfeld et al. 2005; Pew Research Center 2014).

Within this context, this section focuses on indicators related to U.S. students' transitions from high school to postsecondary education. It presents national data on on-time high school graduation rates, long-term trends in immediate college enrollment after high school, choice of STEM majors at the postsecondary level, and academic preparation for college. This section also examines U.S. students' high school graduation and postsecondary entry rates relative to those of their peers in other countries. Together, these indicators present a broad picture of the transition of U.S. students from high school to postsecondary education. (Higher education in S&E is the topic of chapter 2.)

Completion of High School

Estimates of U.S. high school completion rates vary substantially, depending on the definitions, data sources, and methods used in their calculation (Heckman and LaFontaine 2007; Seastrom et al. 2006). Based on a relatively inclusive definition—receiving a regular high school diploma or earning an equivalency credential, such as a General Educational Development (GED) certificate—about 85% of the U.S. population ages 18–24 in 2012 had completed a high school education.[i] This is consistent with the experience of a nationally representative cohort of 2002 high school sophomores; 96% of the cohort members had earned a high school diploma or an equivalency credential by 2012 (Lauff and Ingels 2014).

Beginning with the 2011–12 school year, the U.S. Department of Education required all states to use a more restrictive definition of high school graduation, emphasizing on-time graduation and considering only recipients of regular high school diplomas (Chapman et al. 2011; Curran and Reyna 2010). Under this definition, the high school graduation rate is the percentage of students in a freshman class who graduate with a regular diploma 4 years after entering ninth grade (Stetser and Stillwell 2014).

Because calculating this rate requires following up with the same students over time, and because not all states had the longitudinal data necessary to compute this rate as of the 2011−12 school year, the U.S. Department of Education recommended using the averaged freshman graduation rate (AFGR) to estimate on-time high school graduation rates (Stetser and Stillwell 2014). The AFGR calculation divides the total number of high school diplomas in a particular year by the estimated size of the incoming freshman class 4 years earlier.[ii]

Although not as accurate as a 4-year graduation rate computed from a longitudinal cohort of students followed over time, the AFGR can be estimated with widely available cross-sectional data and is acknowledged by the U.S.

Department of Education as one of the most accurate indicators among several alternative measures that can be calculated using cross-sectional data (Seastrom et al. 2006). The U.S. high school graduation rates discussed below are AFGRs.

On-Time Graduation Rates from 2006 to 2012

The on-time graduation rate among U.S. public high school students has increased steadily since 2006 (Table 1-19). In 2006, 73% of public high school students graduated on time with a regular diploma; by 2012, the figure had climbed to 81%. Hispanic students made the largest gain during this period, an improvement of 15 percentage points, from 61% in 2006 to 76% in 2012. Black students improved as well, gaining 9 percentage points, from 59% in 2006 to 68% in 2012. In comparison, white students gained just 5 percentage points, and Asian or Pacific Islander students gained only 4 percentage points during this period. But substantial differences among racial and ethnic groups persisted: in 2012, the on-time high school graduation rates for Asian or Pacific Islander and white students were 93% and 85%, respectively; and both figures surpassed those of black, Hispanic, and American Indian or Alaska Native students (68%–76%).

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[i]Data drawn from *Digest of Education Statistics 2013* (Snyder and Dillow 2015:42, table 104.40).

[ii] The incoming freshman class size is estimated by summing the enrollment in eighth grade for 1 year, ninth grade for the next year, and tenth grade for the year after, and then dividing by 3. For example, the 2011–12 on-time graduation rate equals the total number of diploma recipients in 2011–12 divided by the average membership of the eighth grade class in 2007–08, the ninth grade class in 2008–09, and the tenth grade class in 2009–10 (Stetser and Stillwell 2014).

Table 1-19 **On-time graduation rates of U.S. public high school students, by sex and race or ethnicity: 2006–12**

(Percent)

Sex and race or ethnicity	2006	2007	2008	2009	2010	2011	2012
All students	73.2	73.4	74.8	76.5	78.2	79.6	80.9
Sex							
Male	69.7	69.5	70.9	73.4	NA	77.0	78.0
Female	77.3	77.0	78.3	80.6	NA	84.0	85.0
Race or ethnicity[a]							
White	80.3	80.4	81.0	81.8	83.0	84.0	84.8
Black	59.2	59.0	61.4	63.6	66.1	66.5	67.7
Hispanic	61.0	60.8	63.4	67.0	71.4	74.7	76.1
Asian or Pacific Islander	89.3	89.6	91.4	93.0	93.5	92.6	93.3
American Indian or Alaska Native	61.8	60.9	64.4	64.2	69.1	68.2	68.4

NA = not available.

[a] Hispanic may be any race. American Indian or Alaska Native, Asian or Pacific Islander, black or African American, and white refer to individuals who are not of Hispanic origin.

SOURCE:	Stetser M, Stillwell R, *Public High School Four-Year On-Time Graduation Rates and Event Dropout Rates: School Years 2010–11 and 2011–12: First Look*, NCES 2014-391 (2014); Stillwell R, Sable J, *Public School Graduates and Dropouts from the Common Core of Data: School Year 2009–10: First Look*, NCES 2013-309rev (2013); Common Core Data Table Library, http://nces.ed.gov/ccd/tables/AFGR.asp and http://nces.ed.gov/ccd/tables/AFGR0812.asp, accessed October 2015. *Science and Engineering Indicators 2016*

Sex differences in on-time graduation rates have also persisted over time. In each year from 2006 through 2012, [iii] the percentage of male students who graduated from high school within 4 years was lower than that of female students. In 2012, the on-time graduation rate for male students lagged behind that for female students by 7 percentage points (78% versus 85%).

High School Graduation Rates in the United States and Other OECD Nations

OECD estimates upper secondary graduation rates for its members and selected nonmember countries by dividing the number of graduates in a country by the number of people at the typical graduation age (OECD 2014).[iv] These estimates enable a broad international comparison. [v]

U.S. graduation rates are lower than those of many OECD countries. Among the 28 OECD nations with available data on graduation rates in 2012, the United States ranked 22nd, with a graduation rate of 79%, compared with the OECD average of 84% (Appendix Table 1-30). The top-ranked countries include Slovenia, Iceland, Germany, the Netherlands, Hungary, Ireland, the United Kingdom, Japan, Spain, Finland, Denmark, and South Korea—all of which had graduation rates above 90%.

Furthermore, the relative standing of U.S. high school graduation rates has not changed much from 2006 to 2012. Among the 21 OECD countries for which graduation rate data were available in 2006, 2008, 2010, and 2012, the United States ranked 16th in 2006, 2008, and 2012 and 17th in 2010 (Table 1-20).

[iii] Sex data were not available in 2010.

[iv] Upper secondary education, as defined by OECD, corresponds to high school education in the United States. In the calculation of the U.S. graduation rates, OECD included only students who earned a regular diploma and excluded those who completed a GED certificate program or other alternative forms of upper secondary education. OECD defines the typical graduation age as the age of the students at the beginning of the school year: students will generally be 1 year older than the age indicated when they graduate at the end of the school year. According to OECD, the typical graduation age in the United States is 17 years old. The U.S. high school graduation rates calculated by OECD cannot be directly compared with U.S. on-time graduation rates because of the different population bases and calculation methods for the two measures.

[v] International comparisons are often difficult because of differences between education systems, types of degrees awarded across countries, and definitions used in different countries. Some researchers have pinpointed various problems and limitations of international comparisons and warned readers to interpret data, including those published by OECD, with caution (Adelman 2008; Wellman 2007).

Table 1-20 **Relative standing of U.S. high school graduation rates among OECD countries: 2006, 2008, 2010, and 2012**

Year and OECD country	Percent
2006	
Germany	103
Greece	100
Finland	95
Japan	93
South Korea	93
Norway	91
Czech Republic	90
Iceland	90
United Kingdom	88
Denmark	86
Ireland	86
Italy	86
Hungary	85
Slovakia	82
Poland	80
United States	**77**
Sweden	76
Luxembourg	72
Spain	72
Turkey	51
Mexico	42
2008	
Germany	97
Ireland	96
Japan	95
Finland	93
South Korea	93
Greece	91
Norway	91
United Kingdom	91
Iceland	89
Czech Republic	87
Italy	85

Year and OECD country	Percent
Denmark	83
Poland	83
Slovakia	81
Hungary	78
United States	**77**
Sweden	76
Luxembourg	73
Spain	73
Mexico	44
Turkey	26
2010	
Japan	96
Greece	94
South Korea	94
Ireland	94
Finland	93
United Kingdom	92
Iceland	88
Norway	87
Germany	87
Denmark	86
Hungary	86
Slovakia	86
Poland	84
Italy	83
Spain	80
Czech Republic	79
United States	**77**
Sweden	75
Luxembourg	70
Turkey	54
Mexico	47
2012	
Iceland	95

Year and OECD country	Percent
Germany	95
Hungary	94
Ireland	93
United Kingdom	93
Japan	93
Spain	93
Finland	93
Denmark	92
South Korea	92
Norway	88
Slovakia	86
Poland	85
Italy	84
Czech Republic	82
United States	**79**
Sweden	77
Greece	71
Luxembourg	69
Turkey	55
Mexico	47

OECD = Organisation for Economic Co-operation and Development.

NOTE: Data include only OECD countries with available data in all four years.

SOURCES: OECD, *Education at a Glance: OECD Indicators 2008* (2008), *Education at a Glance: OECD Indicators 2010* (2010), *Education at a Glance: OECD Indicators 2012* (2012), and *Education at a Glance: OECD Indicators 2014* (2014).

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Enrollment in Postsecondary Education

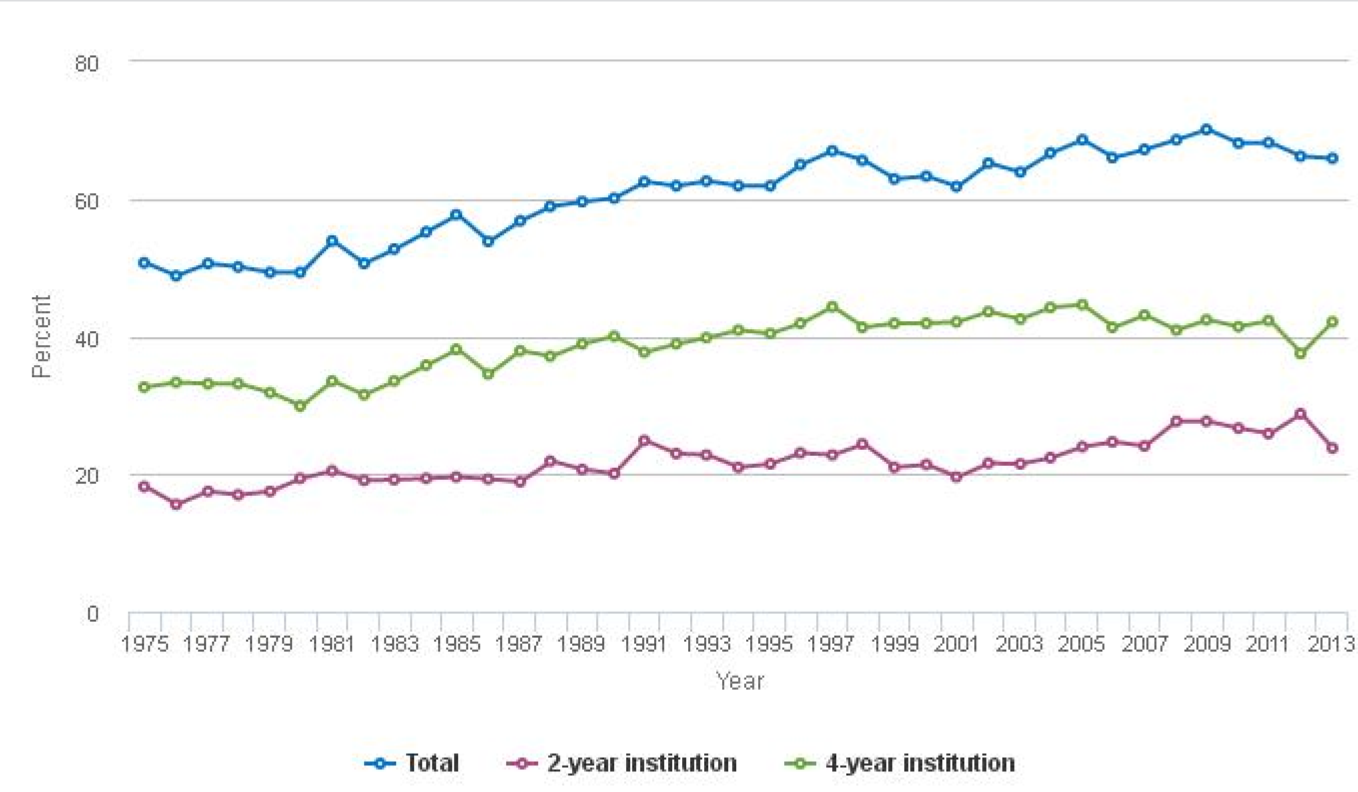
Although high school graduation represents the culmination of elementary and secondary schooling, it also marks a fundamental crossroads at which youth make critical choices about their future. Although some immediately enter the workforce, join the military, or start families, the majority of students go directly into postsecondary education (Ingels et al. 2012). Of the 3.2 million high school graduates in 2012, some 2.1 million (66%) enrolled in a 2- or 4-year college the following fall (Kena et al. 2014). This rate, known as the *immediate college enrollment rate,* is defined as the annual percentage of high school completers, including GED recipients, who enroll in 2- or 4-year colleges by the October following high school completion.

Between 1975 and 2013, the percentage of high school graduates making an immediate transition to college increased from 51% to 66%, although this upward trend peaked at 70% in 2009 and has decreased since then (

Figure 1-19). In each year, more students enrolled in 4-year institutions than in 2-year institutions. Immediate enrollment rates between 1975 and 2013 increased from 33% to 42% for 4-year institutions and from 18% to 24% for 2-year institutions. Between 1975 and 2013, immediate college enrollment was generally higher and rose faster for women (from 49% to 68%) than for men (from 53% to 64%) (Appendix Table 1-31). Since 1975, the immediate college enrollment rate has increased from 49% to 67% for white students, 45% to 57% for black students, and 53% to 66% for Hispanic students. Asians or Pacific Islanders enrolled at consistently higher rates than other groups since 2003, when data on Asian and Pacific Islander students were first available.

Figure 1-19

Immediate college enrollment rates among high school graduates, by institution type: 1975–2013



NOTES: Figure includes students ages 16–24 completing high school in survey year. Immediate college enrollment rates are defined as rates of high school graduates enrolled in college in October after completing high school. Before 1992, high school graduates referred to those who had completed 12 years of schooling. As of 1992, high school graduates are those who have received a high school diploma or equivalency certificate.

SOURCES: Digest of Education Statistics 2013 Data Table Library, tables 302.10, 302.20, 302.30, http://nces.ed.gov/programs/digest/2013menu_tables.asp, accessed November 2014. See appendix table 1-31.

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Large enrollment gaps, however, persisted among students of different socioeconomic backgrounds (Appendix Table 1-31): in 2013, the immediate college enrollment rate of students from low-income families was considerably lower than the rate of those from high-income families (46% versus 79%). Enrollment rates also varied widely with parental education, ranging in 2013 from 43% for students whose parents had less than a high school education to 83% for students whose parents had a bachelor's or higher degree.

Transition to STEM Fields

With the goals of maintaining global competitiveness and enhancing capacity for innovation, U.S. policymakers have called for increasing the number and diversity of students pursuing degrees and careers in STEM fields (NAS COSEPUP 2005; NGA 2007). Likewise, a recent policy report by the President's Council of Advisors on Science and Technology urged U.S. colleges and universities to increase the number of STEM graduates.

In 2011-12, some 23% of U.S. undergraduates were enrolled in STEM fields, including math/computer sciences (5%), natural sciences (6%), engineering (5%), and social/behavioral sciences (7%) (Table 1-21). About 18% of first-year students declared a STEM major upon entering college. The declaration of a STEM major in the first year of college was more common among males (26%) than among females (12%). The sex differences were particularly evident in mathematics or computer sciences (9% versus 2%) and engineering (9% versus 1%).

Table 1-21 **U.S. undergraduates who chose a STEM major, by demographic characteristics: Academic year 2011–12**

(Percent)

		Specific STEM major			
Demographic characteristic	STEM major, total	Math/ computer sciences	Natural sciences	Engineering	Social/ behavioral sciences
All undergraduates	22.6	4.7	5.9	4.9	7.1
First-year students	17.9	4.7	4.5	4.5	4.3
Sex					
Male	26.0	8.7	4.8	9.2	3.3
Female	11.7	1.6	4.2	0.9	5.1
Race or ethnicity[a]					
White	19.1	5.0	4.8	4.8	4.5
Black	13.8	4.1	2.9	3.1	3.7
Hispanic	16.8	3.9	4.0	4.5	4.4
Asian	27.1	6.1	9.0	8.0	4.0
Other	17.7	4.5	4.9	2.6	5.6
Parents' highest education					
High school education or less	15.4	4.6	3.8	3.6	3.4
Some college	17.0	4.6	3.9	3.8	4.7
Bachelor's degree or higher	21.8	4.5	6.0	6.1	5.3

STEM = science, technology, engineering, and mathematics.

[a] Hispanic may be any race. Asian, black or African American, white, and other races refer to individuals who are not of Hispanic origin.

NOTE: Percentages may not add to total because of rounding.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the 2011–12 National Postsecondary Student Aid Study (NPSAS:12), National Center for Education Statistics.

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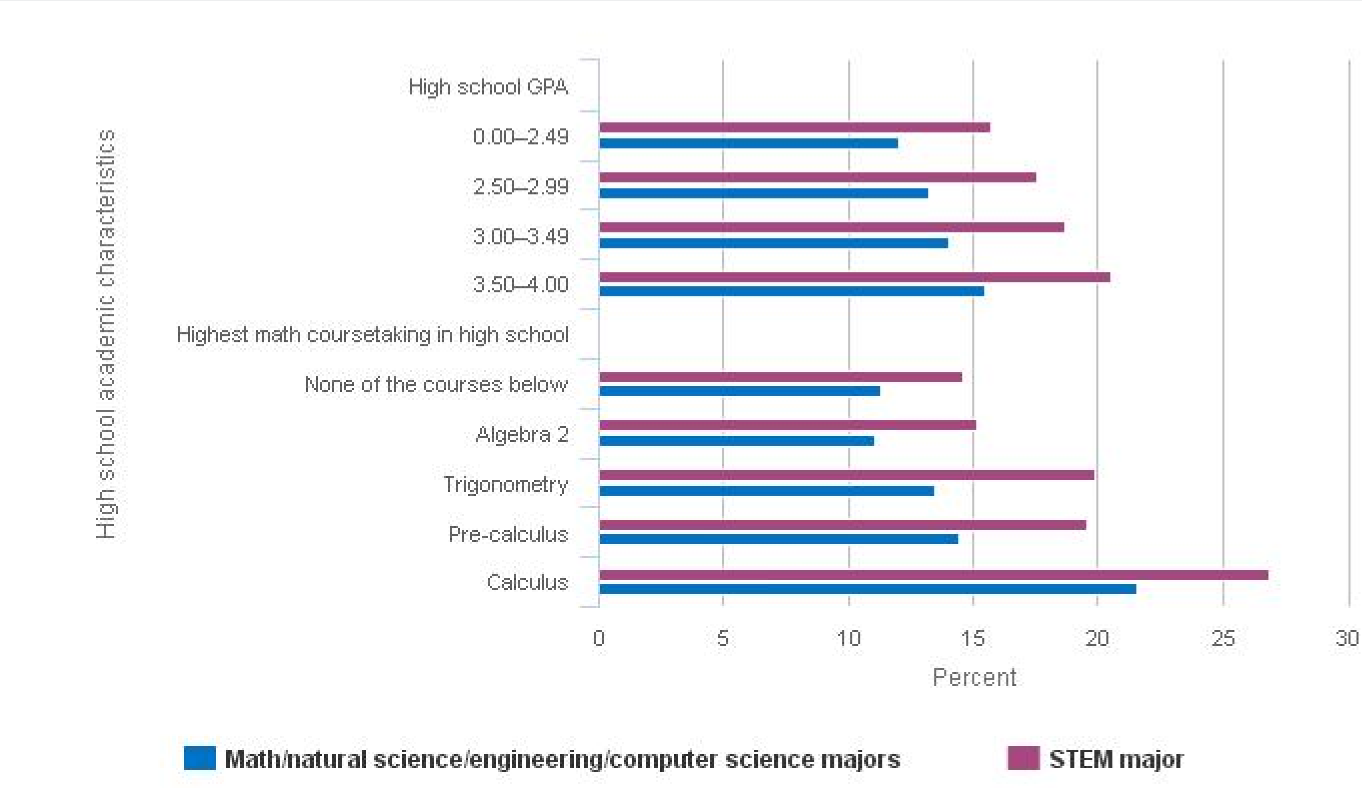
Among all racial and ethnic groups, Asians and Pacific Islanders were the most likely to study STEM subjects. In 2011–12, 27% of Asian and Pacific Islander freshmen were enrolled in STEM fields, compared with 14%-19% of other racial and ethnic groups (Table 1-21). Higher parental education levels were associated with higher STEM enrollment rates: 15% of those with high school-educated parents and 22% of those whose parents had a bachelor's or higher degree enrolled in STEM fields.

For many students, the decision to study STEM has its beginnings before college, and high school academic preparation plays a critical role (Green and Sanderson 2014; Harris Interactive 2011; Moakler and Kim 2014; Tyson et al. 2007; Wang 2013). Among first-year college students in 2011-12, both high school mathematics coursetaking and cumulative grade point average (GPA) were linked to majoring in STEM (Figure 1-20). For example, among college freshmen under age 30, 27% of those who had taken calculus in high school chose a STEM major upon entering college, including 22% who chose a major in mathematics, natural sciences, engineering, or computer sciences. The corresponding figures for those who had not taken any mathematics beyond algebra 2 in high school were 15% and 11%, respectively. Additionally, 21% of freshmen under age 30 with a high school GPA of 3.5 or higher chose a STEM major after entering college, compared with 16% of those with a GPA below 2.0.

Figure 1-20

First-year college students who chose a STEM major, by selected high school academic characteristics: 2011–12



GPA = grade point average; STEM = science, technology, engineering, and mathematics.

NOTES: STEM major field includes mathematics, natural sciences, engineering, computer sciences, and social/behavioral sciences. Information on high school math coursetaking and GPA is not available for students age 30 or above (about 25% of all undergraduates in 2011–12).

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the 2011–12 National Postsecondary Student Aid Study (NPSAS:12), National Center for Education Statistics.

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Postsecondary Enrollment in an International Context

Participation in education beyond secondary schooling has been rising in many countries (Altbach, Reisberg, and Rumbley 2009; OECD 2014). One measure of such participation is the OECD-developed first-time entry rate into a university-level education program (referred to as a "tertiary-type A" program by OECD[i]). OECD calculates this entry rate by dividing the number of first-time entrants of a specific age in university-level education programs by the total population in the corresponding age group and then adding results for each single year of age. This calculation may result in very high entry rates (even higher than 100%) if an unexpected category of people (e.g., international students) decides to enter tertiary education in a particular country. This measure, though not perfect, provides a broad comparison of postsecondary enrollment rates in the United States and those in other OECD countries.

The percentage of American young adults enrolling in university-level education for the first time was 71% in 2012, surpassing the OECD average of 58% (Figure 1-21).[ii] The average age of persons enrolling for the first time was 23 in the United States and 22 in all OECD countries with available data (OECD 2014). The United States ranked eighth out of the 33 countries that participated in this study in 2012. Females enrolled in college at higher rates than males in many OECD countries, including the United States (Appendix Table 1-32). In 2012, U.S. women enrolled at a rate 15 percentage points higher than the rate for men (79% among women, compared with 64% among men). Among all OECD countries, 65% of women and 52% of men enrolled.

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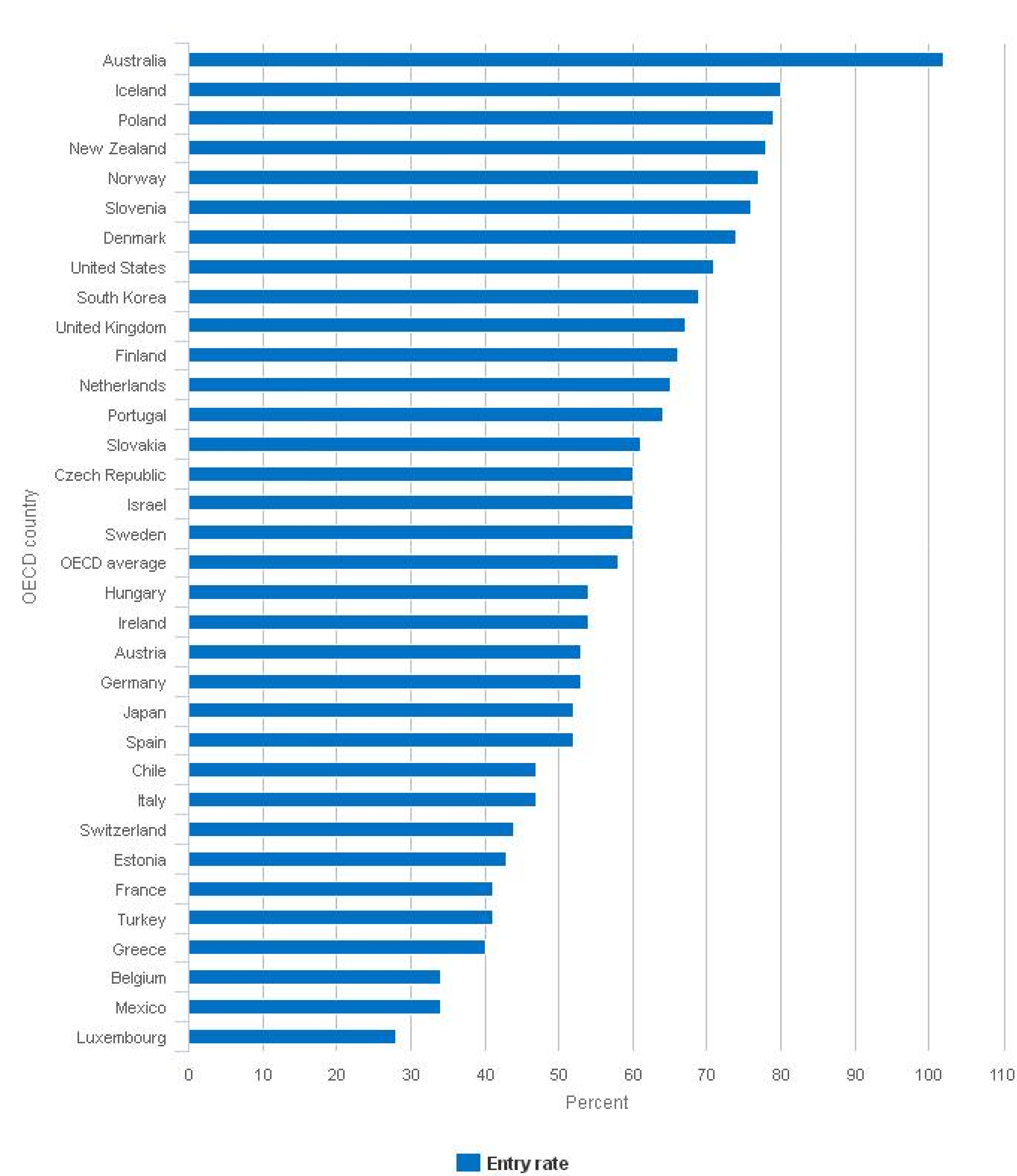
[i] As defined by OECD, a tertiary-type A program provides education that is largely theoretical and is intended to provide sufficient qualifications for gaining entry into advanced research programs and professions with high-skill requirements. Entry into these programs normally requires successful completion of upper secondary education (e.g., high school). Admission is competitive in most cases. Minimum cumulative duration at this level is 3 years of full-time enrollment.

[ii] OECD calculates entry rates by dividing number of first-time entrants of a specific age in each type of tertiary program by the total population in the corresponding age group and then adding results for each single year of age.

Figure 1-21

First-time entry rates into university-level education, by OECD country: 2012



OECD = Organisation for Economic Co-operation and Development.

NOTES: Countries/jurisdictions are ordered by 2012 first-time entry rate. Tied countries are listed alphabetically.

SOURCE: OECD, *Education at a Glance: OECD Indicators 2014* (2014). See appendix table 1-32.

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Preparation for College

Although more U.S. students than ever attend college after high school, many of them are not well prepared during their high school years for college, as evidenced by high rates of postsecondary remediation and low rates of college completion (Roderick, Nagaoka, and Coca 2009; Turner 2004). No direct measures of college readiness are available, and researchers' estimates often vary. Overall, knowledge about what constitutes being college ready and how to measure such readiness reliably remains elusive (Maruyama 2012; Roderick, Nagaoka, and Coca 2009) (see sidebar, Measuring College Readiness).

Measuring College Readiness

What does it mean to be college ready? How do we measure it? Addressing these questions requires clear definitions regarding the knowledge, skills, and attributes that students need to do well in college (Conley 2007). The current literature contains a wide range of definitions and assessments of college readiness, suggesting a lack of consensus about what constitutes being college ready or how to measure it. Nevertheless, recent work has made some progress on answering these questions. Drawing on past research, Roderick, Nagaoka, and Coca (2009) identified four areas of knowledge and skill development that are essential to college readiness:

- Content knowledge and basic skills (e.g., rules of grammar, concepts of science, spelling rules)
- Core academic skills (e.g., writing, analytic thinking, and problem-solving skills)
- Noncognitive skills (e.g., study skills, work habits, time management, and help-seeking behavior that reflect students' self-control, self-monitoring, and self-awareness)
- College knowledge (e.g., understanding college admissions and financial aid processes and college norms and culture)

Gaining access to and succeeding in college require students to have sufficient content knowledge, core academic skills, and noncognitive skills. Colleges traditionally evaluate their applicants' readiness by looking at high school transcripts to determine whether students have been exposed to content that prepares them for introductory college-level courses; achievement test scores to gauge whether students are equipped with adequate basic and core skills, content knowledge, and cognitive ability; and high school grade point average (GPA) to assess whether students have mastered class materials, have developed core academic skills, and possess the work effort and study habits critical to college success (Belfield and Crosta 2012; Kobrin 2007; Noble and Sawyer 2004; Stemler 2012). Thus, these indicators—high school coursetaking, achievement test scores (including college entrance exam scores), and GPA—are commonly recognized as the key components of college readiness (Greene and Winters 2005; Maruyama 2012).

In addition to these indicators, researchers argue that knowledge about college, or lack of such knowledge, may contribute to disparities in college success. Low-income and minority students who demonstrate the same academic qualifications as high-income and white students are less likely to attend selective 4-year institutions. Knowledge of the college application process, the financial aid system, and the range of choices within the postsecondary system may play a role in students' choices. Despite its importance, measuring "college knowledge" has not been fully addressed in national surveys (Roderick, Nagaoka, and Coca 2009).

The question of how to measure college readiness depends on what indicators are used and what outcomes are assessed—access to a 4-year institution, not needing remediation, success in first-year credit-bearing courses, and degree completion. To better measure college readiness, some researchers suggest that assessments of college readiness should use benchmarks with meaning and consequences for students (i.e., indicators tied to tangible consequence in higher education such as remedial course placement or receipt of course credits toward graduation); employ multiple and composite measures to maximize the accuracy of readiness information; and present readiness in terms of probabilities or likelihoods rather than as a single score designating a student as ready or not ready (Maruyama 2012). In sum, college readiness is multifaceted, encompassing not just academic preparation but also the knowledge, skills, attitudes, and behaviors necessary to gain access to college and overcome obstacles on the path to postsecondary success.

Conclusion

Raising overall student achievement, reducing performance gaps among different groups, and improving the international ranking of U.S. students on achievement tests are high priorities for education reform across the United States. How well does this country perform in these areas? The indicators in this chapter present a mixed picture of the status and progress of elementary and secondary mathematics and science education in the United States, both domestically and in international comparisons.

NAEP mathematics assessment results show that average mathematics scores for fourth and eighth graders improved slightly between 2000 and 2013, continuing a pattern of small but consistent increases. Overall mathematics scores for twelfth graders improved slightly between 2005 and 2013. Although the percentage of fourth, eighth, and twelfth grade students achieving a level of proficient or higher on NAEP assessments increased slightly between 2000 and 2013, those percentages stayed well below the 50% mark. Between-group differences in NAEP mathematics performance, based on parent education and race or ethnicity, have persisted over time but narrowed slightly since 1978. Overall, students from disadvantaged backgrounds continue to lag behind their more advantaged peers, with these disparities starting as early as kindergarten, as demonstrated in this chapter's analysis of ECLS-K:2011 kindergarten achievement data. Analysis of HSLS:09 assessment data shows similar patterns among the nation's eleventh graders. In the international arena, PISA data show that the U.S. average mathematics and science literacy scores are below the average scores for all developed countries. In addition, the United States appreciably underproduces students in the highest levels of mathematics achievement relative to other developed countries. It also moderately underproduces students in the highest levels of science achievement and, to an extent, overproduces students in the lowest levels of mathematics and science achievement.

Efforts to improve student achievement include raising high school graduation requirements, strengthening the rigor of curriculum standards, and increasing advanced coursetaking. These efforts have brought some positive changes, as shown in the discussion of student achievement in this chapter. Most states have adopted the Common Core State Standards, and the Next Generation Science Standards are bringing attention to the type of science education needed to keep the United States competitive in the world economy. The majority of high school students are on track to finish algebra 2 and basic science courses by the end of eleventh grade, and the number of students who take AP courses in mathematics and science continues to rise. There is still considerable room for improvement, however. The overall percentage of students taking mathematics and science AP tests remains small, and wide gaps among students from different socioeconomic backgrounds persist in regard to which students take more advanced courses during high school. Sex differences are negligible in the preponderance of mathematics and science achievement and coursetaking. These differences, however, become substantial in the most advanced AP courses and in high school courses in computer science and engineering.

Efforts to improve student achievement also focus on ensuring that all students have access to highly qualified teachers, although there is not a consensus on what constitutes a "highly qualified" teacher. The majority of K−12 mathematics and science teachers held a teaching certificate and had taught their subjects for 3 years or more. Indicators of in-field teaching and undergraduate coursework suggest that high school mathematics and science teachers were generally better prepared for their teaching subjects than were middle and elementary school teachers. Fully certified, well-prepared, and experienced teachers were not evenly distributed across schools or classes. Overall, schools or classes that had lower concentrations of non-Asian or Pacific Islander minority and low-income students and higher concentrations of high-achieving students were more likely to have fully certified and better-prepared mathematics and science teachers. Working conditions were also not evenly distributed across schools: high-poverty schools were more likely to suffer from various problems that inhibit effective teaching, including low student interest, high absenteeism, inadequate teacher preparation, and lack of materials and supplies.

Recent federal and state policies encourage greater use of technology throughout the education system as a way to improve students' learning experiences. The use of instructional technology in K−12 classrooms has been growing rapidly. Many school districts have invested in technology such as computers and mobile devices. The number of students participating in online learning courses is also rising, jumping from 317,000 in 2003 to an estimated 1.8 million in 2010. Rigorous research on the effects of instructional technology and online learning shows some modest positive effects on student mathematics learning, but far more research is needed to determine which technologies are effective and under what conditions.

Ensuring that students graduate from high school and are ready for college or the labor market is an important goal of high school education in the United States. Since 2006, the U.S. on-time high school graduation rates have improved steadily. In 2012, the vast majority of public high school students graduated with a regular diploma 4 years after entering ninth grade. Significant racial and ethnic and sex differences persisted, however, with white, Asian or Pacific Islander, and female students having higher graduation rates than their corresponding counterparts. In the broad international context, the United States ranked 22nd in graduation rates among 28 OECD countries with available data in 2012, and its relative standing has not changed in recent years.

The vast majority of high school seniors expect to attend college after completing high school, and many do so directly after high school graduation. Immediate college enrollment rates have increased for all students from 1975 to 2013. Large gaps persisted among students from different socioeconomic backgrounds. In 2013, the immediate college enrollment rate of students from low-income families was 33 percentage points lower than the rate of those from high-income families.

Glossary

Advanced Placement (AP): Courses that teach college-level material and skills to high school students who can earn college credits by demonstrating advanced proficiency on a final course exam. The curricula and exams for AP courses, available for a wide range of academic subjects, are developed by the College Board.

Blended learning: Any time a student learns at least in part at a supervised, traditional school location away from home and at least in part through online delivery with some element of student control over time, place, path, and /or pace; often used synonymously with "hybrid learning."

Developed country: A developed country, industrialized country, or "more economically developed country" (MEDC), is a sovereign state that has a highly developed economy and advanced technological infrastructure relative to other less industrialized nations. Most commonly, the criteria for evaluating the degree of economic development are gross domestic product (GDP), gross national product (GNP), the per capita income, level of industrialization, amount of widespread infrastructure and general standard of living. Which criteria are to be used and which countries can be classified as being developed are subjects of debate.

Developing country: A developing country, also called a lower developed country, is a nation with an underdeveloped industrial base, and low Human Development Index (HDI) relative to other countries.

Distance education: A mode of delivering education and instruction to students who are not physically present in a traditional setting such as a classroom. Also known as "distance learning," it provides access to learning when the source of information and the learners are separated by time and/or distance.

Elementary schools: Schools that have no grades higher than 8.

Eligibility for National School Lunch Program: Student eligibility for this program, which provides free or reduced-price lunches, is a commonly used indicator for family poverty. Eligibility information is part of the administrative data kept by schools and is based on parent-reported family income and family size.

English language learner: An individual who, due to any of the reasons listed below, has sufficient difficulty speaking, reading, writing, or understanding the English language to be denied the opportunity to learn successfully in classrooms where the language of instruction is English or to participate fully in the larger U.S. society. Such an individual (1) was not born in the United States or has a native language other than English; (2) comes from environments where a language other than English is dominant; or (3) is an American Indian or Alaska Native and comes from environments where a language other than English has had a significant effect on the individual's level of English language proficiency.

GED certificate: This award is received following successful completion of the General Educational Development (GED) test. The GED program, sponsored by the American Council on Education, enables individuals to demonstrate that they have acquired a level of learning comparable to that of high school graduates.

High school completer: An individual who has been awarded a high school diploma or an equivalent credential, including a GED certificate.

High school diploma: A formal document regulated by the state certifying the successful completion of a prescribed secondary school program of studies. In some states or communities, high school diplomas are differentiated by type, such as an academic diploma, a general diploma, or a vocational diploma.

High schools: Schools that have at least one grade higher than 8 and no grade in K–6.

Middle schools: Schools that have any of grades 5–8 and no grade lower than 5 and no grade higher than 8.

Online learning: Education in which instruction and content are delivered primarily over the Internet.

Organisation for Economic Co-operation and Development (OECD): An international organization of 34 countries headquartered in Paris, France. The member countries are Australia, Austria, Belgium, Canada, Chile, Czech Republic, Estonia, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, South Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States. Among its many activities, the OECD compiles social, economic, and science and technology statistics for all member and selected non-member countries.

Postsecondary education: The provision of a formal instructional program with a curriculum designed primarily for students who have completed the requirements for a high school diploma or its equivalent. These programs include those with an academic, vocational, or continuing professional education purpose and exclude vocational and adult basic education programs.

Professional development: In-service training activities designed to help teachers improve their subject matter knowledge, acquire new teaching skills, and stay informed about changing policies and practices.

Remedial courses: Courses taught within postsecondary education that cover content below the college level.

Repeating cross-sectional studies: This type of research focuses on how a specific group of students performs in a particular year, and then looks at the performance of a similar group of students at a later point in time. An example would be comparing fourth graders in 1990 to fourth graders in 2011 in NAEP.

Scale score: Scale scores place students on a continuous achievement scale based on their overall performance on the assessment. Each assessment program develops its own scales.

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Chapter 2.

Higher Education in Science and Engineering

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Highlights

Characteristics of the U.S. Higher Education System

Doctorate-granting institutions with very high research activity, although few, are the leading producers of S&E degrees at the bachelor's, master's, and doctoral levels, but other types of institutions are also important in educating S&E graduates.

- In 2013, doctorate-granting institutions with very high research activity awarded 73% of doctoral degrees, 41% of master's degrees, and 37% of bachelor's degrees in S&E fields.
- Master's colleges and universities awarded 29% of all S&E bachelor's degrees and 26% of all S&E master's degrees in 2013.
- About 30% of Hispanic S&E doctorate recipients who earned their doctorates between 2009 and 2013 had obtained their baccalaureate credential at a high Hispanic enrollment institution, and 25% of black S&E doctorate recipients who received their doctorates in the same period had obtained their baccalaureate degree at a historically black college or university.
- Nearly one in five U.S. citizens or permanent residents who received an S&E doctoral degree from 2009 to 2013 had earned some college credit from a community or 2-year college.

Higher education spending and revenue patterns and trends underwent substantial changes over the last two decades.

- Between 1987 and 2012, average revenue per full-time equivalent (FTE) student from net tuition at public very high research universities nearly tripled, whereas state and local appropriations fell by nearly 40%.
- Although tuition remained lower at public very high research universities than at their private counterparts, average revenue from student tuition increased more rapidly at public institutions.
- In public very high research universities, revenues from federal appropriations, grants, and contracts per FTE student grew by nearly 80% between 1987 and 2012, and research expenditures per FTE student grew by 75% in the same period. In private very high research universities, revenues from federal appropriations, grants, and contracts per FTE student grew by 60%, and research expenditures per FTE increased by 90%.
- Between 2008 and 2010, expanding enrollment in community colleges, coupled with reductions in state and local appropriations, contributed to a 10% reduction in instructional spending per FTE student. Instructional spending per FTE student continued to decline in 2011 but increased in 2012, with a larger drop in enrollment as the U.S. economy improved.

Between 2009–10 and 2014–15, estimated average net tuition and fees paid by full-time undergraduate students in public 4-year colleges increased by about 50% after adjusting for inflation.

- Undergraduate debt varies by type of institution and state. Among recent recipients of S&E bachelor's degrees, the level of undergraduate debt is somewhat higher for degree holders in the life sciences and in the social and related sciences, but overall it does not vary much by major.
- Levels of debt of doctorate recipients vary by field. In S&E fields, high levels of graduate debt were most common among doctorate recipients in the social sciences, psychology, and the medical and other health sciences.

- At the time of doctoral degree conferral, 45% of 2013 S&E doctorate recipients had debt related to their undergraduate or graduate education.

Undergraduate Education, Enrollment, and Degrees

Undergraduate enrollment in U.S. higher education rose from 13.3 million in 2000 to 17.7 million in 2013. The largest increases coincided with the two economic downturns in 2000–02 and 2008–10, continuing a well-established pattern seen in earlier economic downturns. Enrollment peaked at 18.3 million in 2010 but has since declined.

- Associate's colleges enroll the largest number of students, followed by master's colleges and universities and doctorate-granting institutions with very high research activity.
- Increased enrollment in higher education is projected to come mainly from minority groups, particularly Hispanics.

The number of S&E bachelor's degrees has risen steadily over the past 13 years, reaching a new peak of more than 615,000 in 2013. The proportion of all bachelor's degrees awarded in S&E relative to degrees in all fields has remained stable at about 32% during this period.

- All S&E fields experienced increases in the numbers of bachelor's degrees awarded in 2013, including computer sciences, which had declined sharply in the mid-2000s and had remained flat through 2009.
- Women have earned about 57% of all bachelor's degrees and about half of all S&E bachelor's degrees since the late 1990s. Men earn the majority of bachelor's degrees in engineering, computer sciences, mathematics and statistics, and physics, and women earn the majority in the biological, agricultural, and social sciences and in psychology.
- Between 2000 and 2013, the proportion of S&E bachelor's degrees relative to degrees in all fields awarded to women remained flat. During this period, it declined in computer sciences, mathematics, physics, engineering, and economics.

The racial and ethnic composition of those earning S&E bachelor's degrees is changing, reflecting both population changes and increases in college attendance by members of minority groups.

- For all racial and ethnic groups, the total number of bachelor's degrees earned, the number of S&E bachelor's degrees earned, and the number of bachelor's degrees in most broad S&E fields have increased since 2000.
- Between 2000 and 2013, the share of bachelor's degrees awarded to Hispanics among U.S. citizens and permanent residents increased from 7% to 11%, both in S&E and in all fields combined, and remained steady at about 1% for American Indians and Alaska Natives. In the same period, the share of bachelor's degrees awarded to blacks remained stable at 9% in S&E fields but increased from 9% to 10% in all fields.

The number of international undergraduate students in the United States increased by more than 50% between fall 2008 and fall 2014.

- The number of international undergraduate students grew considerably between fall 2011 and fall 2012. Between fall 2012 and fall 2014, the numbers continued to increase but at a somewhat slower rate.
- Between fall 2013 and fall 2014, the largest increases in international students enrolled in S&E fields were in computer sciences, mathematics, engineering, and the physical sciences.

- In fall 2014, China, Saudi Arabia, and South Korea were the top countries sending undergraduates to the United States, both in S&E and in non-S&E fields.

At the bachelor's level, attrition from science, technology, engineering, and mathematics (STEM) majors (i.e., mathematics, physical sciences, biological and life sciences, computer and information sciences, engineering and engineering technologies, and science technologies) was lower than in many non-STEM fields.

- About half of the beginning bachelor's degree students who declared these STEM majors between 2003 and 2009 had either left school altogether by spring 2009 (20%) or left STEM for another field (28%).
- Bachelor's degree students in the humanities, education, and health sciences had higher attrition rates (56%–62%) than students in STEM fields (48%), in the social and behavioral sciences (45%), and in business (50%).
- At the associate's level, attrition was higher than at the bachelor's level (69%) and was similar in STEM and non-STEM fields.

Graduate Education, Enrollment, and Degrees

Graduate enrollment in S&E increased from about 493,000 to more than 615,000 between 2000 and 2013.

- Graduate enrollment grew in most S&E fields, with particularly strong growth in engineering and in the biological and social sciences.
- Women continued to enroll at disproportionately low rates in engineering (24%), computer sciences (26%), physical sciences (33%), and economics (37%).
- In 2013, underrepresented minority students (blacks, Hispanics, and American Indians and Alaska Natives) made up 12% of all students enrolled in graduate S&E programs. Asians and Pacific Islanders represented 6%, and whites represented 44%. Temporary residents accounted for almost one-third of graduate S&E enrollment.

In 2013, the federal government was the primary source of financial support for 17% of full-time S&E graduate students, the lowest proportion since at least 1998.

- The recent decline in the share of S&E graduate students with federal financial support was especially pronounced in the biological sciences (from 35% in 1998 to 29% in 2013) and in the physical sciences (from 35% in 1998 to 28% in 2013).
- In 2013, the federal government funded 60% of S&E graduate students with traineeships, 48% of those with research assistantships, and 23% of those with fellowships.
- Graduate students in the biological sciences, the physical sciences, and engineering received relatively more federal financial support than those in computer sciences, mathematics and statistics, medical and other health sciences, psychology, and social sciences.

Between fall 2013 and fall 2014, the number of international graduate students increased by 18% in S&E fields and by 6% in non-S&E fields.

- A larger proportion of international graduate students than international undergraduate students enrolled in S&E. More than 6 out of 10 international graduate students in the United States in fall 2014 were enrolled in S&E fields, compared with almost 4 in 10 international undergraduates.

- Between fall 2013 and fall 2014, the number of international graduate students enrolled in S&E fields increased most in computer sciences and engineering.
- In fall 2014, more than two-thirds of the international S&E graduate students in the United States came from China and India.

Master's degrees awarded in S&E fields increased from about 96,000 in 2000 to about 166,000 in 2013. In this period, the growth of S&E degrees at the master's level (73%) was higher than growth at the bachelor's (54%) and doctoral levels (47%).

- The number of master's degrees awarded in engineering in 2013 was the highest in the last 14 years. The number of master's degrees in computer sciences awarded in 2013 surpassed its peak in 2004.
- Increases occurred in most major S&E fields, with the largest in engineering, psychology, and political sciences and public administration.
- The number and percentage of master's degrees awarded to women in most major S&E fields have increased since 2000.
- The number of S&E master's degrees awarded increased for all racial and ethnic groups from 2000 to 2013. While the proportion of degrees earned by blacks and Hispanics increased, that of Asians and Pacific Islanders and American Indians and Alaska Natives remained flat, and that of whites decreased.

In 2013, U.S. academic institutions awarded about 39,000 S&E doctorates (excluding other health sciences).

- The number of S&E doctorates conferred annually by U.S. universities increased steadily from 2002 to 2008 then flattened and declined slightly in 2010 but has been growing since then.
- Among fields that award large numbers of doctorates, the biggest increases in degrees awarded between 2000 and 2013 were in engineering (76%) and in the biological sciences (57%).

Students on temporary visas continue to earn high proportions of U.S. S&E doctorates, including the majority of degrees in some fields. They also earned large shares of the master's degrees in S&E fields.

- In 2013, international students earned 57% of all engineering doctorates, 56% of all economics doctorates, 53% of all computer sciences doctorates, and 44% of all physics doctorates. Their overall share of S&E degrees was 37%.
- After steep growth from 2002 to 2008, the number of temporary residents earning S&E doctoral degrees declined through 2010 but has been growing since then.

International S&E Higher Education

In 2012, more than 6 million first university degrees were awarded in S&E worldwide. Students in China earned about 23%, those in the European Union earned about 12%, and those in the United States earned about 9% of these degrees.

- Between 2000 and 2012, the number of S&E first university degrees awarded in China, Taiwan, Germany, Turkey, and Mexico at least doubled. It rose more slowly (by about 50%) in Australia, the United States, and Poland, and declined in France, Japan, and Spain.
- S&E degrees continue to account for about one-third of all bachelor's degrees awarded in the United States. In Japan, nearly 6 out of 10 first degrees were awarded in S&E fields in 2012; in China, nearly half.

- In the United States, about 5% of all bachelor's degrees awarded in 2012 were in engineering. This compares with about 17% throughout Asia and nearly one-third (32%) in China.

In 2012, the United States awarded the largest number of S&E doctoral degrees of any individual country, followed by China, Germany, and the United Kingdom.

- The numbers of S&E doctoral degrees awarded in China and the United States have risen substantially in recent years. S&E doctorates awarded in South Korea and in many European countries have risen more modestly. S&E doctorates awarded in Japan increased fairly steadily through 2006 but have declined since then.
- In 2007, China overtook the United States as the world leader in the number of doctoral degrees awarded in the natural sciences and engineering; since 2010, this number in China was fairly stable.

International student mobility expanded over the past two decades, as countries are increasingly competing for international students.

- The United States remains the destination for the largest number of internationally mobile students worldwide (undergraduate and graduate), although its share decreased from 25% in 2000 to 19% in 2013.
- In addition to the United States, other countries that are among the top destinations for international students include the United Kingdom, France, Australia, and Germany.

Introduction

Chapter Overview

Higher education develops human capital; builds the knowledge base through research and knowledge development; and disseminates, uses, and maintains knowledge (OECD 2008). S&E higher education provides the advanced skills needed for a competitive workforce and, particularly in the case of graduate-level S&E education, the research capability necessary for innovation. This chapter focuses on the development of human capital through higher education.

Indicators presented in this chapter are discussed in the context of national and global developments, including changing demographics, increasing international student mobility, and increasing global competition in higher education. The composition of the U.S. college-age population is becoming more diverse as the Asian and Hispanic shares of the population increase. During the latest economic downturn, public institutions of higher education faced unique pressures from a combination of increasing enrollments and tight state budgets. Private institutions likewise experienced financial challenges stemming from declining incomes and the effects of stock market fluctuations on endowment growth. Technology has enabled very rapid growth in the delivery of online courses; the consequences of these changes are not well understood.

Over the past decade and a half, governments around the globe have increasingly regarded higher education as an essential national resource. Although the United States has historically been a world leader in providing broad access to higher education and in attracting international students, many other countries are providing expanded educational access to their own populations and attracting growing numbers of international students. Nevertheless, increases in international students contributed to most of the growth in overall S&E graduate enrollment in the United States in recent years. Following a decline in the number of international students coming to the United States after 11 September 2001, international student enrollment in S&E has recovered.

Chapter Organization

This chapter begins with an overview of the characteristics of U.S. higher education institutions that provide instruction in S&E, followed by a discussion of characteristics of U.S. undergraduate and graduate education.[i] Trends are discussed by field and demographic group, with attention to the flow of international students into the United States by country of origin. Various international higher education indicators include comparative S&E degree production in several world regions and measures of the growing dependence of industrialized countries on international S&E students.

The data in this chapter come from a variety of federal and nonfederal sources, primarily surveys conducted by the National Science Foundation's (NSF's) National Center for Science and Engineering Statistics (NCSES) and the National Center for Education Statistics (NCES) at the U.S. Department of Education. Data also come from international organizations, such as the Organisation for Economic Co-operation and Development (OECD) and the United Nations Educational, Scientific and Cultural Organization (UNESCO) Institute for Statistics (UIS), as well as individual countries. Most of the data in this chapter are from censuses of the population—for example, all students receiving degrees from U.S. academic institutions—and are not subject to sampling variability.

Data on postdoctoral scientists and engineers are included in chapters 3 and 5. Data on stay rates of doctorate recipients are included in chapter 3.

The U.S. Higher Education System

Higher education in S&E produces an educated S&E workforce and an informed citizenry. It has also received increased attention as an important component of U.S. economic competitiveness. In his 24 February 2009 address to a joint session of Congress, President Barack Obama called for every American to commit to at least 1 year of education or career training after completing high school. A 2012 report by the President's Council of Advisors on Science and Technology (PCAST 2012) states that economic forecasts point to a need to increase the proportion of college graduates going into the natural sciences and engineering over the next decade. This section discusses the characteristics of U.S. higher education institutions providing S&E education and the financing of higher education.

Institutions Providing S&E Education

The U.S. higher education system consists of a large number of diverse academic institutions that vary in their missions, learning environments, selectivity levels, religious affiliations, types of students served, types of degrees offered, and sectors (public, private nonprofit, or private for-profit) (Kena et al. 2014). There were approximately 4,700 postsecondary degree-granting institutions in the United States in the 2013–14 academic year. Of these, 64% offered bachelor's or higher degrees, 30% offered only associate's degrees, and 6% offered degrees that were at least 2-year but less than 4-year as the highest degree awarded (Table 2-1). More than half of the institutions offering bachelor's degrees or above are private nonprofit, 23% are public, and 25% are private for-profit. The majority of the institutions granting associate's degrees are public (53%) or private for-profit (42%) (Table 2-1). In 2013, U.S. academic institutions awarded nearly 3.7 million associate's, bachelor's, master's, and doctoral degrees; 25% of the degrees were in S&E (Appendix Table 2-1).[i] Public institutions produce a larger share of bachelor's and higher-level degrees than private institutions. In 2013, public institutions awarded 63% of all bachelor's and doctoral degrees awarded in the United States and 46% of the master's degrees awarded (Table 2-2).

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[i] For a crosswalk between the Classification of Instructional Programs codes and the academic fields in enrollment and completion tables, see https://webcaspar.nsf.gov/Help/dataMapHelpDisplay.jsp?subHeader=DataSourceBySubject&type=DS&abbr=DEGS&noHeader=1&JS=No, accessed 16 June 2015.

Table 2-1 Degree-granting institutions, by control and highest degree awarded: 2013–14

Highest degree awarded	All degree-granting institutions	Public	Private nonprofit	Private for-profit
Total	4,724	1,625	1,675	1,424
Associate's degree	1,410	743	80	587
At least 2 years but less than 4 years	275	191	8	76
Bachelor's degree or above	3,039	691	1,587	761

SOURCE: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Institutional Characteristics component, 2013–14.

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Table 2-2 Degree awards, by degree level and institutional control: 2013

Degree awards	Total	Public	Private nonprofit	Private for-profit
Bachelor's	1,861,034	1,171,656	547,408	141,970
Master's	756,975	347,706	330,990	78,279
Doctorate	64,887	41,021	20,308	3,558

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; National Science Foundation, National Center for Science and Engineering Statistics, WebCASPAR database, http://webcaspar.nsf.gov.

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Although few in number, doctorate-granting institutions with very high research activity are the leading producers of S&E degrees at the bachelor's, master's, and doctoral levels. In 2013, these research institutions awarded 73% of doctoral degrees, 41% of master's degrees, and 37% of bachelor's degrees in S&E fields (Appendix Table 2-1) (see sidebar, Carnegie Classification of Academic Institutions). Master's colleges and universities awarded another 29% of S&E bachelor's degrees and 25% of S&E master's degrees in 2013.

Carnegie Classification of Academic Institutions

The Carnegie Classification of Institutions of Higher Education is widely used in higher education research to characterize and control for differences in academic institutions.

The 2010 classification update retains the structure adopted in 2005. It includes 4,634 institutions, 483 of which were added after the 2005 update. More than three-quarters of the new institutions (77%) are from the private for-profit sector, 19% are from the private nonprofit sector, and 4% are from the public sector.

The Carnegie classification categorizes academic institutions primarily on the basis of highest degree conferred, level of degree production, and research activity.* In this report, several Carnegie categories have been aggregated for statistical purposes. The characteristics of those aggregated groups are as follows:

- *Doctorate-granting universities* include institutions that award at least 20 doctoral degrees per year. They include three subgroups based on level of research activity: very high research activity (108 institutions), high research activity (99 institutions), and doctoral/research universities (90 institutions). Because doctorate-granting institutions with very high research activity are central to S&E education and research, data on these institutions are reported separately.
- *Master's colleges and universities* include the 724 institutions that award at least 50 master's degrees and fewer than 20 doctoral degrees per year.
- *Baccalaureate colleges* include the 810 institutions at which baccalaureate degrees represent at least 10% of all undergraduate degrees and that award fewer than 50 master's degrees or 20 doctoral degrees per year.
- *Associate's colleges* include the 1,920 institutions at which all degrees awarded are associate's degrees or at which bachelor's degrees account for less than 10% of all undergraduate degrees.

- *Special-focus institutions* are the 851 institutions at which at least 75% of degrees are concentrated in a single field or a set of related fields (e.g., medical schools and medical centers, schools of engineering, schools of business and management).
- *Tribal colleges* are the 32 colleges and universities that are members of the American Indian Higher Education Consortium.

* Research activity is based on two indexes (aggregate level of research and per capita research activity) derived from a principal components analysis of data on research and development expenditures, S&E research staff, and field of doctoral degree. See http://carnegieclassifications.iu.edu/ for more information on the classification system and on the methodology used in defining the categories.

Baccalaureate colleges were the source of relatively few S&E bachelor's degrees (11%) (Appendix Table 2-1), but they produce a larger proportion of future S&E doctorate recipients (14%) (NSF/NCSES 2013). When adjusted by the number of bachelor's degrees awarded in all fields, baccalaureate colleges as a group yield more future S&E doctorates per 100 bachelor's degrees awarded than all other types of institutions except very high research universities (NSF/NCSES 2008, 2013).

Minority-serving academic institutions enroll a substantial fraction of underrepresented minority undergraduates (NSF/NCSES 2015c).[ii] In 2012, historically black colleges and universities (HBCUs) awarded 18% of the 50,000 S&E bachelor's degrees earned by black U.S. citizens and permanent residents, and high Hispanic enrollment institutions (HHEs) awarded about 34% of the 58,000 S&E bachelor's degrees earned by Hispanics. However, the proportion of blacks earning S&E bachelor's degrees from HBCUs and the proportion of Hispanics earning S&E bachelor's degrees from HHEs have both declined in the recent past. Tribal colleges, which mainly offer 2-year degrees, account for about 2% of S&E bachelor's degrees awarded to American Indians; this proportion has been fairly stable over time.[iii]

HHEs and HBCUs also play an important role in training Hispanic and black students for doctoral-level study in S&E fields. Of Hispanics who earned an S&E doctorate between 2009 and 2013, about 30% had obtained their baccalaureate credential at an HHE (Table 2-3). Similarly, 25% of black S&E doctorate recipients had obtained their baccalaureate degree at an HBCU during the same period (Table 2-4), making HBCUs the second-largest contributor of black S&E doctorate recipients, behind only institutions with very high research activity (NSF/NCSES 2013).

[ii] Minority-serving academic institutions include historically black colleges and universities (HBCUs), high Hispanic enrollment institutions (HHEs), and tribal colleges. HBCUs are listed by the White House Initiative on Historically Black Colleges and Universities. The Higher Education Act of 1965, as amended, defines an HBCU as "any historically black college or university that was established prior to 1964, whose principal mission was, and is, the education of black Americans, and that is accredited by a nationally recognized accrediting agency or association determined by the Secretary [of Education] to be a reliable authority as to the quality of training offered or is, according to such an agency or association, making reasonable progress toward accreditation." HHEs are those public and private non-profit institutions whose undergraduate, full-time equivalent student enrollment is at least 25% Hispanic, according to fall 2011 data in the IPEDS, directed by the National Center for Education Statistics. Tribal colleges are fully accredited academic institutions on a list maintained by the White House Initiative on Tribal

Colleges and Universities. These institutions are included in the Tribal Colleges category in the basic classification scheme of the 2010 Carnegie Classification of Institutions of Higher Education. See http://carnegieclassifications.iu.edu/.

[iii] See (NSF/NCSES 2015c, tables 5-8–5-10) for additional details.

Table 2-3 **U.S. citizen and permanent resident S&E doctorate recipients whose baccalaureate origin is a high Hispanic enrollment institution, by ethnicity and race: 2009–13**

		Earned baccalaureate degree from a high Hispanic enrollment institution		
Ethnicity and race	All	Yes	No	Yes (%)
All ethnicities and races	109,106	4,958	104,148	4.5
Hispanic or Latino	6,509	1,938	4,571	29.8
Not Hispanic or Latino				
American Indian or Alaska Native	353	26	327	7.4
Asian	10,926	251	10,675	2.3
Black or African American	5,516	240	5,276	4.4
White	80,008	2,237	77,771	2.8
More than one race	2,619	126	2,493	4.8
Other race or race not reported	899	42	857	4.7
Ethnicity not reported	2,276	98	2,178	4.3

NOTE: Reporting categories for ethnicity and race were expanded in 2013; comparisons with prior-year data should be made with caution.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the 2013 Survey of Earned Doctorates.

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Table 2-4 **U.S. citizen and permanent resident S&E doctorate recipients whose baccalaureate origin is an HBCU, by ethnicity and race: 2009–13**

		Earned baccalaureate degree from an HBCU		
Ethnicity and race	All	Yes	No	Yes (%)
All ethnicities and races	109,106	1,590	107,516	1.5
Hispanic or Latino	6,509	23	6486	0.4
Not Hispanic or Latino				
American Indian or Alaska Native	353	D	D	D
Asian	10,926	10	10,916	0.1

		Earned baccalaureate degree from an HBCU		
Ethnicity and race	All	Yes	No	Yes (%)
Black or African American	5,516	1,389	4,127	25.2
White	80,008	87	79,921	0.1
More than one race	2,619	42	2,577	1.6
Other race or race not reported	899	D	D	D
Ethnicity not reported	2,276	30	2246	1.3

D = suppressed to avoid disclosure of confidential information.

HBCU = historically black college or university.

NOTE: Reporting categories for ethnicity and race were expanded in 2013; comparisons with prior-year data should be made with caution.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the 2013 Survey of Earned Doctorates.

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Community Colleges

Community colleges (also known as public 2-year colleges or associate's colleges) play a key role in increasing access to higher education for all citizens. These institutions serve diverse groups of students and offer a more affordable means of participating in postsecondary education. Community colleges are important in preparing students to enter the workforce with certificates or associate's degrees or to transition to 4-year colleges or universities, often before receiving a 2-year degree. Community colleges tend to be closely connected with local businesses, community organizations, and government, so they can be more responsive to local workforce needs (Olson and Labov 2012).

In the 2013–14 academic year, there were nearly 950 community colleges in the United States, enrolling 6.6 million students, or nearly one-third of all postsecondary students (NCES 2015). More than 6 out of 10 community college students were enrolled part time. With the economic recession between 2007 and 2010, enrollment in community colleges increased by about 910,000 students; however, it has declined by nearly 600,000 between 2010 and 2013 as the labor market improved (Knapp, Kelly-Reid, and Ginder 2009, 2011; Ginder, Kelly-Reid, and Mann 2014).

Community colleges play a significant role in the education of individuals who go on to acquire advanced S&E degrees. About 18% of recent (2009–13) U.S. citizen and permanent resident S&E doctorate holders reported earning some college credit from a community or 2-year college (Table 2-5). According to 2013 data from the National Survey of College Graduates (NSCG), 47% of all recent S&E graduates had done some coursework in a community college, similar to the proportion in 2003 (48%).[iv] Recent S&E bachelor's degree earners reported slightly higher levels of community college course taking than did recent S&E master's degree holders (49% versus 39%). Graduates in the physical sciences and engineering were less likely than those in the biological and social sciences to have attended a community college.

[iv] For the 2003 NSCG, recent graduates include those who received their most recent degree between 1 July 1994 and 30 June 1999; for the 2013 NSCG, recent graduates include those who received their most recent degree in the 5 years between 1 July 2006 and 30 June 2011.

Table 2-5 **U.S. citizen and permanent resident S&E doctorate recipients who reported earning college credit from a community or 2-year college, by ethnicity and race: 2009–13**

		Earned college credit from a community or 2-year college		
Ethnicity and race	All	Yes	No	Yes (%)
All ethnicities and races	107,376	19,774	87,602	18.4
Hispanic or Latino	6,306	1,375	4,931	21.8
Not Hispanic or Latino				
American Indian or Alaska Native	347	112	235	32.3
Asian	11,003	1,393	9,610	12.7
Black or African American	5,433	981	4,452	18.1
White	79,407	14,918	64,489	18.8
More than one race	2,606	559	2,047	21.5
Other race or race not reported	857	201	656	23.5
Ethnicity not reported	1,417	235	1,182	16.6

NOTES: Includes only respondents to the community college question. Reporting categories for ethnicity and race were expanded in 2013; comparisons with prior-year data should be made with caution.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the 2013 Survey of Earned Doctorates.

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In 2013, recent female S&E bachelor's and master's degree recipients were more likely than their male counterparts to have attended a community college (Table 2-6). Attendance levels as measured by the proportion who attended community college were highest among U.S. citizens, followed by permanent visa holders, and were much lower among temporary visa holders. Among racial and ethnic groups, the proportion attending community college was highest among Hispanics and lowest among Asians. Attendance at the community college level fell with rising parental education level, illustrating the special access function of these institutions.

Table 2-6 **Community college attendance among recent recipients of S&E degrees, by sex, race, ethnicity, citizenship status, and parents' education level: 2013**

Characteristic	Number	Percent who attended community college
All recent S&E degree recipients	1,164,000	47
Sex		
Female	579,000	50
Male	585,000	44

Characteristic	Number	Percent who attended community college
Race or ethnicity		
American Indian or Alaska Native	1,000	40
Asian	130,000	37
Black or African American	97,000	51
Hispanic[a]	176,000	57
Native Hawaiian or Other Pacific Islander	4,000	64
White	715,000	46
More than one race	40,000	55
Citizenship status		
U.S. citizen	1,116,000	50
Permanent visa	33,000	36
Temporary visa	15,000	9
Father’s education		
Less than high school	100,000	57
High school diploma or equivalent	270,000	54
Some college, vocational, or trade school	263,000	52
Bachelor’s	266,000	42
Master’s	152,000	42
Professional degree	48,000	33
Doctorate	44,000	34
Not applicable	19,000	51
Mother’s education		
Less than high school	100,000	55
High school diploma or equivalent	271,000	50
Some college, vocational, or trade school	307,000	50
Bachelor’s	282,000	43
Master’s	157,000	42
Professional degree	18,000	31
Doctorate	17,000	39
Not applicable	12,000	53

	[a] Hispanic may be any race. American Indian or Alaska Native, Asian, black or African American, Native Hawaiian or Other Pacific Islander, white, and more than one race refer to individuals who are not of Hispanic origin.
NOTES:	Recent S&E degree recipients are those who earned their bachelor's or master's degrees between 1 July 2006 and 30 June 2011. Data are rounded to the nearest 1,000.
SOURCE:	National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2015) of the 2013 National Survey of College Graduates.
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About one in four of the recent S&E graduates who indicated attending a community college reported doing so after high school but before ever enrolling in a 4-year college or university or while enrolled in college but before receiving a bachelor’s degree. About one in three used a community college as a bridge between high school and college enrollment in dual enrollment. Another one-third attended a community college after receiving their first bachelor’s degree. One in 10 reported taking courses in a community college after leaving a 4-year college without receiving their first bachelor’s degree.[iv]

The most prevalent reason for attending a community college among recent recipients of S&E bachelor’s and master’s degrees was to earn credits toward a bachelor’s degree (31%). Other reasons mentioned included financial reasons (13%); to prepare for college to increase the chance of acceptance at a 4-year institution (12%); to earn credits while still completing high school (10%); to complete an associate’s degree (8%); to gain further skills or knowledge in their academic or occupational fields (8%); to facilitate a change in their academic or occupational fields (7%); for leisure or personal interest (5%); to increase opportunities for promotion, advancement, or higher salary (2%); and for other reasons (5%).[v]

For-Profit Institutions

In 2013–14, more than 1,400 degree-granting institutions in the United States operated on a for-profit basis; 53% of these were 4-year institutions (Table 2-1). Over the last 10 years, the number of degree-granting, for-profit institutions has grown by nearly 67% (NCES 2015). For-profit institutions enroll considerably fewer students than public institutions, particularly at the 2-year level; in 2013, nearly 6.9 million students were enrolled in community colleges, compared with 155,000 students enrolled in 2-year, for-profit institutions.[vi] For-profit institutions play a disproportionate role in the education of blacks, who are more likely than other racial or ethnic groups to enroll in private for-profit academic institutions (NSF/NCSES 2015c). Although the number of degrees awarded by for-profit institutions nearly quadrupled between 2000 and 2013, the upward trend has recently stopped. Enrollment in for-profit institutions has declined by about 16% since 2010, and the number of degrees they awarded in 2013 was 4% lower than in the previous year (Appendix Table 2-2).

[iv] Special tabulation from the 2013 NSCG.

[v] Special tabulation from the 2013 NSCG.

[vi] Special tabulation from the Integrated Science and Engineering Resources Data System (WebCASPAR) database (12 December 2014 run).

In 2013, for-profit academic institutions awarded between 2% and 6% of S&E degrees at the bachelor’s, master’s, and doctoral levels, as well as 25% of S&E degrees at the associate’s level (Appendix Table 2-1 and Appendix Table 2-2). Computer sciences accounted for 74% of the associate’s degrees and 47% of the bachelor’s degrees awarded by for-profit institutions in S&E fields in 2013 (Appendix Table 2-3). For-profit institutions awarded fewer S&E

master's and doctoral degrees than associate's and bachelor's degrees. At the master's level, S&E degrees were mainly in psychology, social sciences, and computer sciences; at the doctoral level, they were almost exclusively in psychology and social sciences. In 2013, degrees in psychology represented nearly 41% of the master's and 74% of the doctoral degrees awarded by for-profit institutions in S&E fields. Degrees in social sciences accounted for 32% of the master's and 18% of the doctoral degrees awarded in S&E fields.

Online and Distance Education

Online and distance education enable institutions of higher education to reach a wider audience by expanding access for students in remote locations while providing greater flexibility for students who face time constraints, physical impairments, responsibility to care for dependents, and similar challenges. Distance education has been around for more than 100 years (Perna et al. 2014), whereas online education is a relatively new phenomenon.

Online enrollment has grown substantially in recent years. According to a report by Allen and Seaman (2014), between fall 2011 and fall 2012, the number of students taking at least one online course increased by nearly 412,000 to 7.1 million. According to Integrated Postsecondary Education Data System (IPEDS) 2012 Fall Enrollment survey data, 13% of all students in 4-year Title IV institutions (i.e., institutions that participate in federal financial aid programs) were enrolled exclusively in distance education courses, and another 13% were enrolled in distance education and regular on-campus courses; however, about 74% of these students were not enrolled in any distance education course at all (Table 2-7) (Ginder 2014).[vii] Exclusive enrollment in distance education courses was considerably higher at private for-profit 4-year institutions than at either 2- or 4-year public or private nonprofit institutions or at private for-profit 2-year institutions. Enrollment in some distance education courses was highest at public institutions. Exclusive enrollment in distance education courses was higher at the graduate level than at the undergraduate level, whereas enrollment in some distance education courses was higher at the undergraduate level rather than the graduate level.

[vii] In 2011–12, IPEDS began asking institutions whether they were exclusively a distance education institution (i.e., whether all of their programs were offered via distance education, defined as "education that uses one or more technologies to deliver instruction to students who are separated from the instructor and to support regular and substantive interaction between the students and the instructor synchronously or asynchronously"). A distance education course is a course in which the instructional content is delivered exclusively via distance education. A distance education program is a program for which all the required coursework for program completion can be completed via distance education courses. Examinations, orientation, and practical experience components of courses or programs are not considered instructional content. For more details, see the IPEDS online glossary at http://nces.ed.gov/ipeds/glossary/.

Table 2-7 **Enrollment in Title IV institutions, by distance education enrollment status, control, and level of institution: Fall 2012**

(Percent)

Institutional control and level	All (number)	Exclusively distance education courses	Some distance education courses	No distance education courses
Total enrollment				
Number	21,147,055	2,642,158	2,809,942	15,694,955
Percent	100	13.3	13.0	74.2

Institutional control and level	All (number)	Exclusively distance education courses	Some distance education courses	No distance education courses
Degree level				
Undergraduate	18,236,340	11.0	14.2	74.9
Degree /certificate-seeking	16,225,545	11.1	15.2	73.7
Non-degree /certificate-seeking	1,623,082	11.9	7.0	81.1
Graduate	2,910,715	22.0	7.8	70.2
Control and level of institution				
Public				
2-year	6,845,174	9.8	17.3	72.9
4-year	8,092,727	7.1	15.1	77.8
Private nonprofit				
2-year	47,524	1.7	4.6	93.7
4-year	3,916,356	11.9	6.6	81.5
Private for-profit				
2-year	413,377	5.3	4.8	90.0
4-year	1,470,191	61.3	8.3	30.4
Institutional category				
All degree-granting	20,642,819	12.8	13.6	73.6
All non-degree-granting	504,236	0.7	0.8	98.5

NOTE: Title IV institutions are those with a written agreement with the Secretary of Education that allows the institution to participate in any of the Title IV federal student financial assistance programs.

SOURCES: U.S. Department of Education, National Center for Education Statistics (NCES), Integrated Postsecondary Education Data System, Fall 2012, Fall Enrollment Component; NCES, 2014, and *Enrollment in Distance Education Courses, by State: Fall 2012*. NCES 2014-023. Washington DC. http://nces.ed.gov/pubs2014/2014023.pdf. Accessed 3 February 2015.

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Allen and Seaman's most recent survey of academic leaders revealed that 90% of them believe that it is "likely" or "very likely" that a majority of all higher education students will take at least one online course within 5 years

(Allen and Seaman 2014). The survey also showed that a very small segment of higher education institutions (5%) are experimenting with massive open online courses (MOOCs). Doctoral research institutions were much more likely than other types of institutions to offer a MOOC.

MOOCs can provide broad access to higher education for free or at a very low cost. Through their online platforms, MOOCs also have the potential to collect massive amounts of information that can be used to conduct experimental research on how people learn and to identify online practices that improve learning (ED/OET 2013).

Nationally representative data on MOOCs are not available. However, research conducted on the first 17 online courses offered by HarvardX and MITx on the edX platform reveals that completion rates were low (Ho et al. 2014).[viii] Out of more than 840,000 registrants in these courses, 5% earned certificates of completion, but 4% explored more than half of the content of the course without receiving their certification, and 54% accessed less than half of the course content. Ho and colleagues (2014) point out that open online registration in a MOOC is different from enrollment in traditional courses because students can enroll at no monetary cost and with a small time commitment. Others emphasize that many students register for MOOCs to explore the course material and do not intend to complete the courses in which they enroll. The low overall completion rates do not take into account students' intentions (Ho et al. 2014).

Online education companies offering MOOCs have recently expanded their offerings to certificate programs. For instance, Coursera began to offer courses in its fee-based Signature Track with a variety of specializations, most of which are in practical fields such as project management, cloud computing, and data mining (Kolowich 2014). Udacity partnered with AT&T to offer "nanodegrees" that teach students a specific set of skills that can be clearly applied to a job; AT&T accepts the nanodegrees as a credential for entry-level jobs and has reserved 100 internships for its graduates (Porter 2014). The Georgia Institute of Technology, in collaboration with Udacity and AT&T, began to offer an online master's program in computer science, which combines MOOC-like course videos and assessments with a support system that works directly with students. The university's goal is to create a master's degree program that is just as rigorous as the one offered on campus but at a much lower cost.

Changing modes of online education are prompting questions about how the use of this technology will affect the higher education sector. In particular, it is not yet clear how many students can sustain commitment to learning in the absence of more personal contact and to what extent the growing access to higher education facilitated by MOOCs will translate into learning and, in the long run, to higher levels of educational achievement.

[viii] HarvardX and MITx are "collaborative institutional efforts between Harvard University and MIT to enhance campus-based education, advance educational research, and increase access to online learning opportunities worldwide" (Ho et al. 2014).

Trends in Higher Education Expenditures and Revenues

Higher education spending and revenue patterns changed substantially over the last two decades, in trends that intensified during the economic downturn of the late 2000s. Although all types of higher education institutions faced competing demands in a stringent budget environment, each type faced unique challenges. Through 2010, increases in the number of students seeking an affordable college education compounded the challenges created by tight budgets. Despite declines in enrollment in 2011–13 (Appendix Table 2-4), these challenges have remained. This section shows trends in inflation-adjusted average spending and revenue per full-time equivalent (FTE) student from 1987 to 2012,[i] based on data from the Delta Cost Project.[ii]

Very High Research Universities—Public and Private Institutions

Net tuition and federal appropriations, grants, and contracts are two large sources of revenues centrally involved with education for both public and private very high research institutions (Appendix Table 2-5).[iii] For public institutions, state and local appropriations are also critical, supplying an amount of revenue similar to either of the other two sources (nearly $8,500 per FTE in 2012); in contrast, they are a small source of revenue for their private counterparts (about $400 per FTE in 2012). Much more important for private institutions are private and affiliated gifts, investment returns,[iv] and endowment income, which are usually the largest sources of revenue other than that from hospitals and other independent operations.[v]

State and local appropriations for public very high research universities have declined since 1987, with a particularly steep drop between 2008 and 2012 (Figure 2-1). This decline coincided with a compensating increase in net tuition. In 1987, average state appropriations per FTE at public very high research institutions were more than three times the amount of net tuition ($13,800 versus $4,000). By 2012, however, appropriations had dropped to almost $8,500 per FTE, whereas net tuition had increased from about $4,000 to about $11,100 per FTE (Appendix Table 2-5). This change represents a shift in tuition burden from state and local governments to individual students and their families. Starting at a higher level, net tuition at private very high research universities also increased during this period. The increase, from almost $17,000 to almost $25,000, was proportionally much smaller.

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[i] FTE enrollments are derived from the “Enrollment by Race/Ethnicity” section of the IPEDS Fall Enrollment survey. The FTE of an institution’s part-time enrollment is estimated by multiplying part-time enrollment by factors that vary by control and level of institution and level of student; the estimated FTE of part-time enrollment is then added to the institution’s FTE. This formula is used by the U.S. Department of Education to produce the FTE enrollment data published annually in the *Digest of Education Statistics*.

[ii] For the definition of “net tuition revenue,” see “Glossary.” Definitions of standard expense categories are available in the Data Dictionary at http://www.deltacostproject.org/delta-cost-project-database, and an explanation of revenue sources is available at http://www.deltacostproject.org/sites/default/files/products/Revenue_Trends_Production.pdf.

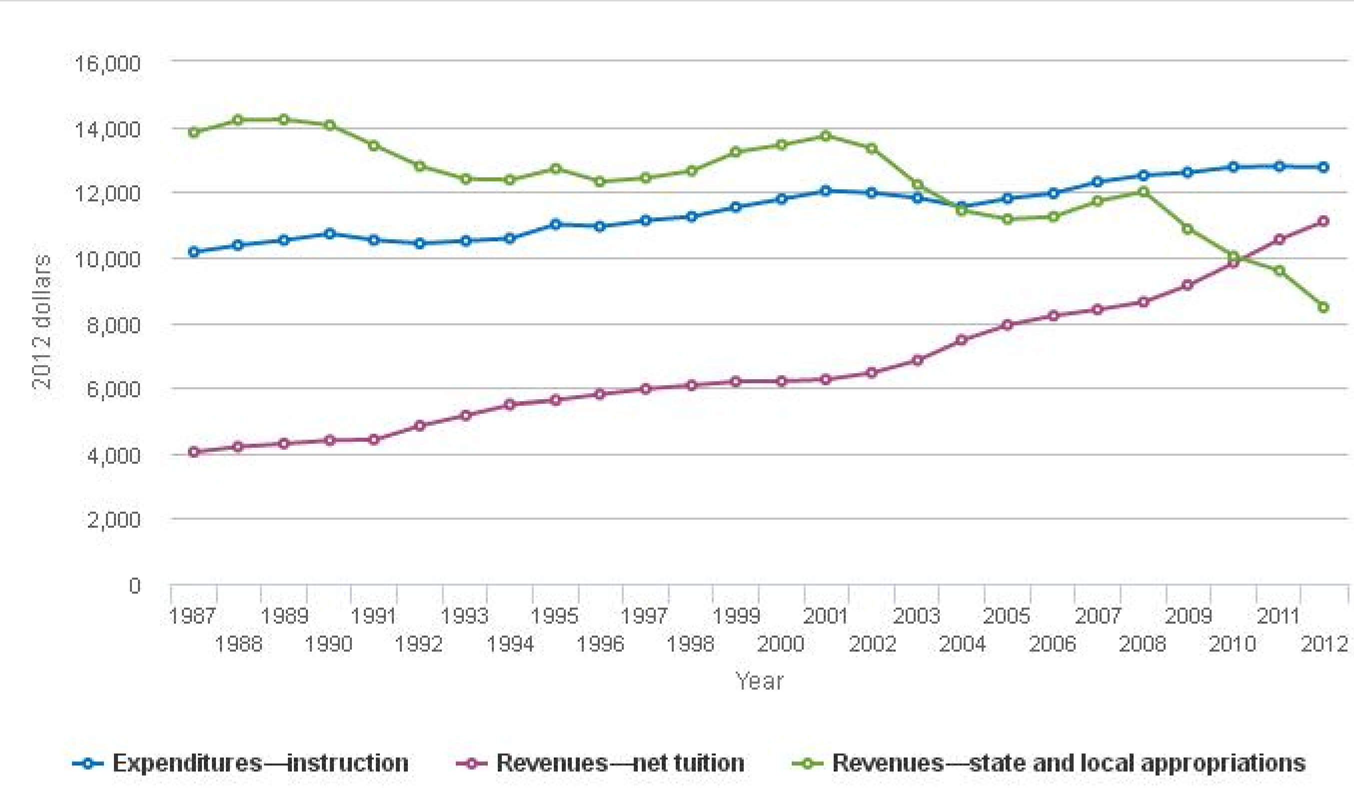
[iii] Another large source of revenue for very high research institutions is “hospitals, independent operations, and other sources,” which includes revenue generated by hospitals operated by the institution and revenues independent of or unrelated to instruction, research, or public services.

[iv] Investment returns include both realized and unrealized gains and losses. Institutions report the change in the value of their investment account, which is the reason behind the negative values under this category in Appendix Table 2-5. So investment returns may not always represent revenue for the institution.

[v] In 2012, income from private and affiliated gifts, investment returns, and endowment income at private very high research institutions was $37,000 per FTE compared with $25,000 in income from net tuition and $28,000 in income from federal appropriations (appendix table 2-5).

Figure 2-1

Selected average revenues and expenditures at public very high research universities: 1987–2012



NOTE: Data are per full-time equivalent.

SOURCE: IPEDS Analytics: Delta Cost Project Database, 1987–2012, special tabulations (2015).

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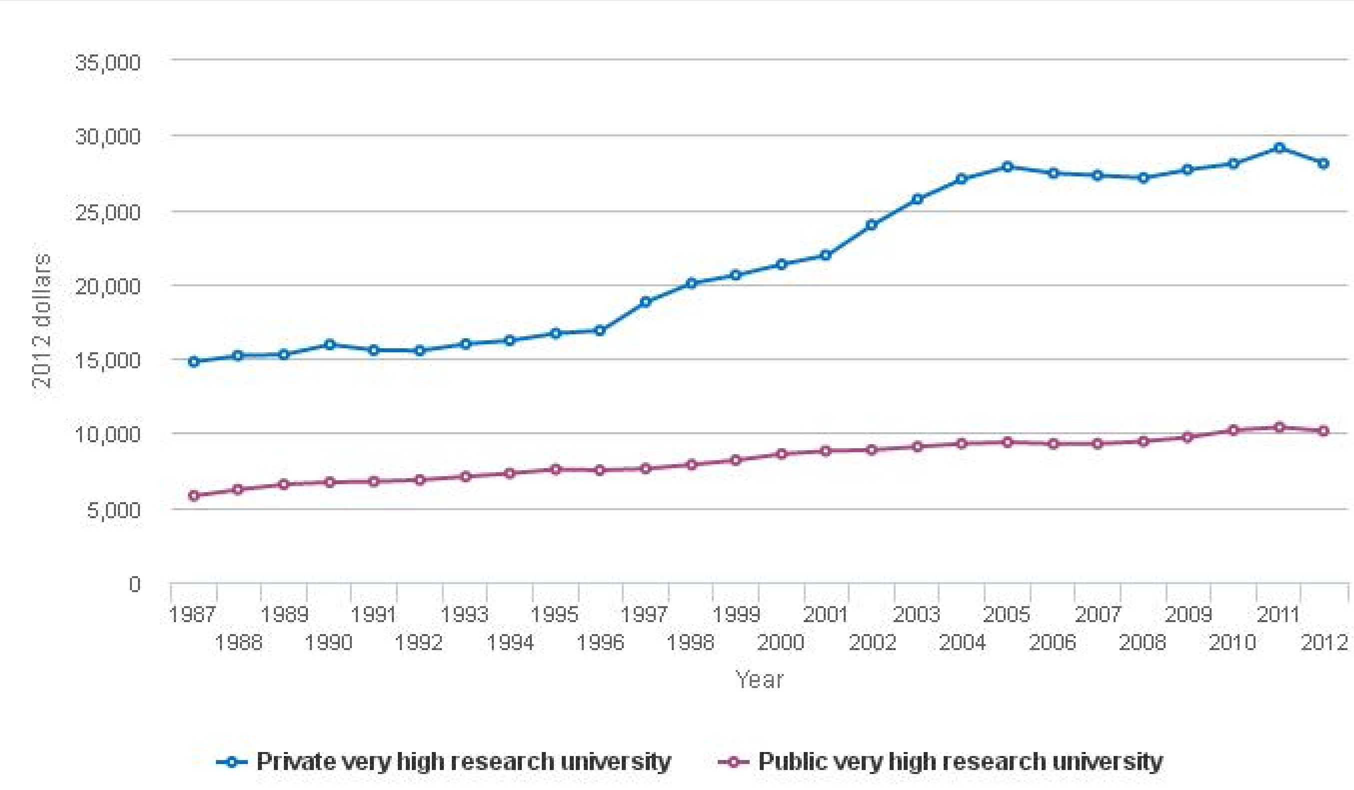
Revenue from federal appropriations, grants, and contracts, the source used for most research expenditures, is highest at the most research-intensive universities (Appendix Table 2-5). Between 1987 and 2012, revenue per FTE from these funds increased at public and private very high research institutions. At the public universities, these funds increased by 78%, reaching a level similar to the state and local appropriations (about $8,700). At private very high research institutions, the funds increased by about 60% in this 25-year period.

Research and instruction are the two largest core education expenditures at public and private very high research universities. Between 1987 and 2012, research expenditures per FTE increased substantially at both types of institutions—by 90% at private universities and by 75% at their public counterparts (Figure 2-2; Appendix Table 2-6). See chapter 5 section Academic R&D, by Public and Private Institutions for greater deatil on university research spending.

Figure 2-2

Average expenditures per FTE on research at public and private very high research universities: 1987–2012



FTE = full-time equivalent.

SOURCE: IPEDS Analytics: Delta Cost Project Database, 1987–2012, special tabulations (2015).

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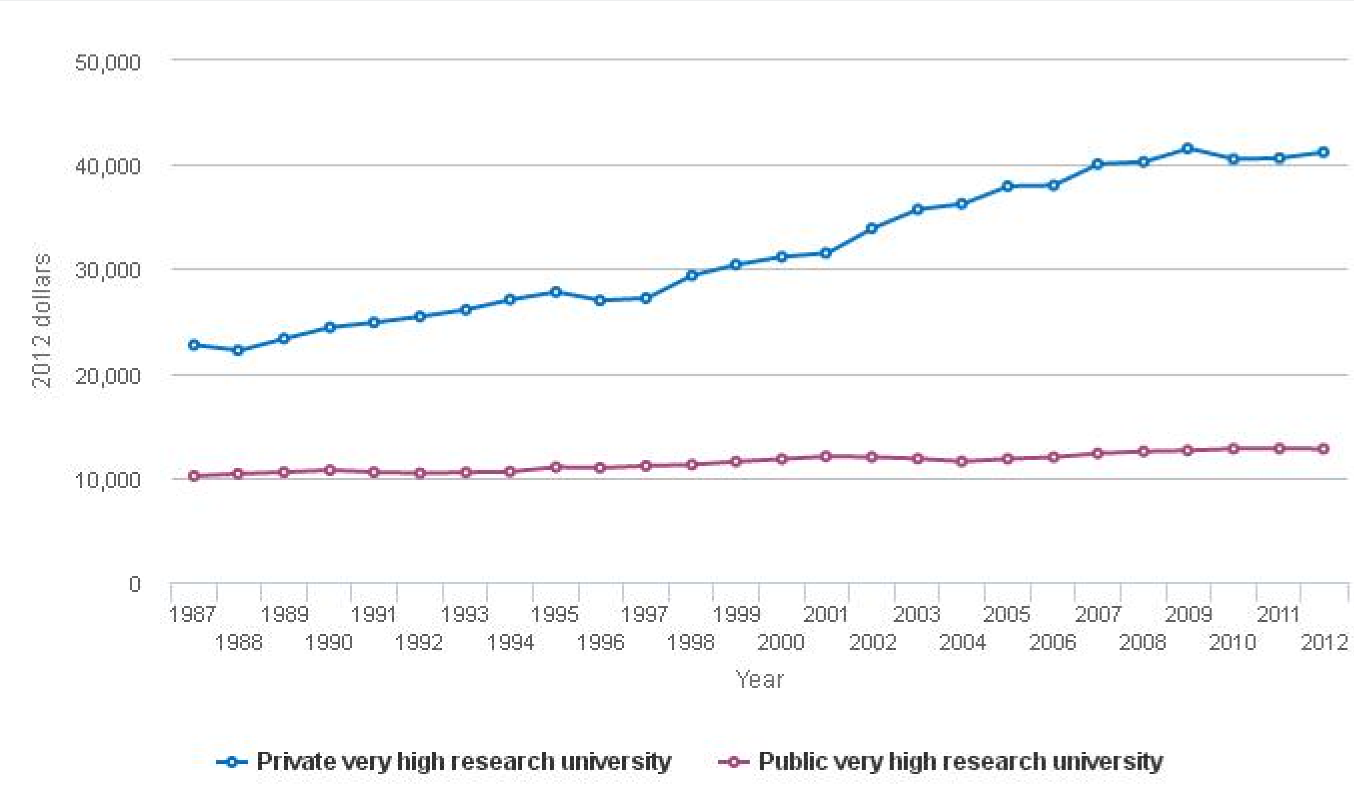
Instructional spending per FTE followed a pattern similar to that of research expenditures. It was much higher at private very high research institutions than at their public counterparts, and it increased at a higher rate. In the late 1980s and early 1990s, instructional spending at private very high research universities was slightly more than double that of the public universities. By the mid-2000s, it was more than triple (Figure 2-3).

Figure 2-3

Average expenditures per FTE on instruction at public and private very high research universities: 1987–2012



FTE = full-time equivalent.

SOURCE: IPEDS Analytics: Delta Cost Project Database, 1987–2012, special tabulations (2015).

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Most other expenditures also increased at both types of very high research institutions; however, at the public ones, spending on plant operation and maintenance declined from 2007 to 2010, with a sharp drop between 2009 and 2010; in 2011 and 2012, this expenditure has remained fairly stable (Appendix Table 2-6). Deferred spending in maintenance may create problems for these institutions in the future.

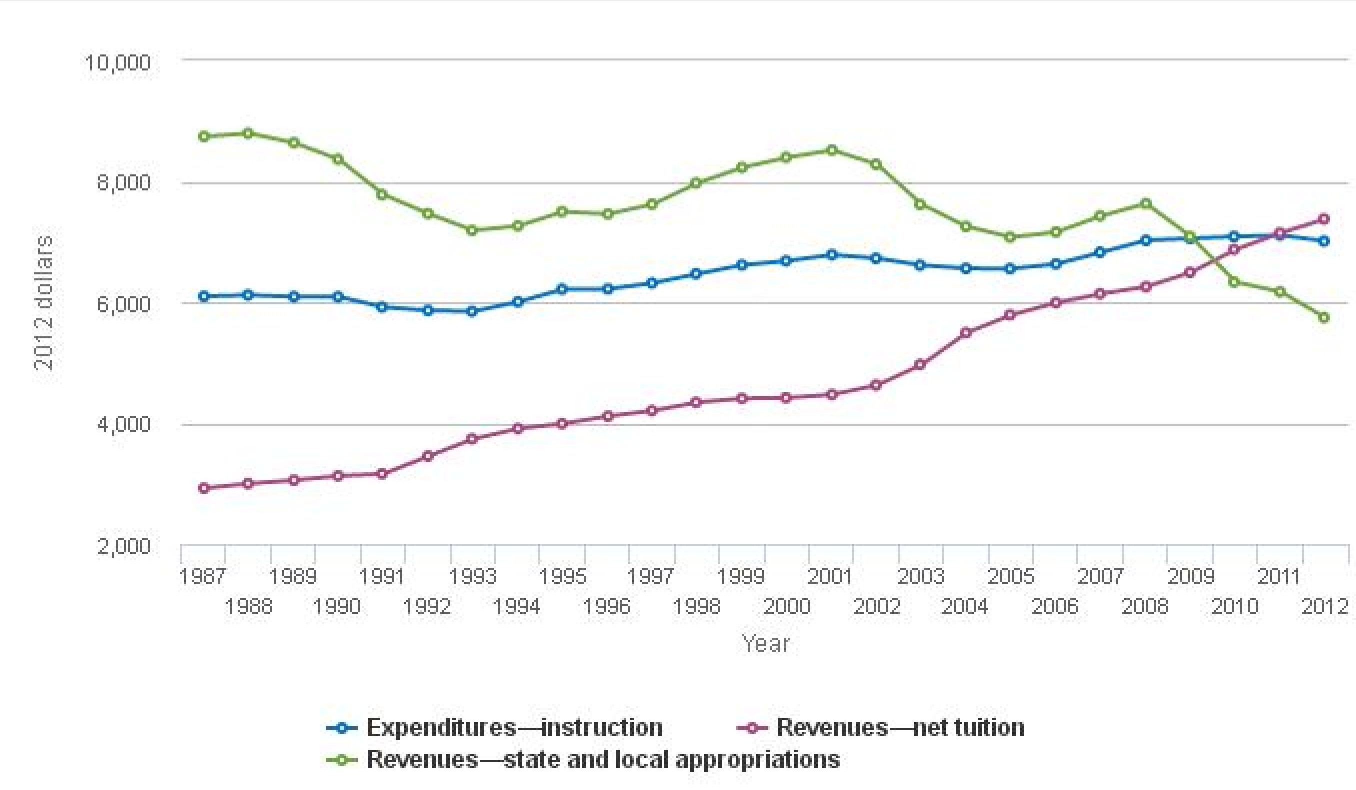
Four-Year and Other Graduate Public Institutions

From 1987 to 2012, state and local appropriations and net student tuition were the largest sources of revenues centrally involved with education at other public institutions offering 4-year and graduate degrees (Appendix Table 2-5).[vi] At these institutions, total revenues from these two sources were lower than those at public very high research universities and higher than those at community colleges. Overall, the percentage drop in revenue per FTE from state and local appropriations was similar to that experienced at the public very high research institutions. In 2010, net student tuition replaced state and local appropriations as the largest source of revenue in the public 4-year institutions. Average state appropriations per FTE in 1987 ($8,700) were three times higher than the corresponding amount of tuition revenue ($2,900). By 2010, average revenues from net student tuition, at almost $6,900 per FTE, exceeded average revenues from state appropriations per FTE by more than $500. By 2012, average revenues from net tuition increased even further, to more than $1,600 over the average revenues from state appropriations (Figure 2-4). As in the case of public very high research institutions, this change represents a shift in tuition burden from state and local governments to individual students and their families.

[vi] The 4-year and graduate institutions category includes the following 2010 Carnegie institution types: doctorate-granting universities—high research activity, doctoral/research universities, master's colleges and universities, and baccalaureate colleges. The data in this section correspond to the public institutions.

Figure 2-4

Selected average revenues and expenditures at public 4-year and other postsecondary institutions: 1987–2012



NOTES: Average expenditures and revenues are per full-time equivalent. Four-year and other postsecondary institutions include doctorate-granting universities—high research activity, doctoral/research universities, master's colleges and universities, and baccalaureate colleges, according to the 2005 Carnegie Classification of Institutions of Higher Education.

SOURCE: IPEDS Analytics: Delta Cost Project Database, 1987–2012, special tabulations (2015).

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Spending on instruction at these institutions has been at least three times as high as almost all the other standard expense categories. It increased from an average of nearly $6,100 per FTE in 1987 to about $7,000 per FTE in 2012 (Appendix Table 2-6). Other expenditures represented much smaller shares of total spending; most of these expenditures increased. Spending on plant operation and maintenance fell by 6% over the 25-year period, with a steep decline from 2009 to 2010 (18%).

Community Colleges

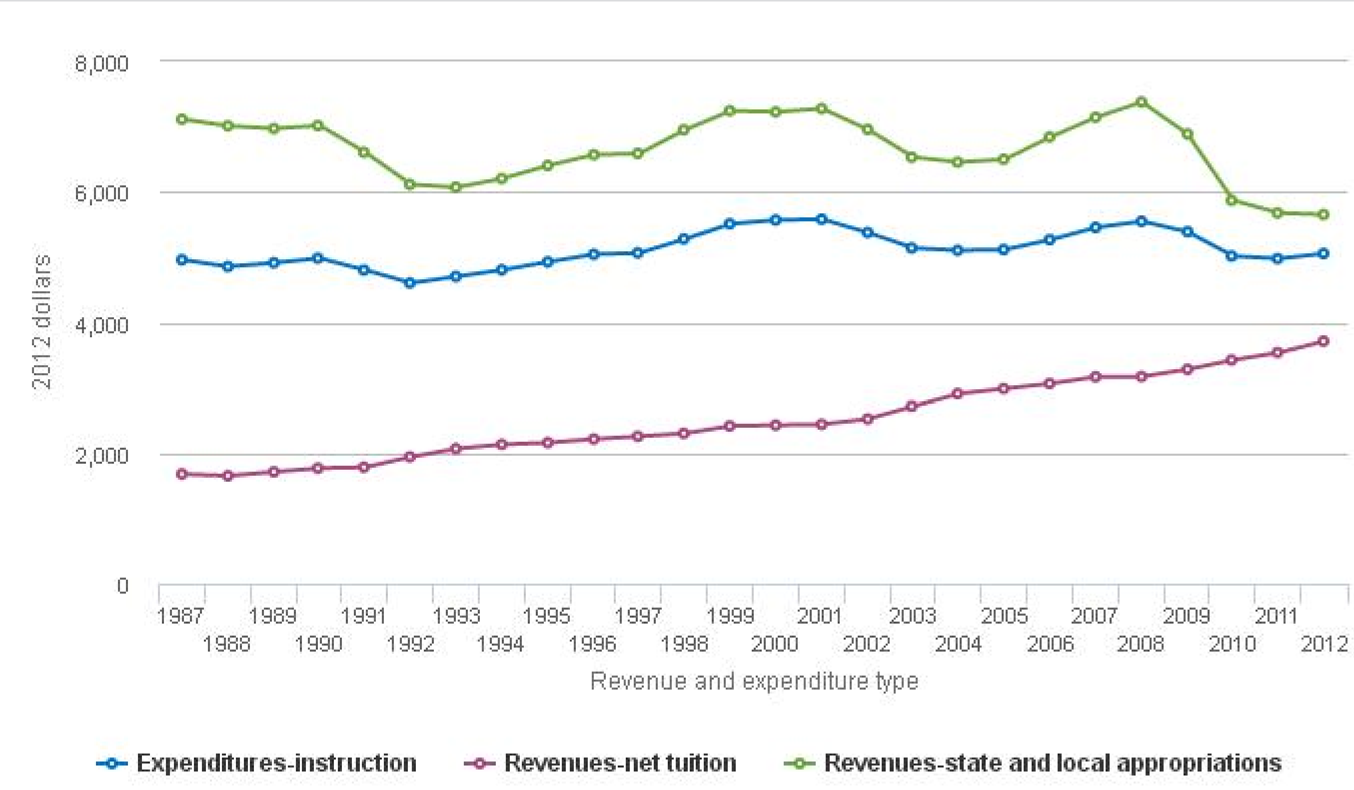
Revenues and expenditures are much lower for community colleges than for other public institutions of higher education.[vii] As in the other institutions, the main sources of revenue at community colleges are state and local appropriations and net student tuition (Appendix Table 2-5). In 2012, average revenues from state and local appropriations at community colleges were about $5,700 per FTE, compared with $8,500 at public very high research institutions; average revenues from net tuition were about $3,700 per FTE, compared with about $11,100 at public very high research institutions. Unlike other public institutions, revenue from state and local appropriations at community colleges still exceeded net tuition revenue in 2012.

Between 1987 and 2012, revenues from state and local appropriations at community colleges decreased from an average of $7,100 per FTE to $5,700 per FTE, with a steep drop from 2008 to 2010 (Figure 2-5). During this 25-year period, as state support declined, revenues from net tuition more than doubled. In 1987, revenues from state and local appropriations represented 64% of total revenues at community colleges, and tuition accounted for 15%. By 2012, state and local appropriations had dropped to 46% of total revenues, whereas the proportion of revenues from tuition doubled to 30%.

[vii] Community colleges are the public “associate’s colleges” in the 2010 Carnegie Classification of Institutions of Higher Education.

Figure 2-5

Selected average revenues and expenditures at community colleges: 1987–2012



NOTES: Revenues and expenditures are per full-time equivalent. Community colleges are public associate's colleges according to the 2005 Carnegie Classification of Institutions of Higher Education.

SOURCE: IPEDS Analytics: Delta Cost Project Database, 1987–2012, special tabulations (2015).

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At community colleges, instruction is by far the largest expenditure (Appendix Table 2-6). In 1987, spending on instruction was about $5,000 per FTE, about 43% of total expenditures. In 2012, average instructional spending per FTE ($5,100) was nearly identical to the 1987 level. Overall, these expenditures had increased somewhat through 2008, dropped by about 10% between 2008 and 2011, and increased by 2% in 2012 (Figure 2-5). Expenditures on student services and institutional and academic support declined in the late 2000s but increased somewhat in 2012. Expenditures in plant operation and maintenance also declined between 2007 and 2011 and remained stable in 2012.

Public Institutions Comparison

Between 1987 and 2012, revenues from state and local appropriations and net tuition, the main two revenue sources at public institutions, grew less at community colleges than at the other two types of public institutions. In community colleges, these two revenue sources combined increased by 6% during this period, lower than the comparable increases at the public 4-year and other graduate institutions (12%) and the very high research institutions (10%). However, trends in these individual revenue sources were substantially different. States and localities cut funding for all three categories of institutions, but the reduction was smaller in the community colleges (21%) than in the public very high research institutions (39%) and in the public 4-year and other graduate public institutions (34%). Unlike the community colleges, however, the other two types of public institutions were able to increase revenues from net tuition to a greater extent. FTE net tuition revenues increased by 175% at the public very high research universities and by 152% at the 4-year and other graduate public institutions, compared with 121% at community colleges (Appendix Table 2-5).

Expenditures for instruction followed a different pattern. They rose most rapidly at the public very high research institutions (26%), where there was pressure to keep faculty salaries (a major component of instructional expenses) competitive with those of their private counterparts, which spent more on instruction to begin with and were increasing these expenses at an even more rapid rate (82%) (Appendix Table 2-6). At community colleges, FTE instructional expenses were essentially the same at the end of the period as they were at the beginning;[viii] in 4-year and other graduate institutions, they fell somewhere in between. Overall, during this period, community colleges had more limited resources and less flexibility to draw on alternate revenue sources to support their instructional expenses. Despite the decline in enrollment in fall 2011 and fall 2012, average expenditures in instruction did not change much in these last 2 years (see section, Undergraduate Enrollment in the United States).

[viii] The proportion of U.S.-trained doctorate holders employed at community colleges in adjunct positions grew from 12% in 1993 to 27% in 2013, according to estimates from the Survey of Doctorate Recipients. This suggests that one of the ways community colleges may have reined in expenses during this period was to increase their reliance on adjuncts.

Financing Higher Education

Cost of Higher Education

Affordability and access to U.S. higher education institutions are continuing concerns (Sullivan et al. 2012; GAO 2014). According to the College Board, between 2009–10 and 2014–15, the estimated average net tuition and fees (i.e., the published prices minus grant aid and tax benefits) paid by full-time undergraduate students in public 4-year colleges increased by about 50% in constant 2014 U.S. dollars (College Board 2014a). Net prices at these institutions had increased considerably between 2009–10 and 2012–13 but declined slightly in the last 2 years. At private nonprofit institutions, net tuition and fees in 2014–15 were 3% lower than in 2009–10, although they increased by 4% in the last year. At public 2-year colleges, net tuition and fees have declined overall; since 2009–10, on average, students enrolled full time have received enough funding through federal and other sources to cover tuition, fees, and other expenses (–$1,740 net tuition in 2014–15) (Table 2-8) (College Board 2014a). Despite large percentage tuition increases in public institutions, they are still more affordable than their private counterparts.

Table 2-8 **Net tuition and fees for full-time undergraduate students by institutional control: 2009–10 through 2014–15**

(2014 U.S. dollars)

Institutional control	2009–10	2010–11	2011–12	2012–13	2013–14	2014–15[a]
Public 2-year	-1,240	-1,680	-1,610	-1,540	-1,780	-1,740
Public 4-year[b]	2,030	2,140	2,960	3,150	2,950	3,030
Private nonprofit 4-year	12,730	12,010	11,910	12,120	11,860	12,360

	[a]Estimated value.
	[b]In-state students.
NOTES:	Prices have been rounded to the nearest $10. Net tuition and fees equal published tuition and fees minus total grant aid and tax benefits.
SOURCE:	The College Board, *Annual Survey of Colleges,Trends in College Pricing* (2014).
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Between 1999–2000 and 2011–2012, changes in the net cost of higher education for dependent undergraduates varied by family income level and type of institution they attended (Table 2-9). During this period, net tuition and fees increased for students from higher income families across all types of institutions. For students from lower income families, net tuition and fees declined at public 2-year institutions and they were stable at public and private nonprofit 4-year master's and baccalaureate institutions and also at private nonprofit 4-year research and doctoral institutions. Net tuition and fees increased at public 4-year research and doctoral institutions for students in all income brackets. Research shows that the vast majority of low-income, high-achieving high school seniors do not apply to any selective college, even though selective institutions cost them less than nonselective ones because of the large amounts of financial aid they are able to offer (Hoxby and Avery 2013). [i]

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[i] In this study, "low-income" referred to high school seniors whose families are in the bottom quartile of the income distribution. "High-achieving" referred to a student who scores at or above the 90th percentile on the ACT comprehensive or the SAT I (math and verbal) and whose high school grade point average is A- or higher. In this research, a "selective college" meant colleges and universities included in the categories from "Very Competitive Plus" to "Most Competitive" in Barron's *Profiles of American Colleges* (Hoxby and Avery 2013).

Table 2-9 **Net tuition and fees for dependent undergraduates attending college or university full time for a full year, by family income quartiles, type of institution, and Carnegie classification: 1999–2000 and 2011–12**

(2012 U.S. dollars)

	Public 2-year		Public 4-year		Private nonprofit 4-year	
Institution type and dependent student family income	1999–2000	2011–12	1999–2000	2011–12	1999–2000	2011–12
All institutions[a]						
Lowest 25%	700	400	1,700	1,900	6,500	8,200
Lower-middle 25%	1,700	1,300	3,600	4,200	10,400	10,500
Upper-middle 25%	1,900	2,300	4,700	7,200	12,600	15,200
Upper 25%	1,800	2,500	5,500	9,000	18,300	21,100
Research and doctoral institutions						
Lowest 25%	NA	NA	2,100	2,600	8,900	12,300
Lower-middle 25%	NA	NA	4,100	5,000	13,600	13,100
Upper-middle 25%	NA	NA	5,000	8,200	16,000	18,000
Upper 25%	NA	NA	6,000	10,200	21,700	25,900

	Public 2-year		Public 4-year		Private nonprofit 4-year	
Institution type and dependent student family income	1999–2000	2011–12	1999–2000	2011–12	1999–2000	2011–12
Master's and baccalaureate institutions						
Lowest 25%	NA	NA	1,300	1,200	5,400	6,500
Lower-middle 25%	NA	NA	2,900	3,400	9,100	9,600
Upper-middle 25%	NA	NA	4,300	6,100	11,000	13,800
Upper 25%	NA	NA	4,400	7,100	15,700	18,600

NA = not available.

[a] Includes all degree-granting institutions: associate's, master's, baccalaureate, research and doctoral, and special focus and other institutions.

NOTES: Full-time status for the purposes of financial aid eligibility was based on 12 credit hours, unless the awarding institution employed a different standard. Data are rounded to the nearest 100. Not all changes observed over time are statistically significant.

SOURCE: U.S. Department of Education, National Center for Educational Statistics, 1999–2000 and 2011–12 National Postsecondary Student Aid Study, 1999–2000 and 2011–12.

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Undergraduate Financial Support Patterns and Debt

Financial Support for Undergraduate Education. With rising tuition, students increasingly rely on financial aid to fund their education. Financial aid for undergraduate students comes mainly in the form of student loans (federal and nonfederal), grants (federal, state, institutional, and private), and tuition tax credits. A financial aid package may contain one or more of these kinds of support. In the 2013–14 academic year,[ii] federal loans constituted 33% of the $185 billion in student aid that undergraduate students received, down from 37% in 2003–04, followed by federal grants (24%, up from 18%), institutional grants (20%, up from 17%), education tax benefits (8% versus 5%), private and employer grants (6%, the same proportion in 2003–04 and in 2013–14), state grants (5% versus 7%), and federal work-study programs (about 1% in both of those years) (College Board 2014b). According to the latest data available from the NCES National Postsecondary Student Aid Study, a higher proportion of undergraduates in private for-profit institutions (90%) and in private nonprofit 4-year institutions (86%) than those in public 4-year (74%) or public 2-year (57%) institutions received some type of financial aid. Undergraduates in private for-profit and private nonprofit institutions were also more likely to incur student loans (75% and 62%) than those in public 4-year institutions (50%) and public 2-year institutions (18%) (Ifill and Shaw 2013).[iii]

Undergraduate Debt. Among recent graduates with S&E bachelor's degrees, the level of undergraduate debt does not vary much by undergraduate major, although it is somewhat higher for recent recipients of life sciences and social and related sciences bachelor's degrees.[iv] Levels of debt vary to a greater extent by type of institution and state. The extent of undergraduate indebtedness of students from public colleges and universities is almost as high as that for students from private nonprofit universities (about 60% at graduation). The level of debt differs, however: $25,600 per borrower for those graduating from a public institution and $31,200 for those graduating from private nonprofits. Students who attend private for-profit institutions are more likely to borrow, and to borrow larger amounts, than those who attend public and private nonprofit institutions (College Board 2014b).

Levels of debt varied widely by state. Average debt for 2013 graduates of public 4-year colleges and universities ranged from $18,065 in Utah to $34,170 in New Hampshire. Average debt for graduates of private nonprofit colleges and universities ranged from $9,757 in Alaska to $36,300 in Connecticut (Institute for College Access & Success, College InSight 2014). Cost of living may account for some of the differences by state.

Graduate Financial Support Patterns and Debt

Financial Support for S&E Graduate Education. In 2013, nearly 40% of all S&E graduate students were primarily self-supporting (i.e., they rely primarily on loans, their own funds, or family funds for financial support) (Appendix Table 2-7). The other 60% receive primary financial support from a variety of sources, including the federal government, universities, employers, nonprofit organizations, and foreign governments. The proportion of S&E graduate students who are self-supporting has been gradually increasing in the last 15 years, from about one-third in 1998 to 38% in 2013. The growth in self-supporting students is related to increasing enrollment of graduate students on temporary visas, who are mostly self-supporting (NSF/NCSES 2015b; IIE 2014).

Sources of funding include federal agency support, nonfederal support, and self-support. Nonfederal support includes state funds, particularly in the large public university systems; these funds are affected by the condition of overall state budgets. Support mechanisms include research assistantships (RAs), teaching assistantships (TAs), fellowships, and traineeships. Most graduate students, especially those who pursue doctoral degrees, are supported by more than one source or mechanism during their time in graduate school, and some receive support from several different sources and mechanisms in any given academic year.

Other than self-support, over time RAs have been the most prevalent primary mechanism of financial support for full-time S&E graduate students (Appendix Table 2-7). In 2013, 25% of full-time S&E graduate students were supported primarily by RAs, 19% primarily by TAs, and 12% primarily by fellowships or traineeships (Appendix Table 2-7).

Primary mechanisms of support differ widely by S&E field of study (Figure 2-6; Appendix Table 2-8). In fall 2013, full-time students in physical sciences were financially supported mainly through TAs (40%) and RAs (37%). RAs were also important in agricultural sciences (49%); earth, atmospheric, and ocean sciences (36%); biological sciences (36%); and engineering (34%; in particular, in materials and chemical engineering). In mathematics, nearly half (49%) of the full-time students were supported primarily through TAs, and 26% were self-supported. Full-time students in computer sciences and the social and behavioral sciences were mainly self-supported (56% and 47%, respectively). About 20% of full-time students in computer sciences received an RA, and 13% had a TA; 21% of those in the social and behavioral sciences had a TA, and only 11% received an RA. Students in medical and other health sciences were mainly self-supported (60%).[v]

[ii] Data for 2013–14 are preliminary (College Board 2014b).

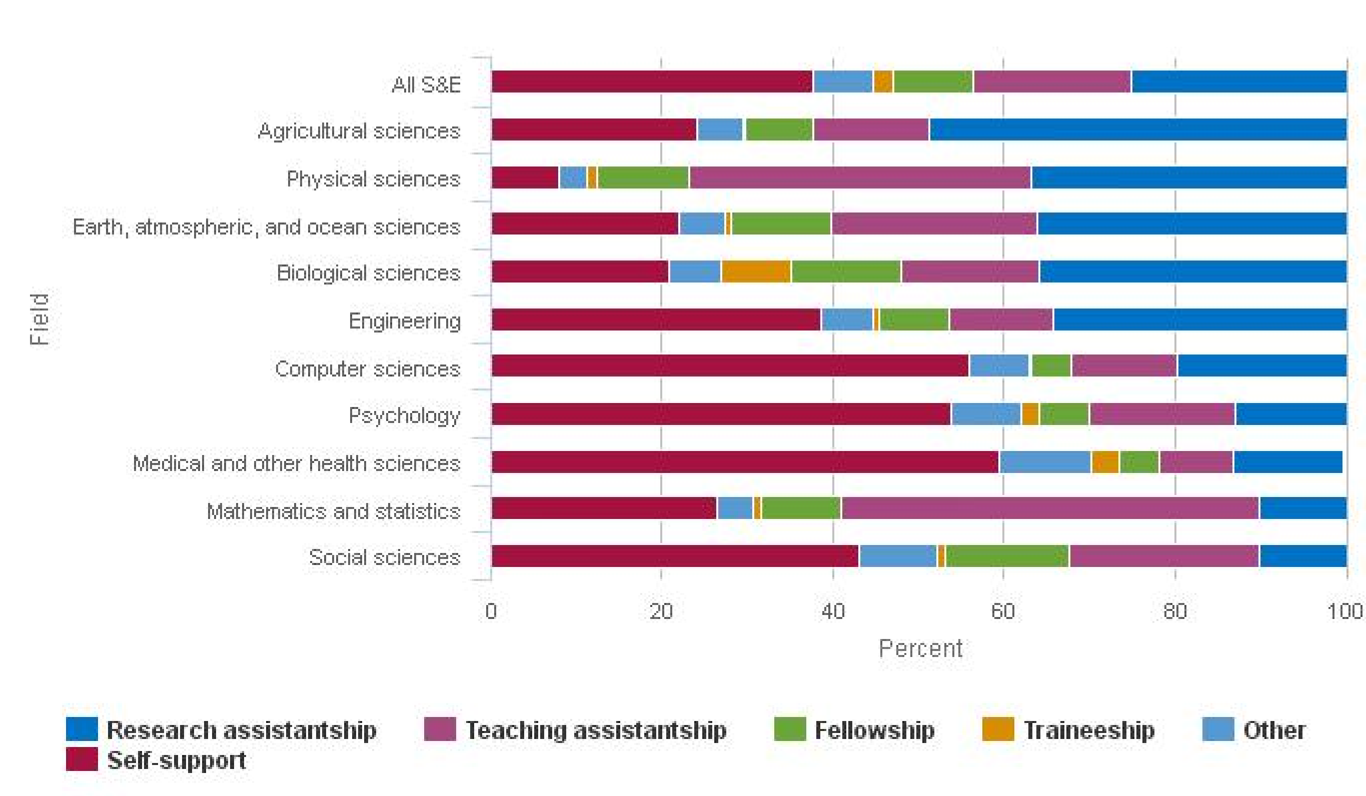
[iii] These percentages include students whose financial aid package included student loans in combination with grants or other student aid, as well as those who only had student loans.

[iv] Based on a special tabulation of the 2013 NSCG. A recent graduate is a respondent who received his or her most recent bachelor's degree between 1 July 2006 and 30 June 2011.

[v] The NSF/NCSES Survey of Graduate Students and Postdoctorates in Science and Engineering does not collect separate data for the master's and the doctoral level. For data on the primary source of financial support of doctorate recipients by broad field of study, see Appendix Table 2-13.

Figure 2-6

Full-time S&E graduate students, by field and mechanism of primary support: 2013



NOTE: Self-support includes any loans (including federal) and support from personal or family financial contributions.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the 2013 Survey of Graduate Students and Postdoctorates in Science and Engineering.

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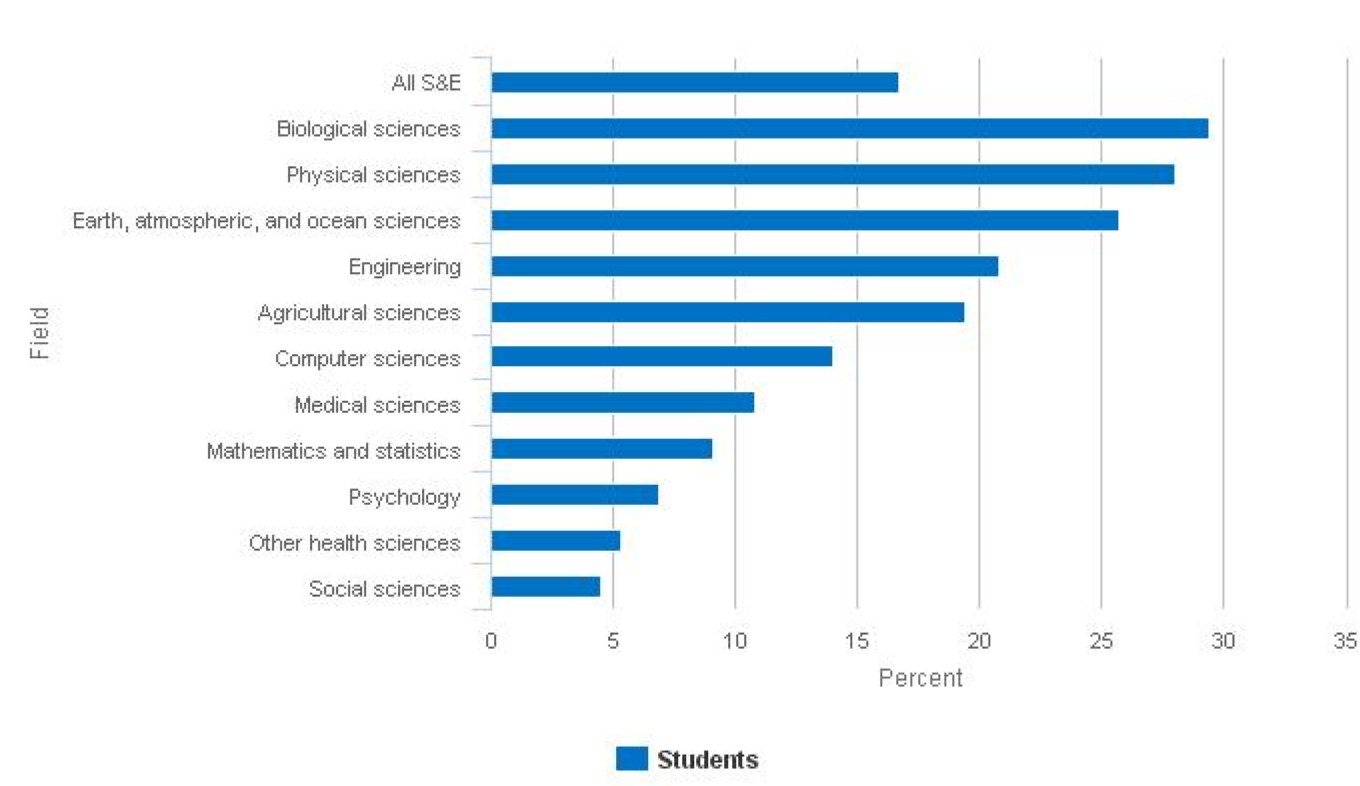
The federal government plays a substantial role in supporting S&E graduate students in some fields but a smaller role in others. Federal financial support for graduate education reaches a larger proportion of students in the biological sciences; the physical sciences; the earth, atmospheric, and ocean sciences; and engineering. Lower proportions of students in computer sciences, mathematics and statistics, medical and other health sciences, psychology, and the social sciences receive federal support (Figure 2-7). Appendix Table 2-9 provides detailed information by field and mechanism.

Figure 2-7

Full-time S&E graduate students with primary support from federal government, by field: 2013



SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the 2013 Survey of Graduate Students and Postdoctorates in Science and Engineering.

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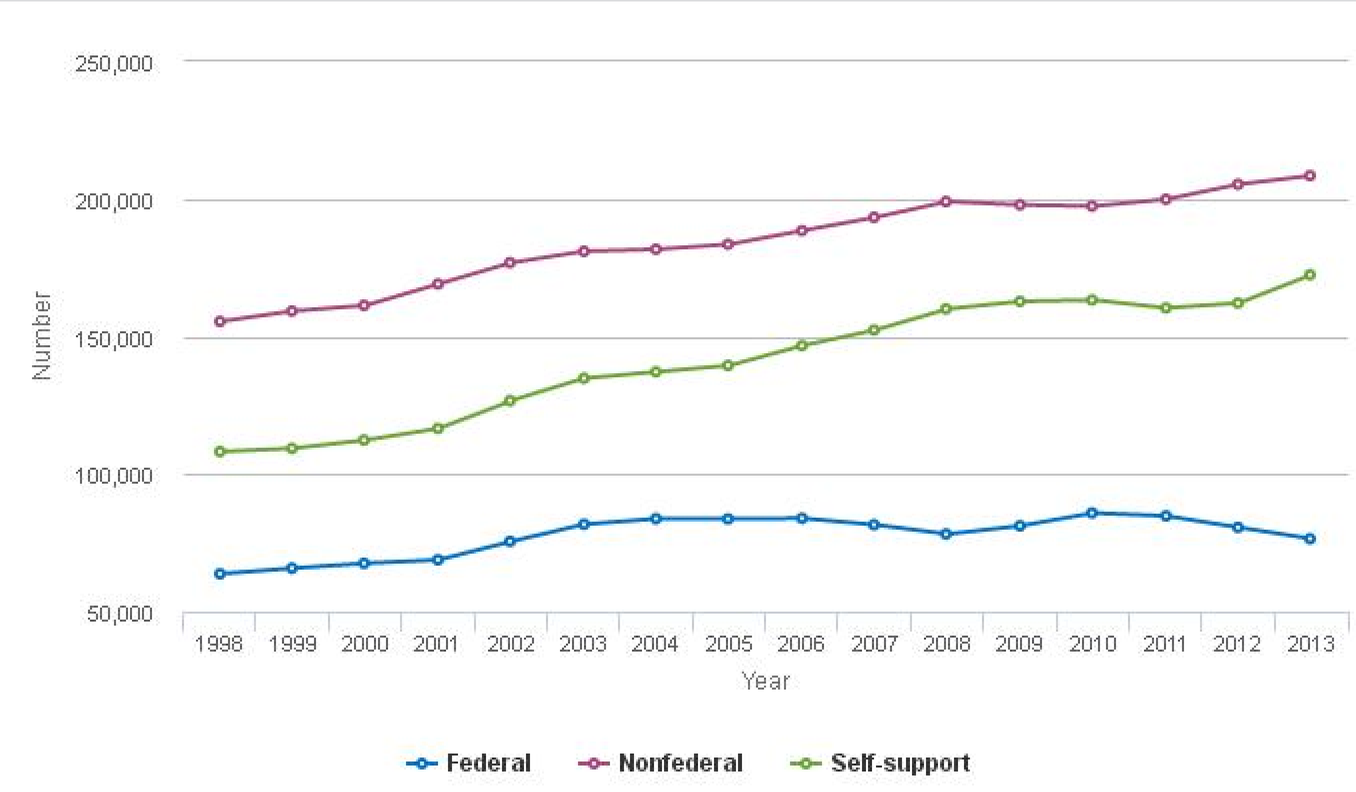
The federal government was the primary source of financial support for 17% of full-time S&E graduate students in 2013, whereas 46% were supported by nonfederal sources (institutional, state or local government, other U.S. sources, or other non-U.S. sources), and 38% were self-supported (Appendix Table 2-7). The number of full-time S&E graduate students supported by the federal government increased between 1998 and 2004 and was fairly stable through 2011, but it declined by 10% in the following 2 years. The number of students supported by nonfederal sources or through self-support has gradually increased in the last 15 years (Figure 2-8). The proportion of full-time S&E students primarily supported by the federal government remained fairly stable at 19%–21% between 1998 and 2006, but has declined since then, reaching its lowest level in at least 15 years in 2013 (17%) (Appendix Table 2-10). This decline was more pronounced in the biological and the physical sciences.

Figure 2-8

Full-time S&E graduate students, by source of primary support: 1998–2013



NOTES: Self-support includes any loans (including federal) and support from personal or family financial contributions. In 2007, the survey was redesigned to improve reporting. In this figure, "2007" shows data as collected in 2007. Because of methodological changes, counts should be used with caution for trend analysis. See http://www.nsf.gov/statistics/nsf10307/ for more detail. S&E excludes fields that were collected in this survey starting in 2007 (architecture, communication, and family and consumer sciences/human sciences) that are not included in other tables in this report from other data sources.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the 2013 Survey of Graduate Students and Postdoctorates in Science and Engineering.

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For some mechanisms of support, the federal role is fairly large. In 2013, the federal government funded 60% of S&E graduate students who were on traineeships, 48% of those with RAs, and 23% of those with fellowships (Appendix Table 2-9).

Most federal financial support for graduate education is in the form of RAs funded through grants to universities for academic research. RAs are the primary mechanism of support for 72% of federally supported full-time S&E graduate students. Fellowships and traineeships are the means of funding for 21% of the federally funded full-time S&E graduate students. For students supported through nonfederal sources in 2013, TAs (i.e., institutional funds) were the most prominent mechanism (40%), followed by RAs (29%) (Appendix Table 2-7).

The National Institutes of Health (NIH) and NSF support most of the full-time S&E graduate students whose primary support comes from the federal government, followed by the U.S. Department of Defense (DOD) (Appendix Table 2-11). In 2013, NIH supported about 22,000 S&E graduate students, NSF about 23,000, and DOD about 8,000. Trends in federal agency support of graduate students show considerable increases from 1998 to 2013 in the proportion of students funded by NSF, from 21% to 30% (Appendix Table 2-11). NSF supported nearly 57% of students in computer sciences or mathematics whose primary support comes from the federal government; 49% of those in earth, atmospheric, and ocean sciences; 40% of those in the physical sciences; and 36% of those in engineering overall (about 46% of those in chemical engineering and 44% of those in electrical engineering) (Appendix Table 2-12). The proportion of students funded by NIH increased from 29% to 33% between 1998 and 2008 but has since decreased to 29%. In 2013, NIH funded about 71% of such students in the biological sciences, 56% of those in the medical sciences, and 38% of those in psychology. The proportion of graduate students supported by DOD decreased slightly between 1998 and 2013. In 2013, DOD supported 44% of the S&E graduate students in aerospace engineering, 33% of those in industrial engineering, 29% of those in electrical engineering, and 21%-23% of those in materials and mechanical engineering and in computer sciences.

For doctoral degree students, notable differences exist in primary support mechanisms by type of doctorate-granting institution (Table 2-10). In 2013, RAs were the primary support mechanism for S&E doctorate recipients from research universities (i.e., doctorate-granting institutions with very high research activity, which receive the most federal funding, as well as those with high research activity). For those from medical schools, which are heavily funded by NIH, fellowships or traineeships accounted for the main mechanism of support. Students at less research-intensive universities relied mostly on personal funds.

Table 2-10 **Primary support mechanisms for S&E doctorate recipients, by 2010 Carnegie classification of doctorate-granting institution: 2013**

Mechanism	All institutions	Research universities—very high research activity	Research universities—high research activity	Doctoral/research universities	Medical schools and medical centers	Other/not classified
Doctorate recipients (number)	39,334	29,415	6,409	1,468	1,250	792
All mechanisms	100.0	100.0	100.0	100.0	100.0	100.0
Fellowship or traineeship	19.8	21.5	12.7	10.7	32.6	11.5
Grant	6.5	6.9	3.3	3.1	19.1	4.5
Teaching assistantship	16.5	16.7	21.8	8.0	1.0	8.0
Research assistantship	33.8	36.8	30.7	12.2	19.0	11.0
Personal	9.0	5.7	14.3	41.5	9.1	28.2
Other	3.8	3.3	5.3	7.1	5.4	4.8
Unknown	10.5	9.2	11.9	17.4	13.8	32.1

NOTES: Personal support mechanisms include personal savings, other personal earnings, other family earnings or savings, and loans. Research assistantships include research assistantships and other assistantships. Traineeships include internships and residencies. Other support mechanisms include employer reimbursement or assistance, foreign support, and other sources. Percentages may not add to total because of rounding.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the 2013 Survey of Earned Doctorates.

Notable differences also exist in primary support mechanisms for doctoral degree students by sex, race and ethnicity, and citizenship (Appendix Table 2-13). In 2011–13, among U.S. citizens and permanent residents, male S&E doctorate recipients were more likely than their female peers to be supported by RAs (31% compared with 23%). Female S&E doctorate recipients were more likely than their male counterparts to receive fellowships or traineeships (28% versus 24%) and to support themselves from personal sources (18% versus 11%). Also, Asians were more likely than any other racial or ethnic group to have primary RA support (32%), followed by whites (28%). Compared with other racial and ethnic groups, Hispanic, black, and American Indian or Alaska Native doctorate recipients depended more on fellowships or traineeships (34%, 35%, and 44%, respectively), and blacks and American Indians or Alaska Natives were more likely to use personal sources (25% and 20%, respectively). S&E doctorate recipients on temporary visas were more likely to have an RA (51%) than their U.S. citizen and permanent resident peers (27%); this is has been a long-standing pattern.

To some extent, the sex, citizenship, and racial and ethnic differences in types of support mechanisms are related to differences in field of study. White and Asian men, as well as international doctoral degree students, are more likely than white and Asian women, along with underrepresented minority students of both sexes, to receive doctorates in engineering and physical sciences, fields that are largely supported by RAs. In turn, women and underrepresented minorities are more likely to receive doctorates in social sciences and psychology, in which self-support is prevalent. However, differences in type of support by sex, race and ethnicity, or citizenship largely remain after accounting for these doctoral field patterns (Appendix Table 2-13).

Graduate Debt. At the time of doctoral degree conferral, 45% of 2013 S&E doctorate recipients have debt related to their undergraduate or graduate education. In 2013, 30% of S&E doctorate recipients reported having undergraduate debt, 33% reported having graduate debt, and 45% had undergraduate and graduate debt. For some S&E doctorate recipients, debt levels were high, especially for graduate debt: 5% reported more than $40,000 of undergraduate debt, 13% reported more than $40,000 of graduate debt, and 21% reported more than $40,000 in cumulative undergraduate and graduate debt (Appendix Table 2-14).

Levels of debt vary widely by doctoral field. A higher percentage of doctorate recipients in non-S&E fields (52%) than those in S&E fields (33%) reported graduate debt. In 2013, within S&E, high levels of graduate debt were most common among doctorate recipients in the social sciences, psychology, and the medical and other health sciences. The proportion of doctorate recipients in these fields who reported graduate debt has increased since 2003.[vi] Psychology doctorate recipients were most likely to report having graduate debt and high levels of debt.[vii] In 2013, 26% of psychology doctoral degree recipients reported graduate debt of more than $70,000 (Appendix Table 2-14). Doctorate recipients in mathematics and computer sciences were the least likely to report graduate debt.

Men and women differed little in level of undergraduate debt, but women were more likely to have accumulated higher graduate debt. U.S. doctorate holders accumulated more debt than temporary visa holders. Blacks, Hispanics, and American Indians and Alaska Natives had higher levels of graduate debt than whites, even accounting for differences in field of doctorate (NSF/NCSES 2015a).

[vi] For the proportions corresponding to the 2003 Survey of Earned Doctorates, please see NSB 2006, Appendix Table 2-23 at http://nsf.gov/statistics/seind06/append/c2/at02-23.pdf.

[vii] Clinical psychology programs and programs that emphasize professional practice (professional schools and PsyD programs) are associated with higher debt, but even in the more research-focused subfields of psychology, lower percentages of doctorate recipients were debt free, and higher percentages had higher levels of debt, than those in other S&E fields. For information on debt levels of clinical versus nonclinical psychology doctorates in 1993–96, see *Psychology Doctorate Recipients: How Much Financial Debt at Graduation?* (NSF 00-321) at http://www.nsf.gov/statistics/issuebrf/sib00321.htm. Accessed 5 October 2015.

Undergraduate Education, Enrollment, and Degrees in the United States

Undergraduate education in S&E courses prepares students majoring in S&E for the workforce. It also prepares nonmajors to become knowledgeable citizens with a basic understanding of science and mathematics concepts. This section includes indicators related to enrollment by type of institution, field, and demographic characteristics; intentions to major in S&E fields; and recent trends in the number of earned S&E degrees.

Undergraduate Enrollment in the United States

Overall Undergraduate Enrollment

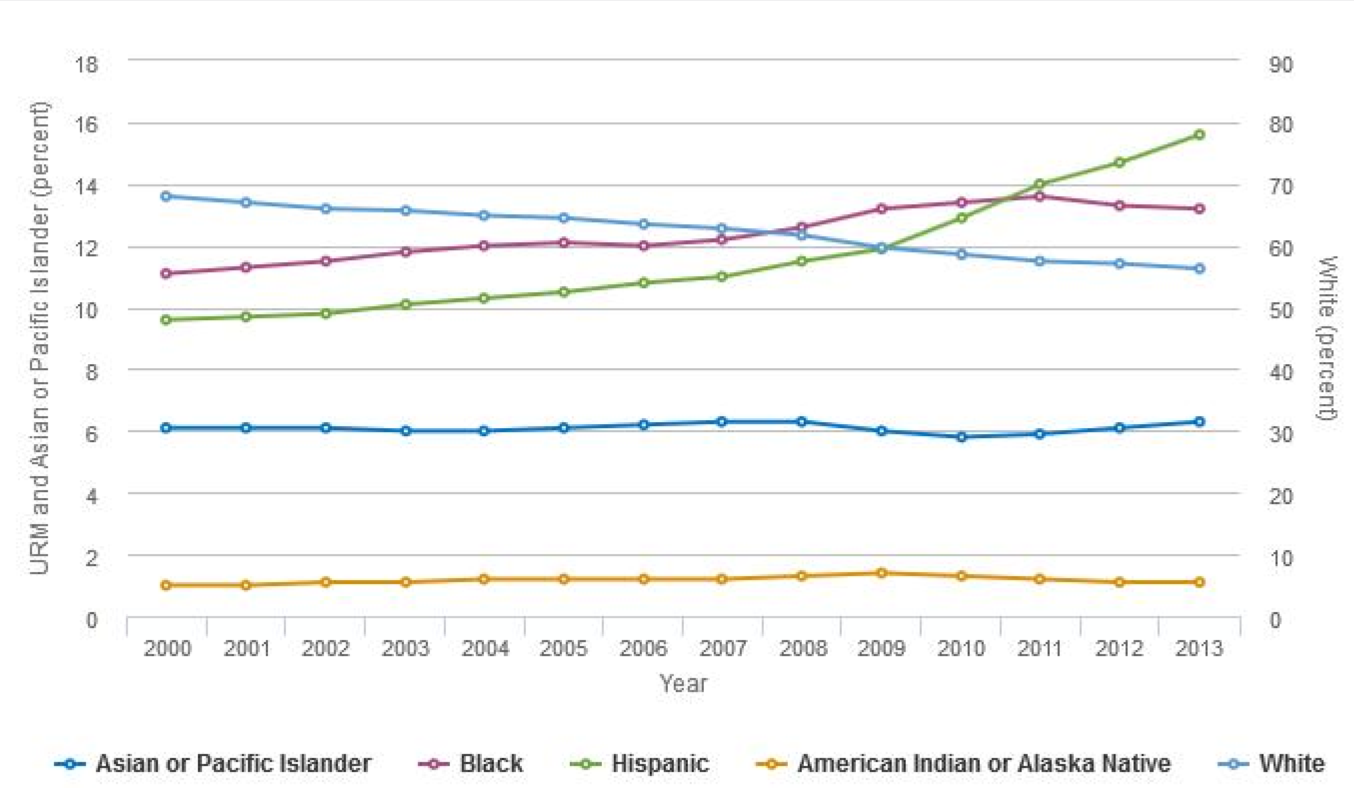
Enrollment in U.S. institutions of higher education at all levels rose from 15.5 million students in fall 2000 to 20.6 million in fall 2013, with two main periods of high growth—between 2000 and 2002 and between 2007 and 2010, continuing a pattern of rising enrollments when there are downturns in the economy. Undergraduate enrollment typically represents about 86% of all postsecondary enrollment (Appendix Table 2-4).

Undergraduate enrollment peaked at 18.3 million in 2010 but has declined to 17.7 million in 2013. As in previous years, the types of institutions enrolling the largest numbers of students at the undergraduate level in 2013 were associate's colleges (7.7 million, 43% of all undergraduates enrolled), master's colleges/universities (3.7 million, 21%), and doctorate-granting universities with very high research activity (2.1 million, 12%). Between 2000 and 2013, undergraduate enrollment increased by 62% at doctoral/research universities, by 37% at master's colleges, by 34% at associate's colleges, and by 27% at baccalaureate colleges (Appendix Table 2-4). (see sidebar, Carnegie Classification of Academic Institutions, for definitions of the types of academic institutions.)

Between 2000 and 2013, the share of Hispanics enrolled full time in undergraduate programs among U.S. citizens and permanent residents increased from 11% to 16%, and the share of blacks increased from 11% to 13%. The shares of Asians or Pacific Islanders and of American Indians or Alaska Natives remained stable at 6% and 1%, respectively. The share of whites declined from 68% to 56% in the same period (Figure 2-9).

Figure 2-9

Share of full-time undergraduate enrollment among U.S. citizens and permanent residents, by race and ethnicity: 2000–13



URM = underrepresented minorities (black, Hispanic, and American Indian or Alaska Native).

NOTES: Hispanic may be any race. American Indian or Alaska Native, Asian or Pacific Islander, black, and white refer to individuals who are not of Hispanic origin. Percentages do not add to total because data do not include individuals who did not report their race and ethnicity.

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Fall Enrollment Survey; National Science Foundation, National Center for Science and Engineering Statistics, WebCASPAR database, http://webcaspar.nsf.gov.

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According to the latest Census Bureau projections, increased enrollment in higher education is projected to come mainly from minority groups, particularly Hispanics. The latest Census Bureau projections report that the number of college-age individuals (ages 20–24) is expected to decline between 2015 and 2020 but increase in the longer term to 24.0 million by 2060 (Appendix Table 2-15). The short-term decline in this segment of the population is mostly due to a drop in the number of non-Hispanic whites, which is projected overall to continue to fall through 2060, and a decline in the population of non-Hispanic blacks between 2015 and 2035. The populations of 20–24-year-old Hispanics and of Asians who are not Hispanic are expected to increase continuously between 2015 and 2060. The proportion of Asians in this age group is expected to increase from 5% to 9%. The proportion of Hispanics in this age group is expected to grow from 22% in 2015 to 32% in 2060. This increase may result in a larger number of academic institutions becoming high Hispanic enrollment and also in considerable increases in the overall enrollment in community colleges, as nearly half of all Hispanic undergraduates are enrolled in community colleges. [i]

Undergraduate Enrollment in S&E

Freshmen intentions to major in S&E. Since 1971, the annual The American Freshman: National Norms survey, administered by the Higher Education Research Institute at the University of California, Los Angeles, has asked freshmen at a large number of universities and colleges about their intended majors.[ii] Data show that up until 2007, about one-third of all freshmen planned to study S&E; this proportion gradually rose to 45% by 2014. Increases in the proportion of freshmen planning to major in biological and agricultural sciences and in engineering account for most of this growth. In 2014, about 14% of freshmen intended to major in the biological and agricultural sciences (up from about 9% in 2007), and a similar proportion intended to major in engineering (up from about 8% in 2007). About 14% planned to major in engineering; 10% in the social and behavioral sciences; 5% in mathematics, statistics, or computer sciences; and 3% in the physical sciences (Appendix Table 2-16). The percentage of all freshmen intending to major in mathematics, statistics, or computer sciences declined for more than 10 years since the late 1990s, but has increased since 2011.

In 2014, more than half of Asian American or Asian freshmen reported that they intended to major in S&E; proportions were lower for Hispanic or Latino freshmen (45%) and lower still for whites and blacks (40% each) and for American Indian or Alaska Native (30%) freshmen (Figure 2-10). Since the late 1990s, the proportions intending to major in S&E increased in all racial and ethnic groups except in the American Indian or Alaska Native group.[iii]

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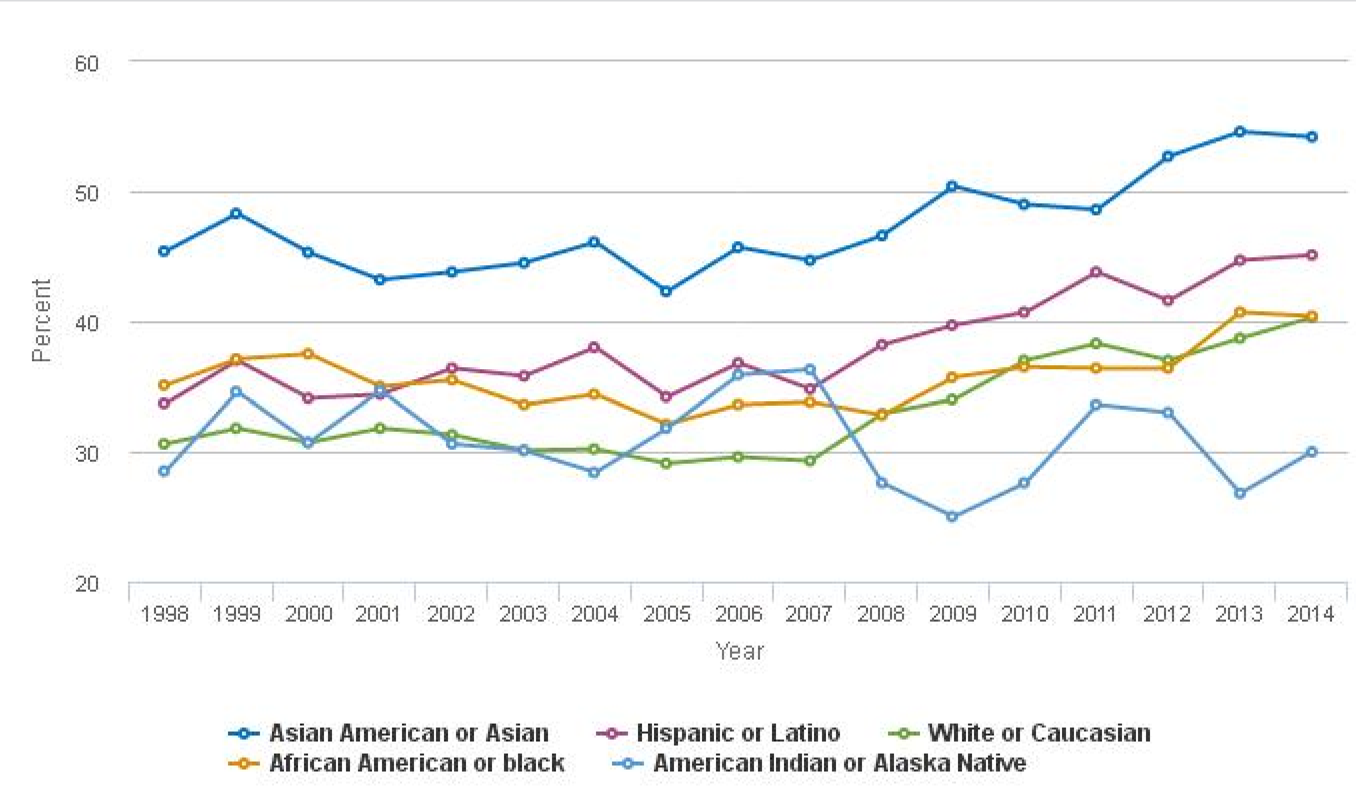
[i] Special tabulation from the IPEDS Fall Enrollment survey, available at https://ncsesdata.nsf.gov/webcaspar/.

[ii] For details on the methodology of this survey and its limitations, please see appendix A of the annual report *The American Freshman: National Norms Fall 2014*, published by the Cooperative Institutional Research Program at the Higher Education Research Institute at the University of California, Los Angeles (http://www.heri.ucla.edu/monographs/TheAmericanFreshman2014.pdf). These data are subject to sampling error. Information on estimated standard errors can be found in appendix D. Data reported here are significant at the 0.05 level.

[iii] Data for racial and ethnic groups are for U.S. citizens and permanent residents only.

Figure 2-10

Freshmen intending S&E major, by race and ethnicity: 1998–2014



NOTE: In 2001, Native Hawaiian or Pacific Islander was added as a category under Asian American or Asian.

SOURCE: Higher Education Research Institute, University of California, Los Angeles, special tabulations (2015) of The American Freshman: National Norms.

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Among whites, Asians, and Hispanics, the proportions planning to major in S&E were higher for men than for women (Appendix Table 2-16). A higher proportion of Asian American or Asian freshmen than of those from other racial and ethnic groups planned to major in the natural sciences and engineering, and higher proportions of blacks and Hispanics or Latinos intended to major in the social and behavioral sciences.

There has been growing concern about the ability to produce and retain science, technology, engineering, and mathematics (STEM) talent in the United States (PCAST 2012). Some students start undergraduate programs and do not complete their degrees, or they complete their degrees but switch majors (see sidebar, Attrition in STEM Fields).

Generally, the percentages of students earning bachelor's degrees in specific S&E fields are similar to the percentages planning to major in those fields, with the exception of engineering and social and behavioral sciences. (See the Undergraduate Degree Awards and Appendix Table 2-17 and Appendix Table 2-18 for trends in bachelor's degrees; see the section on "Persistence and Retention in Undergraduate Education [S&E versus Non-S&E Fields]" in [NSB 2012] for a discussion of longitudinal data on undergraduate attrition in S&E.) For both sexes and all racial and ethnic groups, the percentage of students earning bachelor's degrees in engineering is smaller than the percentage planning to major in it (Figure 2-11 and Figure 2-12). The percentage earning bachelor's degrees in social and behavioral sciences in 2013 (16%) (Appendix Table 2-17) is larger than the percentage that planned to major in those fields as freshmen 6 years earlier (10%) (Appendix Table 2-16). For women, Asians, blacks, and Hispanics, the proportion earning bachelor's degrees in the natural sciences is smaller than the proportion that begins college planning to major in these fields (Figure 2-13 and Figure 2-14).

Attrition in STEM Fields

The retention of undergraduate students with declared science, technology, engineering, and mathematics (STEM) majors has become a policy focus. In 2014, nearly 45% of incoming freshmen intended to major in S&E, and just over 1 in 10 of these freshmen indicated that there was "a very good chance" that they would change their major down the road (Eagan et al. 2014). During their undergraduate years, several of these students switch to other majors—for a variety of reasons—but are essentially replaced by students without declared majors or majors in non-STEM fields (for detailed data on field-switching from STEM, non-STEM fields, and undeclared majors, see [Table (NSB 2012) 2-9]).

These broad relationships provide no information about the specific paths and factors that make students declare, enter, and leave an S&E major and earn STEM degrees. To provide more insight into these questions, the National Center for Education Statistics followed the 2003–04 college cohort through 2009 and examined potential factors underlying STEM attrition (Chen and Soldner 2013). The study focused on identifying the factors related to attrition from STEM fields and did not include students who switched from non-STEM fields into STEM fields, or those who had not initially declared a major but later decided to major in a STEM field. The study's STEM definition included engineering and science technologies together with engineering, information sciences together with computer sciences, and excluded all social and behavioral science fields. Appropriate statistical controls were applied throughout the study.

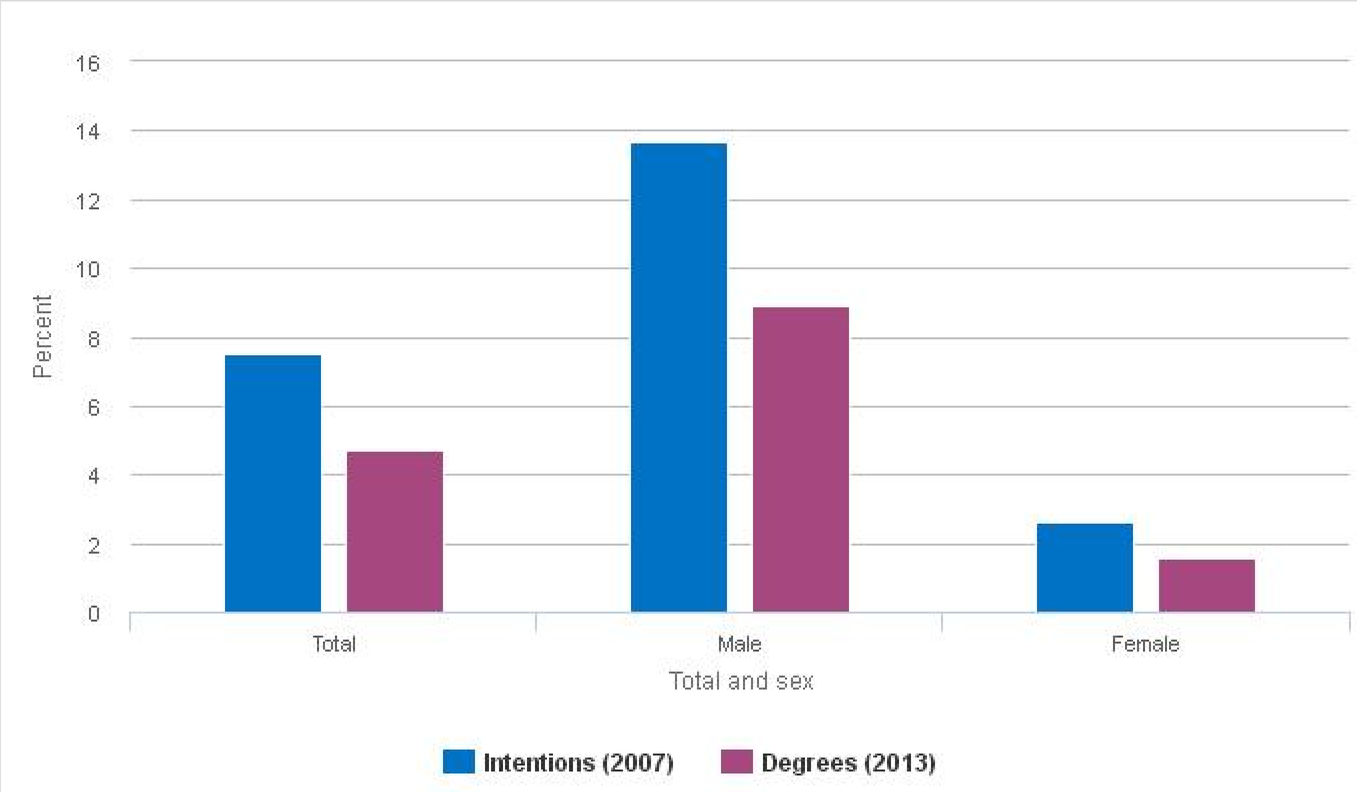
About half of the beginning bachelor's degree students who declared STEM majors during any of these years had either left college altogether by 2009 (20%) or left STEM for another field (28%). Attrition was particularly high among computer and information sciences majors and among associate's degree students. Overall, however, attrition from STEM majors was lower than in most other fields. For bachelor's and associate's students who declared STEM majors, taking fewer STEM courses in the first year, choosing less demanding mathematics courses in the first year, and performing poorly in STEM classes relative to non-STEM classes were factors associated with an increased probability of switching out of STEM majors. For bachelor's degree students, withdrawing or failing STEM courses was associated with an increased probability of switching out of STEM majors.

With regard to students leaving STEM fields by dropping out of college, overall college performance and the level of success in STEM courses was critical. Bachelor's and associate's STEM entrants who earned a low college grade point average and accumulated a large number of incompletes in STEM courses dropped out of college at higher rates. For associate's degree students, being less successful in STEM courses than in non-STEM courses was also a factor for dropping out of college.

Beginning bachelor's degree students starting at private nonprofit 4-year colleges were less likely than those starting at public 4-year institutions to abandon STEM majors by switching to another field. In addition, students from selective colleges were less likely to leave college than their counterparts who started at nonselective institutions.

Figure 2-11

Engineering: Freshmen intentions and degrees, by sex



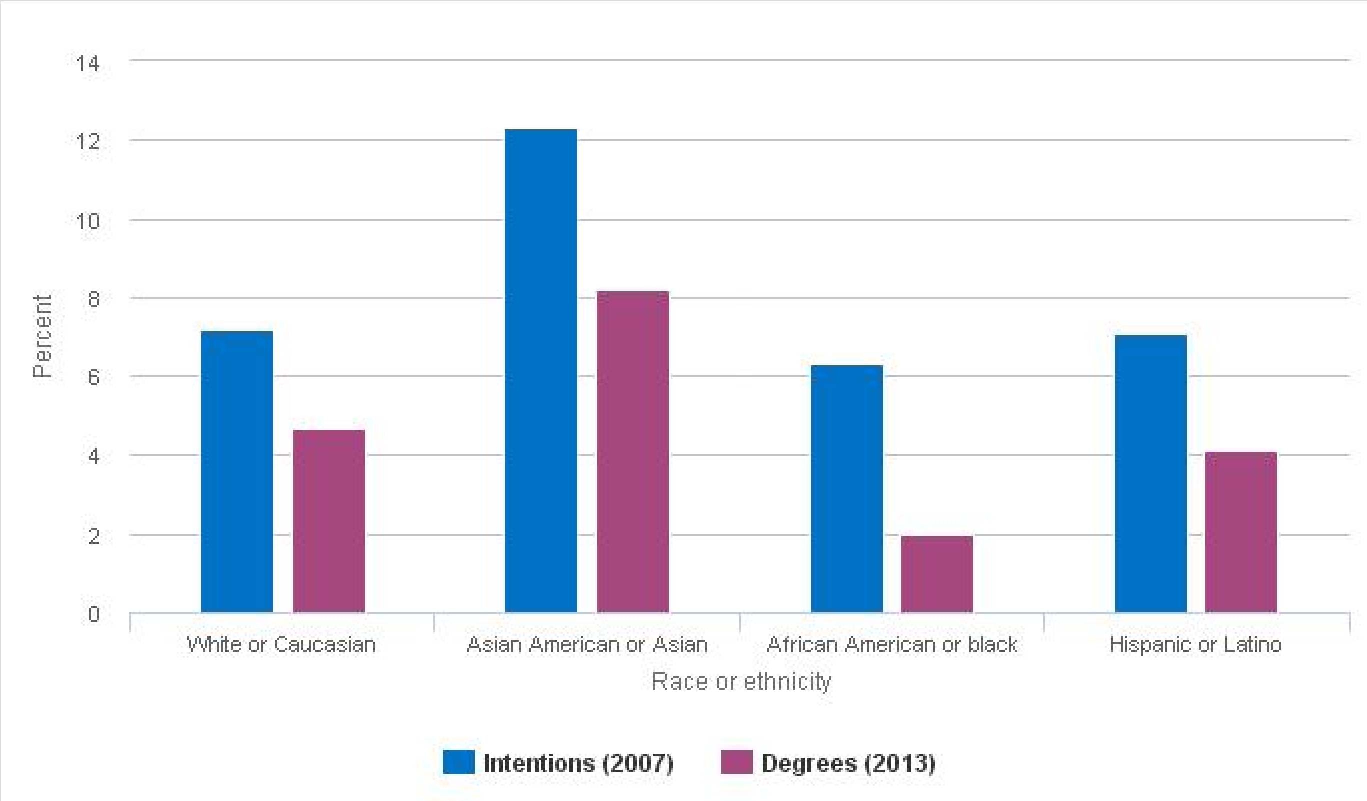
NOTE: Degrees do not reflect the same student cohort.

SOURCES: Higher Education Research Institute, University of California, Los Angeles, special tabulations (2015) of The American Freshman: National Norms; National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey, 2013; National Science Foundation, National Center for Science and Engineering Statistics, WebCASPAR database, http://webcaspar.nsf.gov.

Science and Engineering Indicators 2016

Figure 2-12

Engineering: Freshmen intentions and degrees, by race and ethnicity



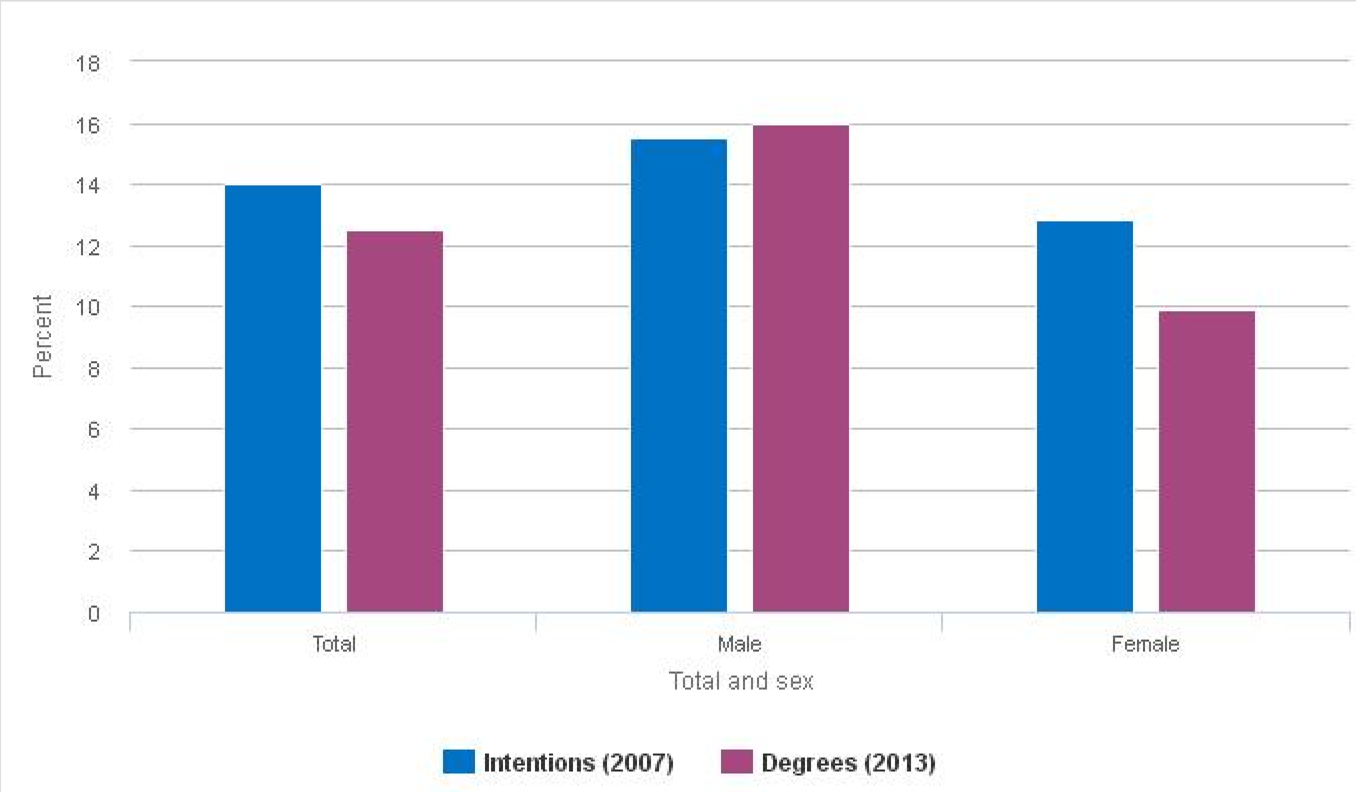
NOTES: Degrees do not reflect the same student cohort. Asian American or Asian includes Native Hawaiian or Pacific Islander.

SOURCES: Higher Education Research Institute, University of California, Los Angeles, special tabulations (2015) of The American Freshman: National Norms; National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey, 2013; National Science Foundation, National Center for Science and Engineering Statistics, WebCASPAR database, http://webcaspar.nsf.gov.

Science and Engineering Indicators 2016

Figure 2-13

Natural sciences: Freshmen intentions and degrees, by sex



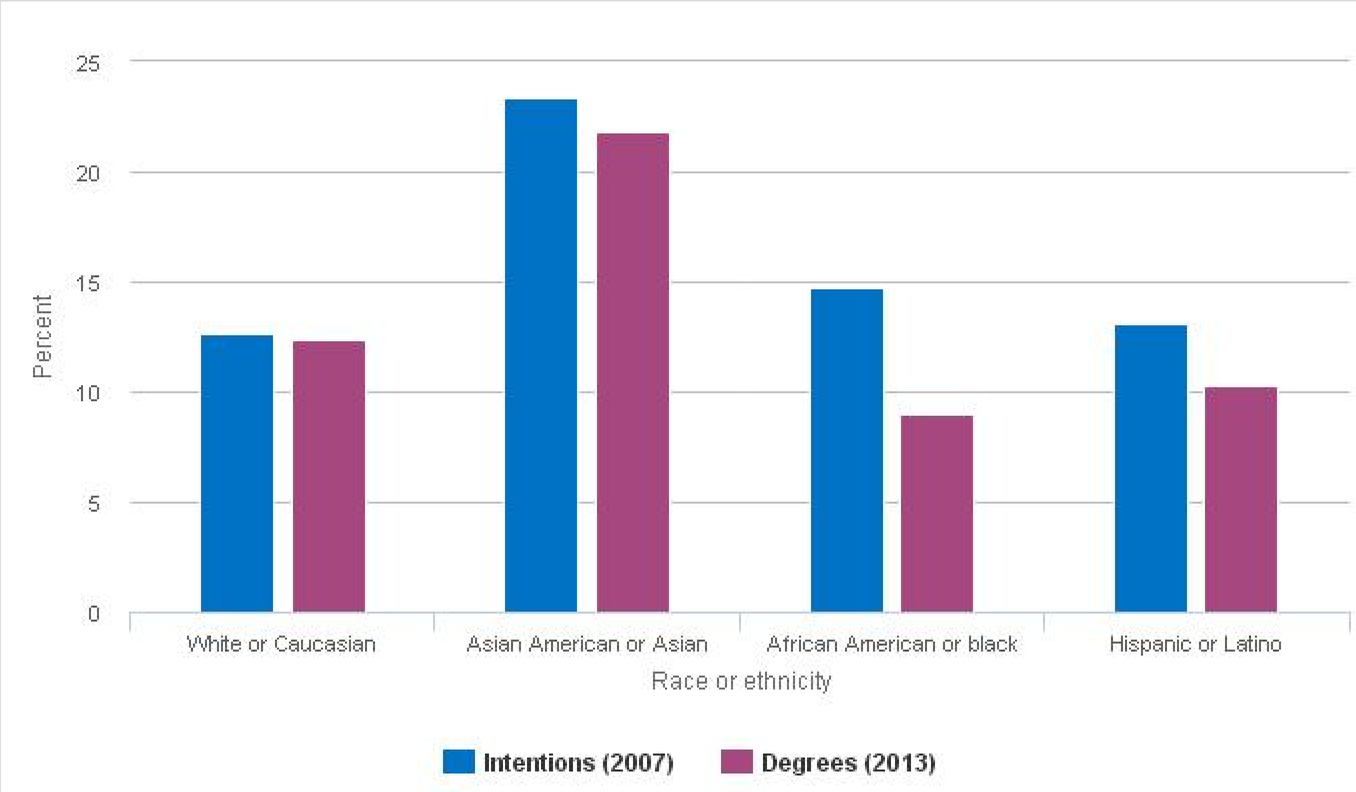
NOTE: Degrees do not reflect the same student cohort.

SOURCES: Higher Education Research Institute, University of California, Los Angeles, special tabulations (2015) of The American Freshman: National Norms; National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey, 2013; National Science Foundation, National Center for Science and Engineering Statistics, WebCASPAR database, http://webcaspar.nsf.gov.

Science and Engineering Indicators 2016

Figure 2-14

Natural sciences: Freshmen intentions and degrees, by race and ethnicity



NOTES: Degrees do not reflect the same student cohort. Asian American or Asian includes Native Hawaiian or Pacific Islander.

SOURCES: Higher Education Research Institute, University of California, Los Angeles, special tabulations (2015) of The American Freshman: National Norms; National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey, 2013; National Science Foundation, National Center for Science and Engineering Statistics, WebCASPAR database, http://webcaspar.nsf.gov.

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The demographic profile of students planning to major in S&E has become more diverse over time. The proportion of white students declined from about three-quarters in 1998 to less than two-thirds in 2014. On the other hand, in the same period, the proportion of Asian American or Asian students more than doubled to 18%, and the proportion of Hispanic students more than tripled, to 17%, in 2014. American Indian or Alaska Native and black students accounted for roughly 2% and 10%, respectively, of freshmen intending to major in S&E in both 1998 and 2014 (Appendix Table 2-19).

International undergraduate enrollment. In recent years, international undergraduate enrollment has been on the rise.[iv] In the 2013–14 academic year, the number of international students enrolled in undergraduate programs in U.S. academic institutions rose 9% from the previous year, to approximately 370,000 (IIE 2014). The number of international undergraduates enrolled in 2013–14 was 42% above the number in 2001–02 before the post-9/11 decline. New enrollments of international undergraduates in the 2013–14 academic year increased by 7% over the previous academic year. The countries that accounted for the largest numbers of international undergraduates enrolled in a U.S. institution in 2013–14 were China (111,000), South Korea (37,000), Saudi Arabia (27,000), Canada (14,000), India (13,000), and Vietnam (12,000). The numbers of undergraduates from Saudi Arabia increased by 30% over the previous year; the number of Chinese by 18%; the number of students from the United Kingdom by 11%; from Brazil, by 9%; and from Indonesia, 8%. The numbers of South Korean, Taiwanese, and Indian undergraduates decreased by 3%, 2%, and 1%, respectively. In 2013–14, among all international students (undergraduate and graduate), the number of those studying mathematics and computer sciences increased by 18% over the preceding year, the number of those studying engineering increased by 10%, and the number of those studying social sciences increased by 7%. The number of those studying physical and life sciences grew by 2% (IIE 2014).

More recent data from the Student and Exchange Visitor Information System (SEVIS) at the Department of Homeland Security show a substantial increase in international undergraduate enrollment in the United States between November 2013 and November 2014 (Table 2-11; Appendix Table 2-20).[v] This increase reflects a larger influx of international students in the United States, and because of the way these data are collected, the increase may also reflect a larger portion of international students staying in the United States to pursue another degree.[vi] The increase in international enrollment was higher in S&E (14%) than in non-S&E fields (7%). A growing proportion of foreign undergraduates enrolled come to study in S&E fields, from 29% in 2008 to 37% in 2014. Within S&E, the largest increases were in engineering and computer sciences. The top five countries of origin of international S&E undergraduate students in fall 2014 (China, Saudi Arabia, South Korea, India, and Kuwait) were similar to those in the preceding year (Appendix Table 2-20). In 2014, the proportion of undergraduate students enrolled in S&E fields was 50% or higher among students from Kuwait, Oman, Malaysia, India, Nepal, and Nigeria.[vii] Between 2008 and 2011, international S&E enrollment at the undergraduate level increased each year by about 6%–10%, with the growth rate spiking in 2012 (21%). In the last 2 years, the growth rate was lower but remained high (12% in 2013 and 14% in 2014) (Table 2-11). About 45% of the growth in international undergraduate enrollment in the last year, both in S&E and non-S&E fields, is accounted for by the increase in the number of students from China.

[iv] The data in this section come from the Institute of International Education (IIE) and the Student and Exchange Visitor Information System (SEVIS). IIE conducts an annual survey of about 3,000 accredited U.S. higher education institutions. In this survey, an *international student* is defined as anyone studying at an institution of higher education in the United States on a temporary visa that allows academic coursework, primarily F and J visas. SEVIS collects administrative data, including the numbers of all international students enrolled in colleges and universities in the United States.

[v] The figures include active foreign national students on F-1 visas in the SEVIS database, excluding those participating in optional practical training (OPT). Students with F visas have the option of working in the United States by engaging in OPT, temporary employment directly related to the student's major area of study, either during or after completion of the degree program. Students can apply for 12 months of OPT at each level of education. Starting in 2008, students in certain STEM fields became eligible for an additional 17 months of OPT. The number of students in OPT varies according to labor market conditions. According to data from SEVIS, the number of students with F-1 visas in OPT declined sharply between November 2010 and November 2011 and rose back up steeply by November 2012 (68,510 in November 2010, 22,820 in November 2011, and 80,680 in November 2012).

[vi] For example, an international student who is about to earn a bachelor's degree and stays in the United States to pursue a graduate degree would remain in the SEVIS database. It is not possible to determine the extent to which international students stay to pursue another degree because of the way the data are collected.

[vii] These data include international students pursuing both bachelor's and associate's degrees. Comparable data for U.S. citizen and permanent resident students do not exist. However, the proportion of S&E associate's and bachelor's degree awards earned by U.S. citizens and permanent residents is considerably lower.

Table 2-11 **International students enrolled in U.S. higher education institutions, by broad field and academic level: 2008–14**

Field and level	2008	2009	2010	2011	2012	2013	2014
All fields							
All levels	526,570	525,680	537,650	574,360	635,650	676,280	750,360
Undergraduate	266,320	272,980	284,770	297,950	351,030	373,740	407,810
Graduate	260,260	252,710	252,890	276,400	284,620	302,540	342,540
S&E fields							
All levels	229,010	229,230	235,990	260,280	280,020	307,480	358,100
Undergraduate	76,780	81,110	87,590	96,400	116,640	130,990	149,090
Graduate	152,230	148,120	148,400	163,880	163,390	176,490	209,020
Non-S&E fields							
All levels	297,560	296,460	301,670	314,080	355,630	368,810	392,250
Undergraduate	189,530	191,870	197,180	201,560	234,390	242,750	258,730
Graduate	108,030	104,590	104,490	112,520	121,240	126,060	133,530

NOTES: Data include active foreign national students on F-1 visas and exclude those on optional practical training. Undergraduate level includes associate's and bachelor's degrees; graduate level includes master's and doctoral degrees. Numbers are rounded to the nearest 10. Detail may not add to total because of rounding.

SOURCE: U.S. Department of Homeland Security, U.S. Immigration and Customs Enforcement, special tabulations (2014) of the Student and Exchange Visitor Information System database.

Science and Engineering Indicators 2016

Engineering enrollment. For the most part, students do not declare majors until their sophomore year. Because of this, undergraduate enrollment data for domestic students are not available by field. However, engineering is an exception. Engineering programs generally require students to declare a major or an intent to major in the first year of college, so engineering enrollment data can serve as an early indicator of both future undergraduate engineering degrees and student interest in engineering careers. The Engineering Workforce Commission administers an annual fall survey that tracks enrollment in undergraduate and graduate engineering programs (EWC 2014).

Undergraduate engineering enrollment was flat in the late 1990s, increased from 2000 to 2003, declined slightly through 2006, rose steadily to a peak of 544,000 in 2012, and declined slightly to 542,000 in 2013 (Appendix Table 2-21). The number of undergraduate engineering students increased by 34% between 2006 and 2013. Full-time freshman enrollment followed a similar pattern, reaching 131,000 in 2012, the highest since 1982, but declining slightly in 2013. These trends correspond with declines in the college-age population through the mid-1990s, particularly the drop in white 20–24-year-olds, who account for the majority of engineering students (NSF/NCSES 2015c).

Enrollment by disability status. According to the most recent available estimates, 11% of undergraduate students reported a disability in 2012 (NSF/NCSES 2015c).[viii] Undergraduates with disabilities were older than those without disabilities and were somewhat more likely to attend a 2-year institution. About one in four undergraduates with a disability was in an S&E field, a similar proportion among undergraduates without disabilities, and there were no major differences in field distribution at the broad field level.

[viii] See (NSF/NCSES 2015c, tables 2-6 and 2-7; Figure 1-E).

Undergraduate Degree Awards

The number of undergraduate degrees awarded by U.S. academic institutions has been increasing over the past two decades in S&E and non-S&E fields. According to projections from the U.S. Department of Education, these trends are expected to continue at least through 2022 (Hussar and Bailey 2014).

S&E Associate's Degrees

Community colleges often are an important and relatively inexpensive gateway for students entering higher education. Associate's degrees, largely offered by 2-year programs at community colleges, are the terminal degree for some, but others continue their education at 4-year colleges or universities and subsequently earn higher degrees. About 18% of recent S&E bachelor's degree holders in 2013—those who had earned their degree between academic years 2006–07 and 2010–11—had previously earned an associate's degree.[i] Many who transfer to baccalaureate-granting institutions do not earn associate's degrees before transferring; they may be able to transfer credit for specific courses.[ii]

In 2013, 86,000 out of more than 1 million associate's degrees were in S&E fields. S&E associate's degrees from all types of academic institutions have been rising continuously since 2000, after a steep decline between 2003 and 2007. The overall trend mirrors the pattern of computer sciences, which account for a large portion of S&E associate's degrees and peaked in 2003, declined through 2007, and increased through 2012.[iii]

The number of associate's degrees in S&E technologies, not included in S&E degree totals because of their applied focus, has nearly doubled since 2000. In 2013, nearly 157,000 associate's degrees were in S&E technologies. Associate's degrees in these fields accounted for 15% of all associate's degrees in 2013; this proportion has ranged between 13% and 16% since 2000. Nearly three-quarters of the associate's degrees in S&E technologies are in health technologies, and close to one-quarter are in engineering technologies. The proportion of associate's degrees in engineering technologies, however, has declined from 48% of all S&E technologies degrees in 2000 to 24% in 2013 (or from 7% of all associate's degrees to 4%), whereas the proportion of associate's degrees in health technologies has increased from 50% in 2000 to 74% in 2013 (or from 7% of all associate's degrees to 11%).

Women have earned between 60% and 62% of all associate's degrees awarded between 2000 and 2013 (Appendix Table 2-22). The proportion of women earning S&E associate's degrees, however, declined from 48% in 2000 to 43% in 2013. Most of the decline is attributable to a decrease in women's share of computer sciences associate's degrees, which dropped continuously from 42% in 2000 to 21% in 2013.

Students from underrepresented minority groups (blacks, Hispanics, and American Indians and Alaska Natives) earn a higher proportion of associate's degrees than of bachelor's or more advanced degrees, both in S&E fields and in all fields.[iv] (See the "S&E Bachelor's Degrees by Race and Ethnicity" and "S&E Doctoral Degrees by Race and Ethnicity" sections.) In 2013, underrepresented minorities earned 31% of S&E associate's degrees—more than one-third of all associate's degrees in social and behavioral sciences and biological sciences; about 30% of those in physical sciences, mathematics, and computer sciences; and 24% of those in engineering (Appendix Table 2-23).

S&E Bachelor's Degrees

The baccalaureate is the most prevalent S&E degree, accounting for nearly 70% of all S&E degrees awarded. S&E bachelor's degrees have consistently accounted for roughly one-third of all bachelor's degrees for at least the past 15 years. The number of S&E bachelor's degrees awarded rose steadily from about 400,000 in 2000 to more than 615,000 in 2013 (Appendix Table 2-17).[v]

In the last decade, the number of bachelor's degrees awarded increased fairly consistently, although to different extents, in all S&E fields. The exception was computer sciences, where the number increased sharply from 2000 to 2004, dropped as sharply through 2009, but increased again since then (Figure 2-15; Appendix Table 2-17).

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[i] Based on a special tabulation of the 2013 NSCG. A recent graduate is a respondent who received his or her most recent degree between 1 July 2006 and 30 June 2011.

[ii] Some credentials in the form of certificates take up to a year or less to complete. The most recent research on licenses and certification from the U.S. Census Bureau's Survey of Income and Program Participation shows that the vast majority of these types of credentials are in health care, education, and trades; business/finance management; legal/social services; and other non-S&E fields. Only 2% of the licenses and certifications are in S&E, specifically in computer sciences (Ewert and Kominski 2014).

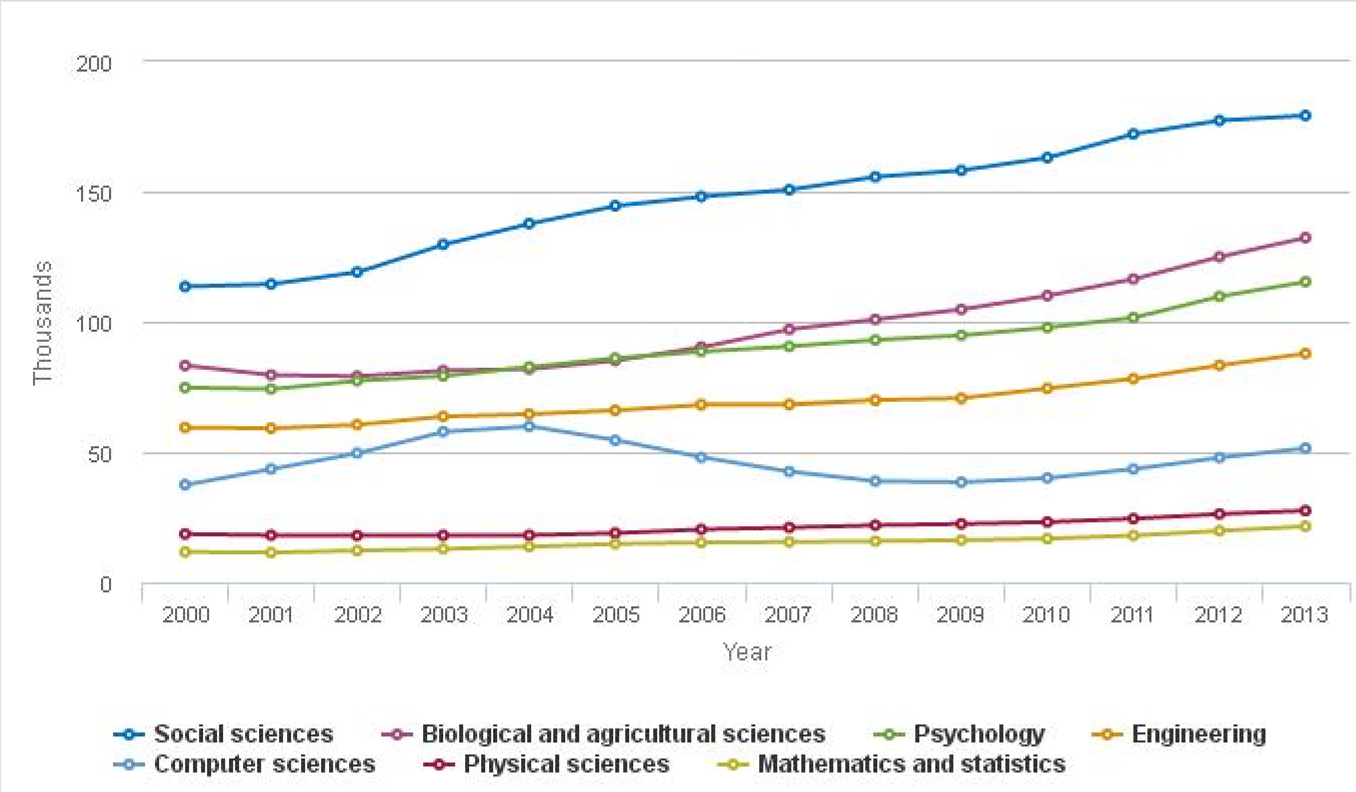
[iii] Data on degree completion from the NCES were obtained from WebCASPAR (https://webcaspar.nsf.gov/). Data uploaded in WebCASPAR correspond to NCES provisional data, which undergo all NCES data quality control procedures and are imputed for nonresponding institutions. These data are used by NCES in its First Look (Provisional Data) publications.

[iv] Data for racial and ethnic groups are for U.S. citizens and permanent residents only.

[v] Data on degree completion from NCES were obtained from WebCASPAR (https://webcaspar.nsf.gov/). Data uploaded in WebCASPAR correspond to NCES provisional data, which undergo all NCES data quality control procedures and are imputed for nonresponding institutions. These data are used by NCES in its First Look (Provisional Data) publications.

Figure 2-15

S&E bachelor's degrees, by field: 2000–13



NOTE: Physical sciences include earth, atmospheric, and ocean sciences.

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; National Science Foundation, National Center for Science and Engineering Statistics, WebCASPAR database, http://webcaspar.nsf.gov.

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S&E bachelor's degrees by sex. Since 1982, women have outnumbered men in undergraduate education. They have earned relatively constant fractions of all bachelor's and S&E bachelor's degrees for several years. Since the late 1990s, women have earned about 57% of all bachelor's degrees and about half of all S&E bachelor's degrees. Among U.S. citizens and permanent residents, women also earn about half of all S&E bachelor's degrees (NSF/NCSES 2015c).

Men and women tend to study different fields; these tendencies are also observed at the master's and doctoral levels, as will be seen below and in the workforce data in chapter 3. In 2013, men earned the vast majority of bachelor's degrees awarded in engineering, computer sciences, and physics and more than half of the degrees in mathematics and statistics. Women earned half or more of the bachelor's degrees in psychology, biological sciences, agricultural sciences, and all the broad fields within social sciences except for economics (Appendix Table 2-17).

Since 2000, changes have not followed a consistent pattern. The share of bachelor's degrees awarded to women declined in computer sciences (by 10%) (see sidebar, Retention of Women in Computer Sciences Programs), mathematics and statistics (by 5%), physics (by 3%), and engineering (by 1%) (Figure 2-16; Appendix Table 2-17). Fields in which the proportion of bachelor's degrees awarded to women grew during this period include atmospheric sciences (by 10%); agricultural sciences (by 7%); anthropology (by 4%); and astronomy, area and ethnic studies, and political science and public administration (by 2% each) (Appendix Table 2-17).

Retention of Women in Computer Sciences Programs

In the last two decades, the proportion of women earning bachelor's degrees in computer sciences has declined from 28% to 18% (NSF/NCSES 2015c), even though the proportion of freshmen women declaring a computer sciences major when first enrolled in a 4-year institution has remained stable (at about 20% in recent years).* Several studies have attempted to identify possible factors that affect retention of women in computer sciences departments (Margolis and Fisher 2002; Cohoon and Aspray 2006). One nationwide study concluded that departmental environment had measurable consequences on the gender composition of enrolled students and the likelihood that women who declared a computer science major would remain in the program at rates comparable to their male classmates (Cohoon 2006).[†] The study statistically controlled for a range of characteristics across the programs under study that are likely to affect retention, including size, highest degree level offered, geographic location, and administrative type of institution.

The study concluded that the most important factor was the ability to rely on same-sex peer support, measured by the proportion of enrolled women. Findings from focus group research suggested that women preferred to ask questions and get help from female classmates. Women's retention rates were higher in departments with higher proportions of female students, suggesting greater ease in drawing on the support of same-sex peers. In addition, three factors related to faculty characteristics were important. Broad faculty encouragement of women to persist in this male-dominated field was important, as was faculty mentoring if it aimed explicitly at overcoming underrepresentation. Faculty concern over insufficient staffing—especially prevalent in public institutions in the post dot-com boom period—was related to higher female attrition. Finally, high demand from faculty (e.g., expectation of long hours of study, extensive homework assignments, and limited extracurricular activities) was related to lower rates of women's attrition.

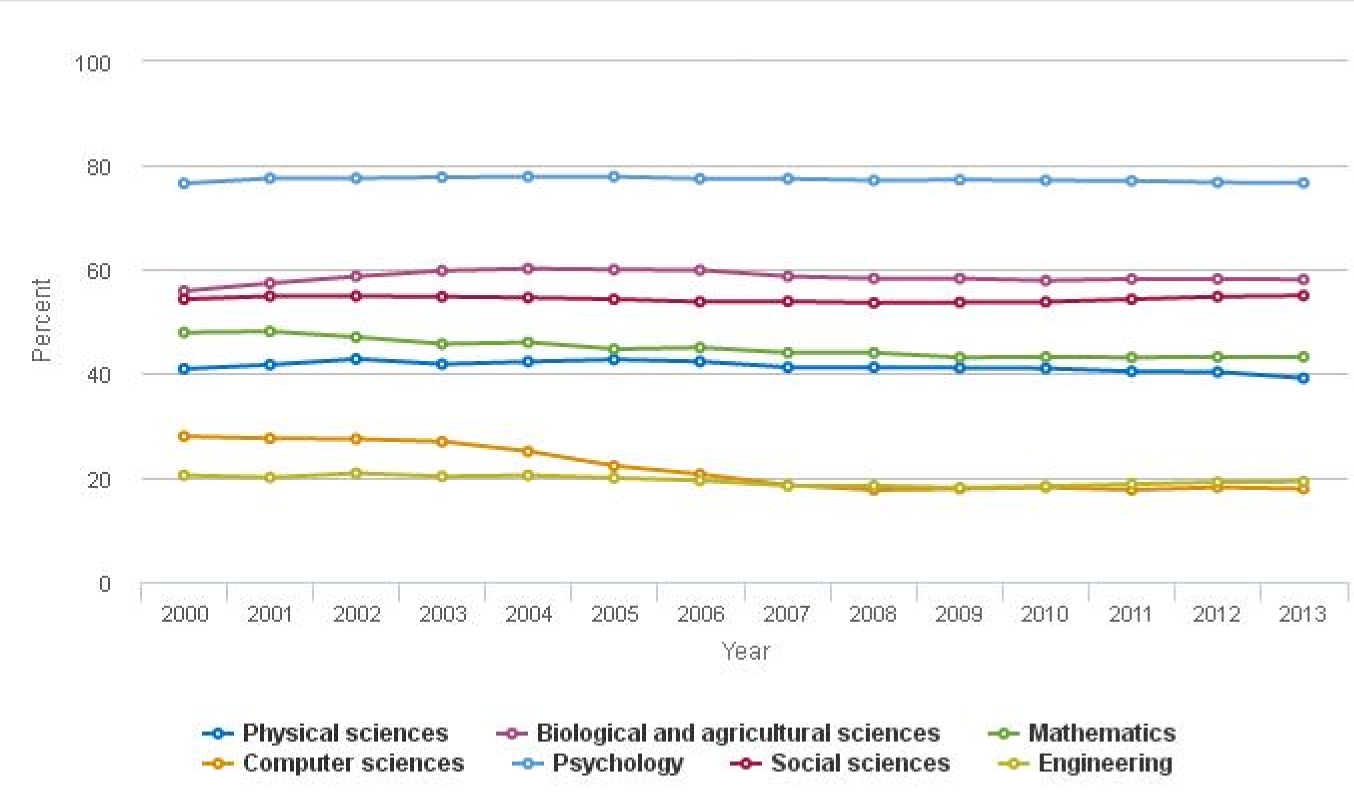
Recent nationally representative data on factors that are important for retention are not available. However, some computer science departments have shown success in increasing recruitment and retention of women. For example, the computer science department at Harvey Mudd College has succeeded in increasing the proportion of women computer science majors from 12% in 2005 to around 35% to 40% in recent years, as had the Carnegie Mellon University computer science department in the early 2000s. The strategies implemented included, but were not limited to, expanding the required first-year computer science courses to include social impacts of computer science and creative, real-world applications; providing summer research opportunities for women after their first year; and increasing the number of women computer science faculty members (DuBow et al. 2012; Miller 2014).

* Special tabulations, Beginning Postsecondary Students Longitudinal Study, Second Follow-up (BPS:96/01 and BPS:04/09)

[†] The study first conducted interviews and focus groups at 18 undergraduate computer science departments that varied by region, institution type, highest degree granted, reputation, and sex composition. The results of the focus groups were then used to design a survey of faculty and chairs in 209 largest or most highly ranked computer science departments in the United States. The study relied on official enrollment and disposition data to calculate attrition rates of males and females.

Figure 2-16

Women's share of S&E bachelor's degrees, by field: 2000–13



NOTE: Physical sciences include earth, atmospheric, and ocean sciences.

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; National Science Foundation, National Center for Science and Engineering Statistics, WebCASPAR database, http://webcaspar.nsf.gov.

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S&E bachelor's degrees by race and ethnicity. The racial and ethnic composition of the cohort of S&E bachelor's degree recipients has changed over time, reflecting population changes and increasing rates of college attendance by members of minority groups.[vi] Between 2000 and 2013, the share of S&E degrees, but not the number, earned by white students among U.S. citizens and permanent residents declined from 71% to 62% (Figure 2-17; Appendix Table 2-18). The share awarded to Hispanic students increased from 7% to 11%. The shares awarded to Asian and Pacific Islander (9%), black (9%), and American Indian or Alaska Native students (1%) have remained flat since 2000. The number of S&E bachelor's degrees earned by students of other or unknown race or ethnicity nearly tripled in this period, to about 44,000 in 2013 (about 7% of all S&E bachelor's recipients), suggesting that the specific percentages just cited are best viewed as approximations.[vii]

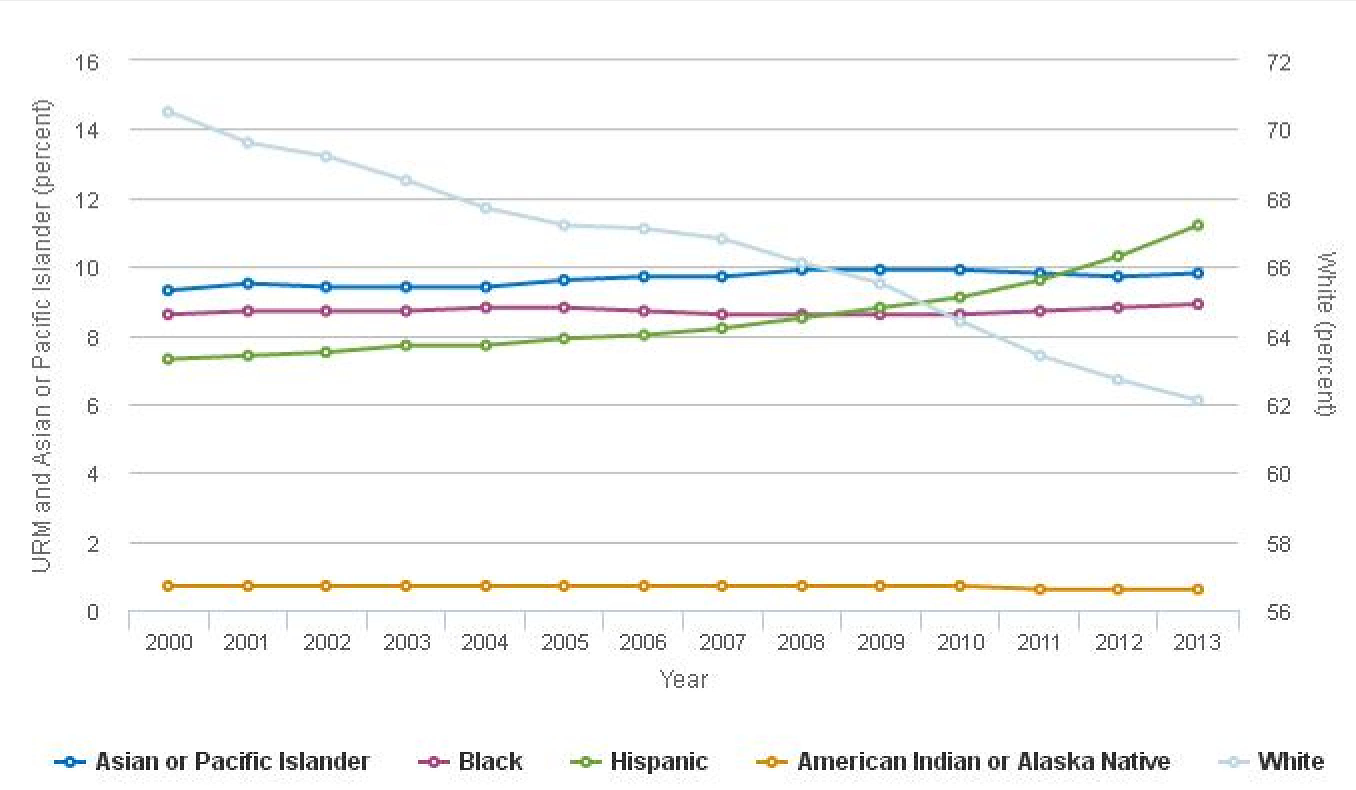
[vi] Data for racial and ethnic groups are for U.S. citizens and permanent residents only.

[vii] In 2011, institutions in IPEDS were required to report race and ethnicity in the categories mandated by the U.S. Office of Management and Budget effective 1 January 2003. So for the first time, the 2011 Completions Survey provides data on degree recipients of multiple races. In the appendix tables, this category is included under "other

or unknown race or ethnicity” because institutions were not required to update the race and ethnicity data of individuals who were already in the system; therefore, the number is likely to be an undercount. Of the 44,159 S&E bachelor’s degrees earned by individuals in the “other or unknown race or ethnicity” category, 12,149 are of multiple race (special tabulations from WebCASPAR).

Figure 2-17

Share of S&E bachelor's degrees among U.S. citizens and permanent residents, by race and ethnicity: 2000–13



URM = underrepresented minorities (black, Hispanic, and American Indian or Alaska Native).

NOTES: Hispanic may be any race. American Indian or Alaska Native, Asian or Pacific Islander, black, and white refer to individuals who are not of Hispanic origin. Percentages do not add to 100% because data do not include individuals who did not report their race and ethnicity.

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; National Science Foundation, National Center for Science and Engineering Statistics, WebCASPAR database, http://webcaspar.nsf. gov.

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The gap in educational attainment at the bachelor's level between young minorities and whites continues to be wide, despite considerable progress for underrepresented minority groups over the past two decades. From 1980 to 2014, the percentage of the population ages 25–29 with bachelor's or higher degrees changed from 12% to 22% for blacks, 8% to 15% for Hispanics, and 25% to 41% for whites (NCES 2015). Continuing differences in completion of S&E bachelor's degrees reflect lower rates of high school completion, college enrollment, and college persistence and attainment by blacks, Hispanics, and American Indians and Alaska Natives. (For information on immediate post–high school college enrollment rates, see the Transition to Higher Education section in chapter 1.)

Among those who do graduate from college, blacks, Hispanics, and American Indians and Alaska Natives are about as likely as whites to earn bachelor's degrees in S&E fields. Asians or Pacific Islanders are far more likely to earn an S&E bachelor's degree than any other group. S&E degrees make up almost half of all degrees for Asians and Pacific

Islanders, compared with about one-third of all bachelor's degrees earned by each of the other racial and ethnic groups. However, Asians and Pacific Islanders earn degrees in the social and behavioral sciences at rates similar to those of other groups (Appendix Table 2-18).

The contrast in field distribution among whites, blacks, Hispanics, and American Indians and Alaska Natives on the one hand and Asians and Pacific Islanders on the other is apparent in S&E. White, black, Hispanic, and American Indian or Alaska Native S&E baccalaureate recipients share a similar distribution across broad S&E fields. In 2013, between 9% and 12% of all baccalaureate recipients in each of these racial and ethnic groups earned their degrees in the natural sciences and 2%–5% in engineering. Asian and Pacific Islander baccalaureate recipients earned 22% of their bachelor's degrees in the natural sciences and 8% in engineering (Appendix Table 2-23).

Since 2000, the total number of bachelor's degrees and the number of S&E bachelor's degrees rose for all racial and ethnic groups. The number of bachelor's degrees in all broad S&E fields except computer sciences also rose for most racial and ethnic groups (Appendix Table 2-18). In all racial and ethnic groups, the number of degrees in computer sciences followed the pattern for the general population: it increased considerably through 2003–04 and then sharply declined through 2008–09. In the last 2 or 3 years, the numbers started to increase, and in the case of Hispanics, the number of earned bachelor's degrees in computer sciences in 2013 was 26% above the peak reached in 2004.[viii]

S&E bachelor's degrees by citizenship. Students on temporary visas in the United States have consistently earned a small share (about 4%) of S&E degrees at the bachelor's level. In 2013, these students earned a larger share of bachelor's degrees awarded in economics and in chemical, electrical, and industrial engineering (10%–15%). The number of S&E bachelor's degrees awarded to students on temporary visas increased from about 15,000 in 2000 to about 19,000 in 2004, then declined to nearly 17,000 by 2008, but it increased through 2013, peaking at almost 27,000 (appendix table 2-18).

[viii] For patterns on S&E bachelor's degrees awarded to minority men and minority women, see (NSF/NCSES 2015c).

Graduate Education, Enrollment, and Degrees in the United States

Graduate education in S&E contributes to global competitiveness, producing the highly skilled workers of the future and the research needed for a knowledge-based economy. This section includes indicators related to U.S. graduate enrollment; recent trends in the number of advanced degrees in S&E fields; and the participation by women, minorities, and international students in graduate education in U.S. academic institutions.

Graduate Enrollment by Field

S&E graduate enrollment in the United States increased by 25% between 2000 and 2013, to more than 615,000 (Appendix Table 2-24).[i] Most of the growth occurred in the 2000s; since 2008, graduate enrollment in S&E has been fairly stable. In the period between 2000 and 2013, graduate enrollment grew considerably in most S&E fields, particularly in engineering and in the biological sciences, where enrollment has reached record numbers and risen faster than enrollment for all S&E fields. Three-quarters of the graduate students in engineering were enrolled full time in 2013, up from 69% in 2000.[ii]

Enrollment has also grown in the social sciences (where most of the growth is accounted for by the increase of graduate enrollment in political science and public administration). Graduate enrollment in computer sciences grew rapidly in the early 2000s, then decreased through 2006, but it has generally increased since then.

The number of full-time students enrolled for the first time in S&E graduate departments is an indicator of developing trends. First-time, full-time graduate enrollees are typically students pursuing a master's or a doctoral degree right after or within about a year after earning their undergraduate degrees. This indicator can be sensitive to economic conditions; for example, high unemployment tends to lead to an increase in first-time, full-time graduate enrollment. Despite some drops in first-time, full-time enrollment in engineering and computer sciences in the early to mid-2000s, this indicator has increased fairly steadily in most broad S&E fields. In 2013, the number of first-time, full-time S&E graduate students reached a new peak in both of these fields (Appendix Table 2-25).

Graduate Enrollment by Sex

In 2013, 45% of the S&E graduate students enrolled in the United States were women (Appendix Table 2-24). The proportions of female graduate students enrolled in S&E differed considerably by field, with the lowest proportions in engineering, computer sciences, and physical sciences (particularly in physics). Women constituted the majority of graduate students in psychology, medical and other health sciences, biological sciences, and social sciences, and they represented half or close to half of graduate students in agricultural sciences and earth, atmospheric, and ocean sciences. Among the social sciences, economics has an unusually low proportion of women. Between 2000 and 2013, the proportion of women enrolled increased in most broad S&E fields except for computer sciences and mathematics. The proportion of women enrolled in graduate programs in computer sciences peaked in 2000 and declined through 2011 but increased slightly in the last 2 years. In mathematics and statistics, the proportion of women peaked in 2000 and has declined slightly and gradually since then.

Graduate Enrollment of Underrepresented Groups

In 2013, among U.S. citizens and permanent residents, underrepresented minority students (blacks, Hispanics, and American Indians and Alaska Natives) accounted for 18% of students enrolled in graduate S&E programs (Appendix Table 2-26).[iii] The proportion of underrepresented minorities was highest in psychology and the social sciences (23%), medical and other health sciences (20%), and computer sciences (16%); it was lowest in the earth, atmospheric, and ocean sciences (9%) and in the physical sciences (11%). Between 2000 and 2013, the proportion of underrepresented minorities enrolled has increased in all broad S&E fields, particularly in computer sciences and psychology.

In 2013, whites accounted for about 64% of S&E graduate enrollment among U.S. citizens and permanent residents. They constituted a larger proportion of graduate students enrolled in agricultural sciences and in earth, atmospheric, and ocean sciences (about 80%) and a smaller proportion of those enrolled in computer sciences and social sciences (about 60%). The proportions of whites in other fields fell in between. Over time, however, the proportion of whites among graduates enrolled in S&E has declined in all broad S&E fields except for computer sciences, where the proportion of whites has been fairly stable.

Asians and Pacific Islanders accounted for 9% of S&E graduate enrollment among U.S. citizens and permanent residents in 2013, with larger proportions in computer sciences (15%), engineering (13%), and the biological and medical sciences (about 11% each), as well as a lower proportion in the agricultural sciences (4%); earth, atmospheric, and ocean sciences (4%); psychology (5%); and the social sciences (6%). Between 2000 and 2013, the proportion of Asians and Pacific Islanders enrolled increased slightly in most broad fields, but it declined in computer sciences (from 21% in 2000 to 15% in 2013).

About 20% of graduate students reporting a disability were enrolled in S&E fields. About 60% of those enrolled in S&E fields and reporting a disability were women, and about 90% were 24 years old or older (NSF/NCSES 2015c).

Graduate Enrollment of International Students

In recent years, enrollment of international students in S&E fields has been on the rise while overall graduate enrollment has remained flat (NSF/NCSES 2014). In 2013, nearly 200,000 international students on temporary visas were enrolled in S&E graduate programs (Appendix Table 2-26). The concentration of international enrollment was highest in computer sciences, engineering, physical sciences, mathematics and statistics, and economics.[iv]

After a post-9/11 decline, the numbers of first-time, full-time international graduate students enrolled increased more or less consistently in most broad fields through 2013 (Appendix Table 2-25). Declines and subsequent increases in number were concentrated in engineering and computer sciences, the fields heavily favored by international students. Between 2000 and 2013, international students' share of first-time, full-time S&E graduate enrollment increased in most broad fields, except for the physical sciences (from 43% to 38%), the biological sciences (from 24% to 21%), and the social sciences (from 29% to 27%).

According to data collected by IIE, the overall number of international graduate students in all fields increased by 6% from academic years 2012–13 to 2013–14 (IIE 2014). The number of international graduate students enrolling for the first time in a U.S. institution in fall 2013 increased by 8%. China, India, South Korea, Canada, Saudi Arabia, and Taiwan were the top originating locations for international graduate students, similar to the leading international sources of undergraduate enrollment.

More recent data from SEVIS show an overall 13% increase in international graduate students from November 2013 to November 2014 in all fields (Table 2-11; Appendix Table 2-27).[v] As stated previously, this increase reflects a larger influx of international students in the United States, and because of the way these data are collected, the increase may also reflect a larger portion of international students staying in the United States to pursue another degree.[vi] In 2014, 61% of all international students in graduate programs at U.S. institutions were enrolled in S&E fields. Between fall 2013 and fall 2014, the number of international graduate students enrolled in S&E fields increased most in computer sciences and engineering, with both combined accounting for more than 75% of the total increase in international enrollment in this period. The top sending locations were India and China, accounting for 68% of the international S&E graduate students in the United States in late 2014, followed by Iran, South Korea, Saudi Arabia, and Taiwan. More than 8 in 10 graduate students from Iran were enrolled in an S&E field, particularly in engineering. Graduate students from South Korea, Saudi Arabia, and Taiwan sent larger numbers of graduate students who enrolled in non-S&E than in S&E fields.

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[i] The Survey of Graduate Students and Postdoctorates in Science and Engineering (GSS) was redesigned in 2007. Because of methodological changes, the data collected from 2007 through 2010 are not strictly comparable with those collected before 2007. As a result, care should be used when assessing trends within the GSS data. Throughout the appendix tables in this chapter, "2007new" reports the data as collected in 2007, and "2007old" provides the data as they would have been collected in 2006. In addition, between 2008 and 2010, the survey conducted a more rigorous follow-up with institutions regarding the exclusion of practitioner-oriented graduate degree programs. Some or all of the declines in psychology and other health fields in 2008–10 are likely due to this increased effort to exclude practitioner-oriented graduate degree programs rather than changes in actual enrollments. Care should therefore be used when examining long-term trends. Because of this methodological change, in this section, "S&E" excludes psychology and other health fields. For a detailed discussion on the survey redesign, please see (NSF/SRS 2007, appendix A, "Technical Notes").

[ii] Special tabulation from the Graduate Student and Postdoctorates in Science and Engineering, available at https://ncsesdata.nsf.gov/webcaspar/ (10 August 2015).

[iii] For patterns on S&E graduate degrees awarded to minority men and minority women, see (NSF/NCSES 2015c).

[iv] See (NSF/NCSES 2015c) for more detail on enrollment of international students by sex.

[v] The data include active foreign national students on F-1 visas in the SEVIS database, excluding those on OPT (temporary employment directly related to the student's major area of study either during or after completing the degree program). See note 32.

[vi] For example, an international student who is about to earn a master's degree and stays in the United States to pursue a doctoral degree would remain in the SEVIS database. It is not possible to determine the extent to which international students stay to pursue another degree because of the way the data are collected.

Table 2-11 **International students enrolled in U.S. higher education institutions, by broad field and academic level: 2008–14**

Field and level	2008	2009	2010	2011	2012	2013	2014
All fields							
All levels	526,570	525,680	537,650	574,360	635,650	676,280	750,360
Undergraduate	266,320	272,980	284,770	297,950	351,030	373,740	407,810
Graduate	260,260	252,710	252,890	276,400	284,620	302,540	342,540
S&E fields							
All levels	229,010	229,230	235,990	260,280	280,020	307,480	358,100
Undergraduate	76,780	81,110	87,590	96,400	116,640	130,990	149,090
Graduate	152,230	148,120	148,400	163,880	163,390	176,490	209,020

Field and level	2008	2009	2010	2011	2012	2013	2014
Non-S&E fields							
All levels	297,560	296,460	301,670	314,080	355,630	368,810	392,250
Undergraduate	189,530	191,870	197,180	201,560	234,390	242,750	258,730
Graduate	108,030	104,590	104,490	112,520	121,240	126,060	133,530

NOTES: Data include active foreign national students on F-1 visas and exclude those on optional practical training. Undergraduate level includes associate's and bachelor's degrees; graduate level includes master's and doctoral degrees. Numbers are rounded to the nearest 10. Detail may not add to total because of rounding.

SOURCE: U.S. Department of Homeland Security, U.S. Immigration and Customs Enforcement, special tabulations (2014) of the Student and Exchange Visitor Information System database.

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S&E Master's Degrees

Master's degrees awarded in S&E fields increased from about 96,000 in 2000 to about 166,000 in 2013, with growth concentrated in two periods, 2002–04 and 2007–13 (Appendix Table 2-28).[i] Increases occurred in all major science fields. Master's degrees awarded in engineering and computer sciences declined between 2004 and 2007, but they have since increased. The number of master's degrees awarded in engineering and in computer sciences in 2013 was the highest in the last 14 years (Figure 2-18). During this period, growth was largest in engineering, psychology, and the social sciences (particularly in political science and public administration) (Appendix Table 2-28). In some fields, such as engineering and geosciences, a master's degree can fully prepare students for an established career track. In other fields, master's degrees primarily mark a step toward doctoral degrees.

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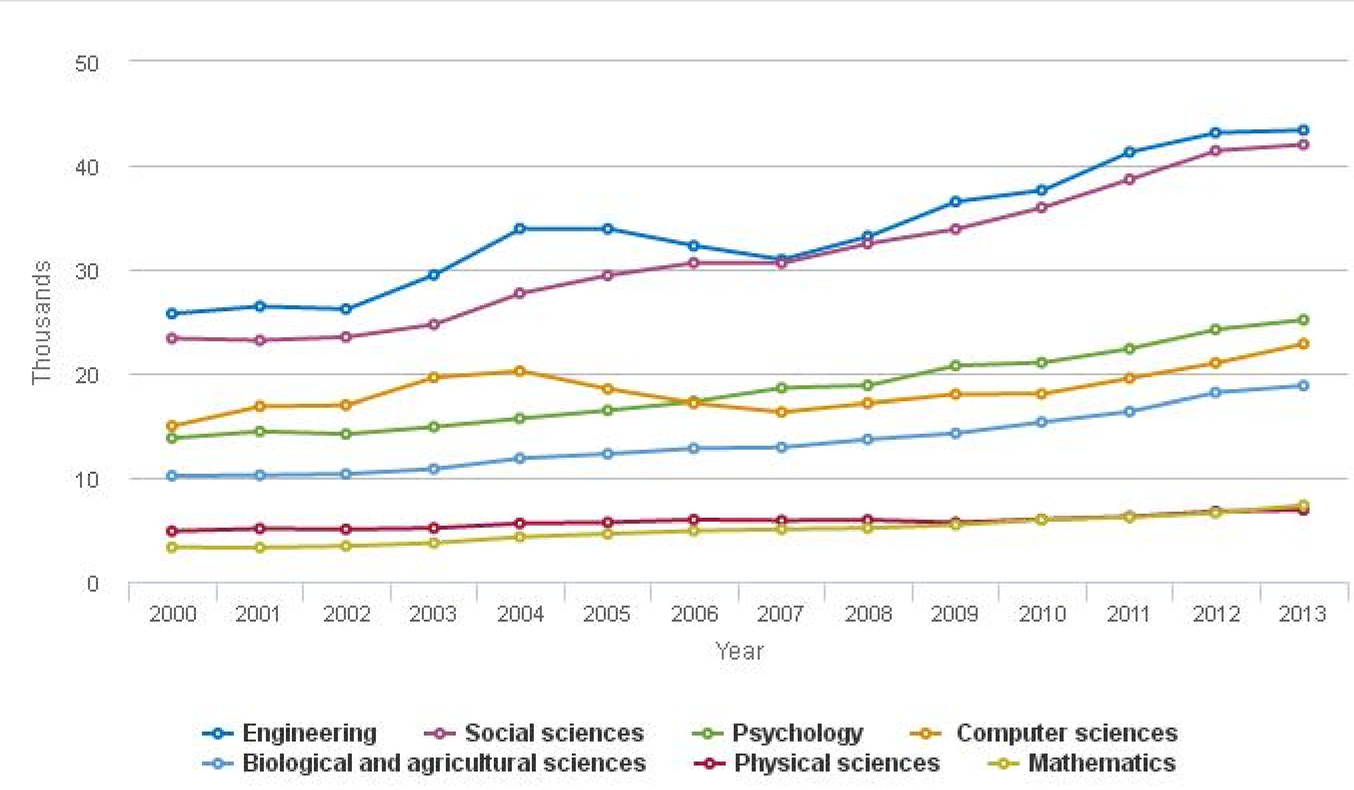
[i] Data on degree completion from NCES were obtained from WebCASPAR (https://webcaspar.nsf.gov/). Data uploaded in WebCASPAR correspond to NCES provisional data, which undergo all NCES data quality control procedures and are imputed for nonresponding institutions. These data are used by NCES in its First Look (Provisional Data) publications.

Figure 2-18

S&E master's degrees, by field: 2000–13



NOTE: Physical sciences include earth, atmospheric, and ocean sciences.

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; National Science Foundation, National Center for Science and Engineering Statistics, WebCASPAR database, http://webcaspar.nsf.gov.

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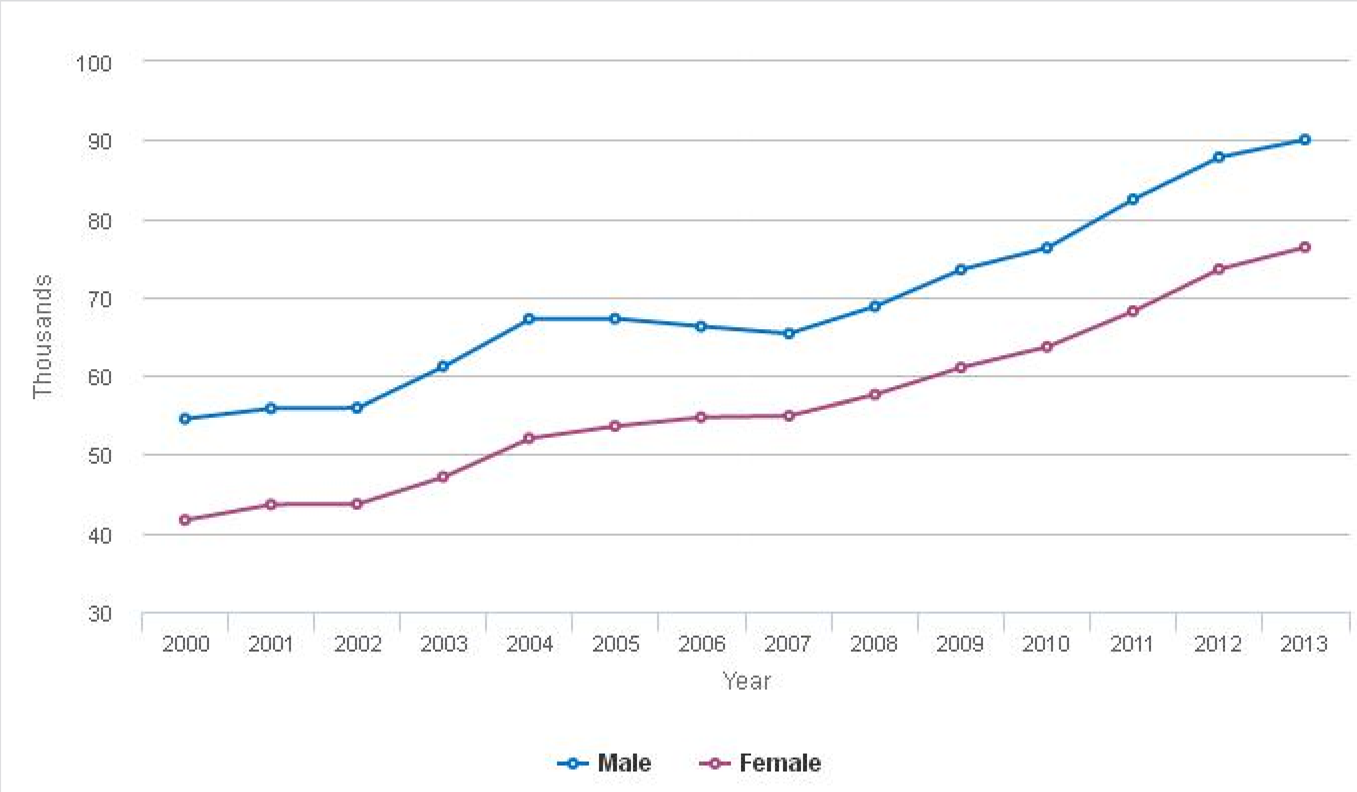
Professional Science Master's (PSM) programs, which stress interdisciplinary training, are a relatively new direction in graduate education. PSM degrees provide advanced training in an S&E field beyond the bachelor's degree level while also developing administrative and business skills that are valued by employers, such as leadership, project management, teamwork, and communication (for details on PSM degrees, see [NSB 2014:2–30]). As of April 2015, there were 334 PSM programs and 157 PSM-affiliated institutions (PSM 2015).

S&E Master's Degrees by Sex

The number of S&E master's degrees earned by both men and women rose between 2000 and 2013 (Figure 2-19). In 2000, women earned 43% of all S&E master's degrees; by 2013, they earned 46% (Appendix Table 2-28). Among U.S. citizens and permanent residents, women earned nearly half of all S&E master's degrees. However, among temporary residents, women earned slightly more than one-third of all S&E master's degrees (NSF/NCSES 2015c).

Figure 2-19

S&E master's degrees, by sex of recipient: 2000–13



SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; National Science Foundation, National Center for Science and Engineering Statistics, WebCASPAR database, http://webcaspar.nsf.gov.

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Women's share of S&E master's degrees varies widely by field. As with bachelor's degrees, in 2013, women earned a majority of master's degrees in psychology, biological sciences, agricultural sciences, and most social sciences except economics, but low proportions of master's degrees in engineering, computer sciences, and physics. The proportion of master's degrees in engineering earned by women in 2013, however, was slightly higher than in 2000 (Appendix Table 2-28).

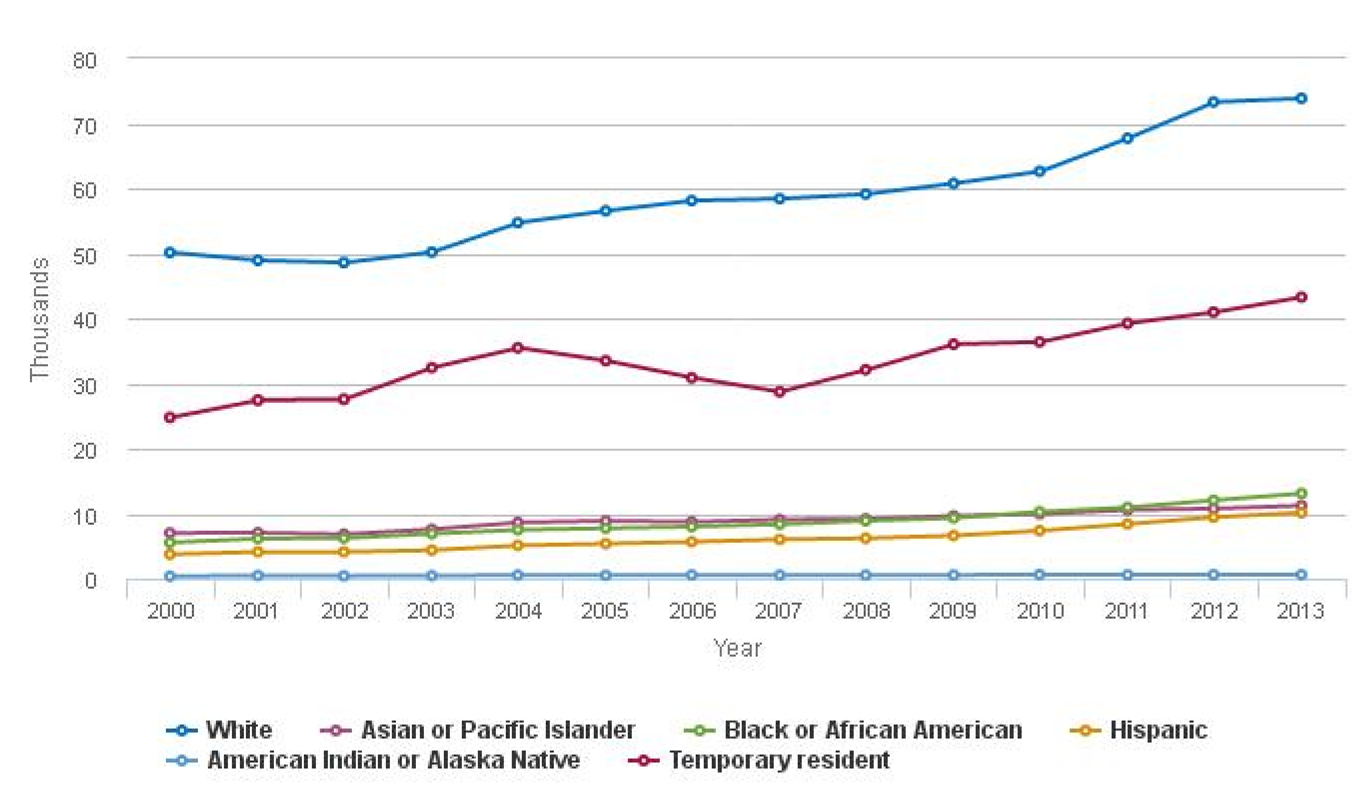
S&E Master's Degrees by Race and Ethnicity

The number of S&E master's degrees awarded to U.S. citizens and permanent residents increased for all racial and ethnic groups between 2000 and 2013 (Figure 2-20; Appendix Table 2-29).[ii]

[ii] Data for racial and ethnic groups are for U.S. citizens and permanent residents only.

Figure 2-20

S&E master's degrees, by race, ethnicity, and citizenship: 2000–13



NOTES: Data on race and ethnicity include U.S. citizens and permanent residents. Hispanic may be any race. American Indian or Alaska Native, Asian or Pacific Islander, black or African American, and white refer to individuals who are not of Hispanic origin.

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; National Science Foundation, National Center for Science and Engineering Statistics, WebCASPAR database, http://webcaspar.nsf.gov.

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The proportion of U.S. S&E master's degrees earned by underrepresented racial and ethnic minorities increased from 14% to 19% between 2000 and 2013; that earned by whites fell from 70% to 60%. The trends are not very different from those found in the data on bachelor's degree awards among racial and ethnic groups. Blacks accounted for 11% of S&E master's degree recipients in 2013, up from 8% in 2000; Hispanics accounted for 8%, up from 5%; and American Indians and Alaska Natives accounted for 0.5%, similar to the proportion in 2000. The proportion of Asian and Pacific Islander S&E recipients also remained flat in this period.[iii]

S&E Master's Degrees by Citizenship

The number of international master's students who earned an S&E degree increased from nearly 25,000 in 2000 to 43,000 in 2013. International students make up a much higher proportion of S&E master's degree recipients than of bachelor's or associate's degree recipients. In 2013, international students earned more than one-quarter of S&E master's degrees. Their degrees were heavily concentrated in computer sciences, economics, and engineering, where they received more than 4 out of 10 of all master's degrees awarded in 2013 (Appendix Table 2-29). Within engineering, students on temporary visas earned more than half of the master's degrees in electrical and chemical engineering.

The number of S&E master's degrees awarded to students on temporary visas reached its highest point in a decade in 2013 (43,000), after a sharp decline between 2004 and 2007. Most of the drop during this period was accounted for by decreasing numbers of temporary residents in the computer sciences and engineering fields, but in both fields, numbers rebounded by more than 50% in the following years.

[iii] For patterns on S&E master's degrees awarded to minority men and minority women, see (NSF/NCSES 2015c).

S&E Doctoral Degrees

Doctoral education in the United States generates new knowledge by closely linking specialized education and hands-on research experience. The results are important for the society as a whole and for U.S. competitiveness in a global knowledge-based economy. Doctoral education prepares a new generation of researchers in academia, industry, government, and nonprofits, as well as a highly skilled workforce for other sectors of the economy. Decades-long participation of large and growing numbers of temporary visa holders attests to the attractiveness of this model.

The number of S&E doctorates (excluding those in other health sciences[i]) conferred annually by U.S. universities increased steadily between 2002 and 2008, declined through 2010, and increased by 14% through 2013, to nearly 39,000 (Appendix Table 2-30).[ii] The growth in the number of S&E doctorates between 2000 and 2013 occurred among U.S. citizens and permanent residents as well as temporary visa holders. The largest increases in S&E doctorates were in engineering and the biological sciences (Figure 2-21).

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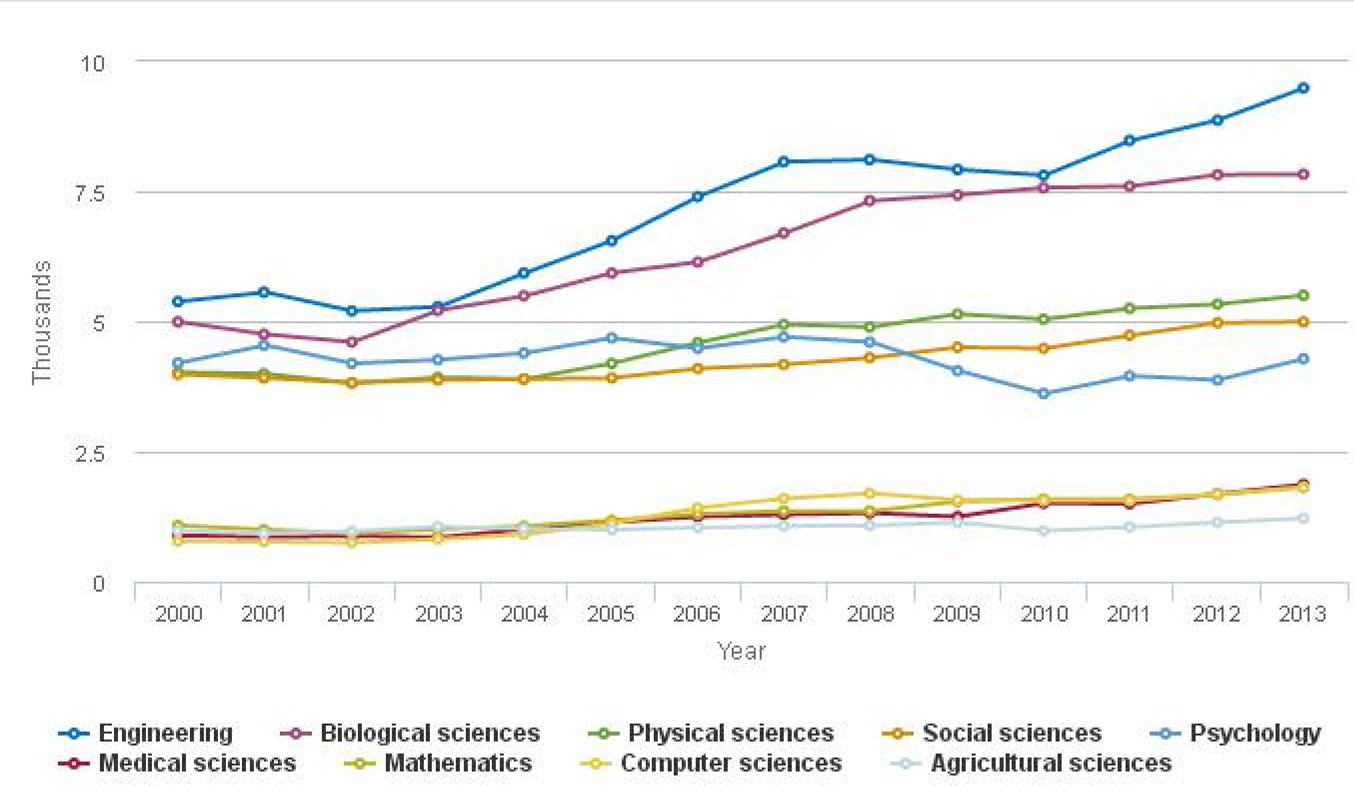
[i] Other health sciences include the fields of nursing; rehabilitation and therapeutic professions; and other health, professional, and related clinical sciences.

[ii] Data on degree completion from NCES were obtained from WebCASPAR (https://webcaspar.nsf.gov/). Data uploaded in WebCASPAR correspond to NCES provisional data, which undergo all NCES data quality control procedures and are imputed for nonresponding institutions. These data are used by NCES in its First Look (Provisional Data) publications.

Figure 2-21

S&E doctoral degrees earned in U.S. universities, by field: 2000–13



NOTES: Physical sciences include earth, atmospheric, and ocean sciences. Data differ from doctoral degree data in other tables and figures in this report that are based on the National Science Foundation Survey of Earned Doctorates and that refer to research doctorates only. Greatest differences are in psychology and medical sciences.

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; National Science Foundation, National Center for Science and Engineering Statistics, WebCASPAR database, http://webcaspar.nsf.gov.

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Time to Doctoral Degree Completion

The time required to earn a doctoral degree and the success rates of those entering doctoral programs are concerns for those pursuing a degree, the universities awarding the degree, and the agencies and organizations funding doctoral study. Longer times to degree mean lost earnings and a higher risk of attrition. Time to degree (as measured by time from graduate school entry to doctorate receipt) increased through the mid-1990s but has since decreased in all S&E fields from 7.7 to 6.9 years (Appendix Table 2-31). The physical sciences and mathematics had the shortest time to degree, whereas the social sciences and medical and other health sciences had the longest.

Time to degree varied among institution types (see sidebar, Carnegie Classification of Academic Institutions). Time to degree was shortest at research universities with very high research activity (6.7 years in 2013, down from 7.2 years in 1998). Doctorate recipients at medical schools also finished quickly (6.7 years in 2013). Time to degree was longer at universities that were less strongly oriented toward research (Table 2-12).

Table 2-12 **Median number of years from entering graduate school to receipt of S&E doctorate, by 2010 Carnegie classification of doctorate-granting institution: 1998–2013**

Year	All institutions	Research universities—very high research activity	Research universities—high research activity	Doctoral/research universities	Medical schools and medical centers	Other/not classified
1998	7.3	7.2	8.2	9.2	6.9	7.9
1999	7.2	7.2	7.9	9.0	6.7	7.7
2000	7.5	7.2	8.2	9.2	7.2	7.9
2001	7.2	7.2	8.2	9.7	6.9	7.7
2002	7.5	7.2	8.1	9.9	6.9	8.2
2003	7.6	7.2	8.2	9.7	6.9	9.0
2004	7.2	7.0	8.0	9.3	6.9	7.7
2005	7.3	7.2	7.9	9.3	7.0	8.1
2006	7.2	7.0	7.9	9.0	6.9	7.7
2007	7.0	6.9	7.7	8.9	6.9	7.7
2008	7.0	6.9	7.7	8.9	6.7	7.7
2009	7.0	6.9	7.7	9.2	6.8	7.7
2010	7.0	6.9	7.7	8.9	6.7	7.3
2011	7.0	6.9	7.7	8.7	6.7	7.7
2012	7.0	6.8	7.7	8.9	6.7	7.9
2013	6.9	6.7	7.4	9.3	6.7	7.7

NOTE: Includes only doctorate recipients who reported year of entry to first graduate school/program.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the 2013 Survey of Earned Doctorates.

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The median time to degree varies by demographic groups, but these variations reflect differences among broad fields of study. In 2013, across all doctorate recipients, women have a longer time to degree than men (7.7 versus 7.2 years, respectively) (Appendix Table 2-32). However, with few exceptions, these differences were very small when comparing men and women within broad S&E fields. In engineering, women took slightly less time than men (6.3 versus 6.7 years, respectively), and in medical and other health sciences, the difference reversed and was larger (9.7 for women versus 8.0 for men).

In most broad natural sciences and S&E fields, time to degree was longer for temporary visa holders than for U.S. students, particularly in the physical sciences (6.7 versus 5.9, respectively). However, in the medical and other health sciences, as in computer sciences, temporary visa holders finished faster. Among U.S. students, in most broad S&E fields, median time to degree was shorter for whites than for other groups. In computer sciences, time to degree of Hispanic doctorate recipients (7.3) was shorter than that of whites (7.6), Asians (9.6), and blacks (9.8).

S&E Doctoral Degrees by Sex

Among U.S. citizens and permanent residents, women's proportion of S&E doctoral degrees (excluding those in other health sciences[iii]) grew from 43% in 2000 to 48% in 2013 (Appendix Table 2-30). During this decade, women made gains in most major fields, among continuing disparities in other fields. In 2013, women earned half or more of doctorates in non-S&E fields, in most social and behavioral sciences except for economics, in the biological sciences, and in the medical and other health sciences. They earned fewer than one-third of the doctorates awarded in physical sciences, mathematics and computer sciences, and engineering (Appendix Table 2-30). Although low, the proportions of degrees earned by women in computer sciences, engineering, and the physical sciences (particularly in physics) are higher than they were in 2000.

The number of S&E doctorates earned by women grew faster than that earned by men. The number of U.S. citizen or permanent resident women earning doctorates in S&E increased from nearly 9,000 in 2000 to nearly 12,000 in 2013, while the number earned by men increased from almost 11,000 to more than 13,000 (Appendix Table 2-33). The increase in the number of S&E doctorates earned by women occurred in most major S&E fields. For example, the number of engineering doctorates earned by U.S. women increased from approximately 500 in 2000 to more than 1,000 in 2013. Similar growth patterns occurred in women's biological sciences doctorates from 1,700 to 3,100, and in physical sciences doctorates from 600 to more than 900. These differential growth rates partly reflect a decrease in the number of doctorates earned by U.S. men in many S&E fields early in the last decade. However, since around 2005, the number of doctorates earned by men has increased in all major S&E fields except for psychology.

S&E Doctoral Degrees by Disability Status

In 2012, 5% of S&E doctorate recipients reported having a disability; they were similar to those who did not report a disability in terms of broad field of study. Nearly half of the S&E doctorate recipients who reported one or more disabilities of any type indicated that they had visual disabilities, 17% reported cognitive disabilities, 19% reported hearing disabilities, 11% reported lifting disabilities, and 7% reported walking disabilities (NSF/NCSES 2015c).

S&E Doctoral Degrees by Race and Ethnicity

The number and proportion of doctoral degrees in S&E fields earned by underrepresented minorities increased between 2000 and 2013. In 2013, blacks earned 1,434 S&E doctorates, Hispanics earned 1,569, and American Indians and Alaska Natives earned 114—altogether accounting for 8% of S&E doctoral degrees (excluding doctorates in other health sciences[iii]) earned that year, up from 6% in 2000 (Appendix Table 2-33).[iv] Their share of the S&E doctorates earned by U.S. doctorate holders rose from 9% to 13% in the same period. Gains by all groups contributed to this rise, although the number of S&E degrees earned by blacks and Hispanics rose considerably more than the number earned by American Indians and Alaska Natives (Figure 2-22). Asian or Pacific Islander U.S. citizens and permanent residents earned 6% of all S&E doctorates in 2013, similar to 2000.[v]

[iii] In 2008, NCES allowed optional reporting in three new doctoral degree categories: doctor's—research /scholarship, doctor's—professional practice, and doctor's—other. Degrees formerly classified as professional degrees (e.g., MDs and JDs) could then be reported as doctoral degrees, most often as doctor's—professional practice. Data for 2008 and 2009 included only those doctorates reported under the old category plus those reported as doctor's—research/scholarship. Data for 2010 and 2011 included data reported as doctor's—research /scholarship, as the old category was eliminated. As a result of these methodological changes, doctor's—research /scholarship degrees in "other health sciences" declined sharply between 2009 and 2010. To facilitate comparability

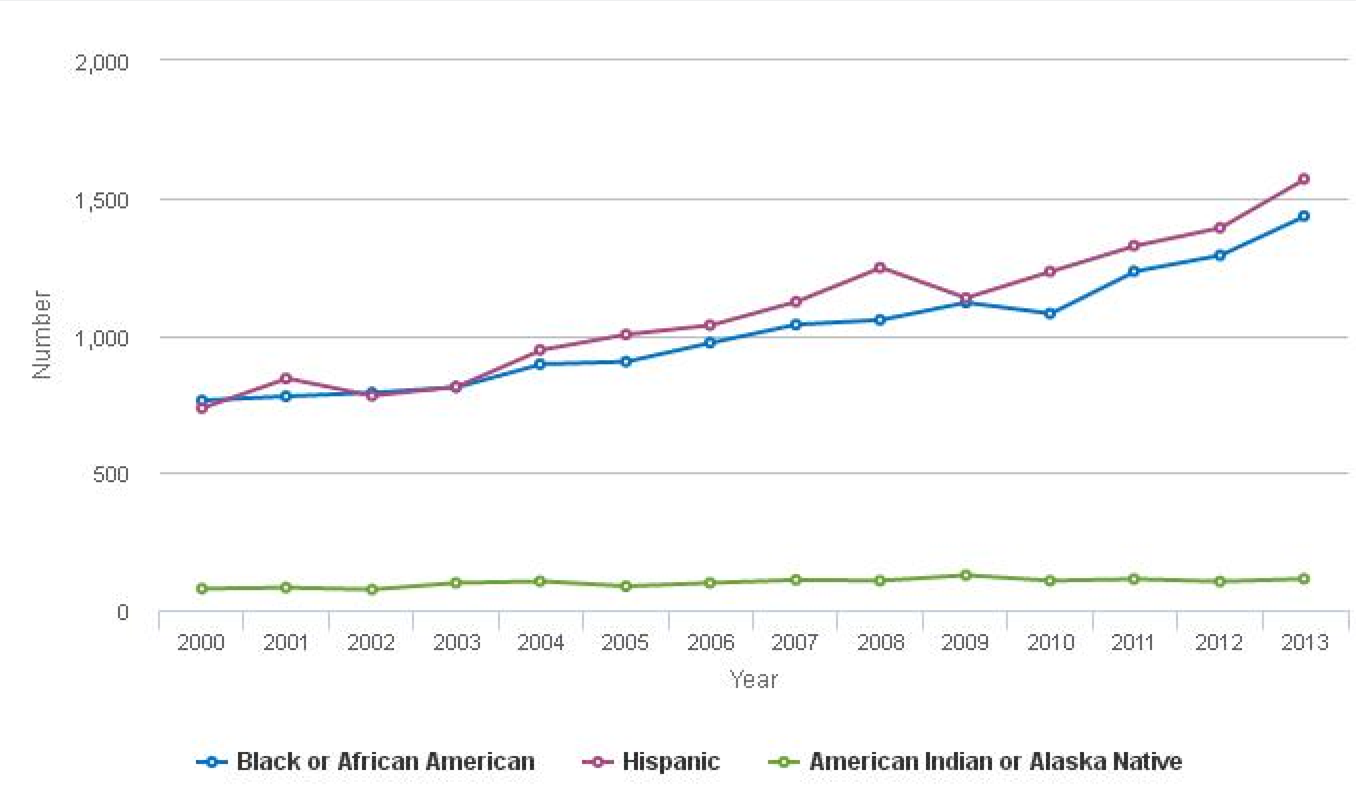
over time, "S&E" excludes "other health sciences" throughout the sections "S&E Doctoral Degrees," "Doctoral Degrees by Sex," and "Doctoral Degrees by Race and Ethnicity."

[iv] For the corresponding proportion in the 1990s, see (NSB 2008).

[v] For patterns on S&E doctorates awarded to minority men and minority women, see (NSF/NCSES 2015c).

Figure 2-22

S&E doctoral degrees earned by U.S. citizen and permanent resident underrepresented minorities, by race and ethnicity: 2000–13



NOTES: Data differ from doctoral degree data in other tables and figures in this report that are based on the National Science Foundation Survey of Earned Doctorates and that refer to research doctorates only. Greatest differences are in psychology and medical/other health sciences. S&E excludes other health sciences. Hispanic may be of any race. American Indian or Alaska Native and black or African American refer to individuals who are not of Hispanic origin.

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; National Science Foundation, National Center for Science and Engineering Statistics, WebCASPAR database, http://webcaspar.nsf.gov.

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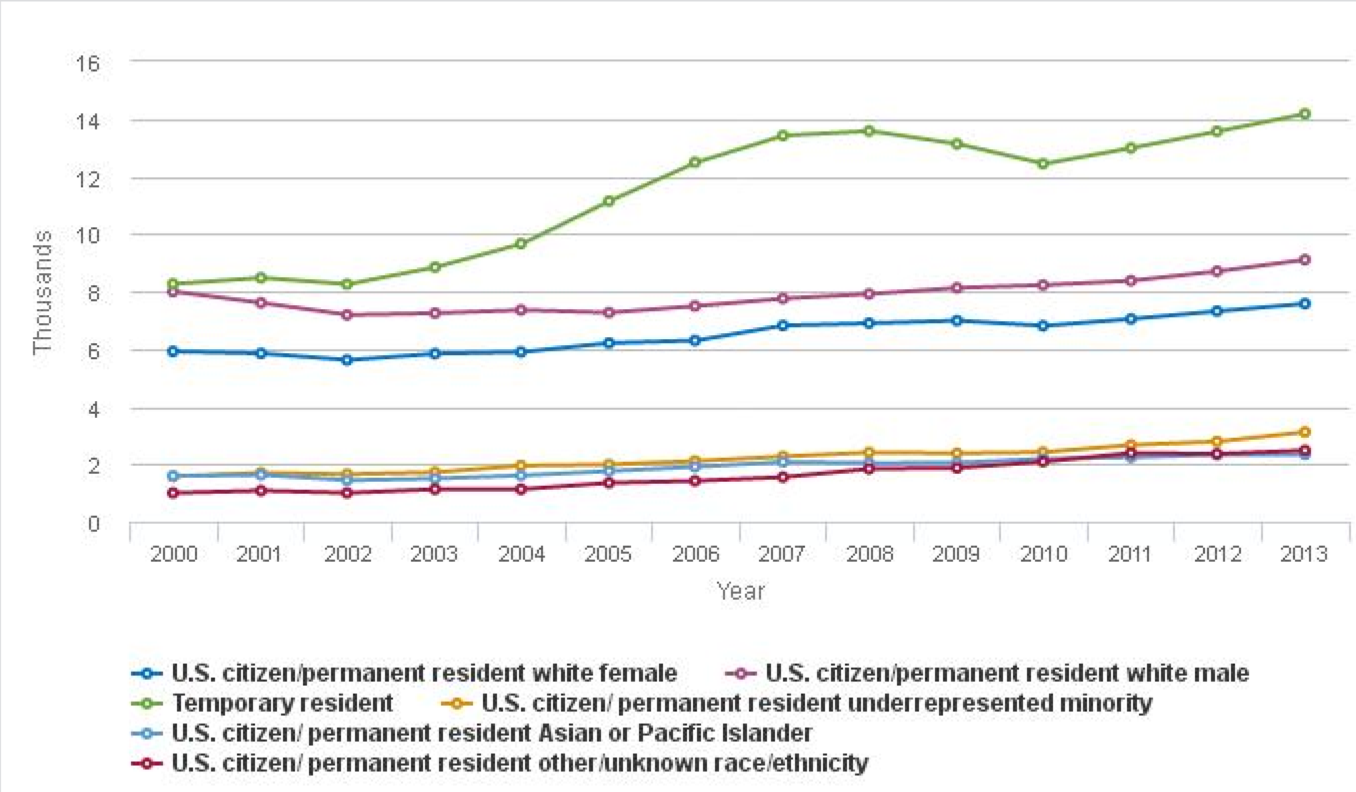
Although the number of S&E doctorates earned by white U.S. citizens and permanent residents increased between 2000 and 2013 (Figure 2-23), their share of all U.S. S&E doctorates fell from 53% in 2000 to 43% in 2013, reflecting the relatively faster growth among underrepresented minorities and temporary visa holders (Appendix Table 2-33).

Figure 2-23

S&E doctoral degrees, by sex, race, ethnicity, and citizenship: 2000–13



NOTES: Minority includes American Indian or Alaska Native, Asian or Pacific Islander, black or African American, and Hispanic. Data differ from doctoral degree data in other tables and figures in this report that are based on the National Science Foundation Survey of Earned Doctorates and that refer to research doctorates only. Greatest differences are in psychology and medical/other health sciences. S&E excludes other health sciences.

SOURCES: National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; National Science Foundation, National Center for Science and Engineering Statistics, WebCASPAR database, http://webcaspar.nsf.gov. See appendix tables 2-30 and 2-33.

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International S&E Doctorate Recipients

Temporary residents earned more than 14,000 S&E doctorates in 2013, up from about 8,000 in 2000. International students on temporary visas earned a larger proportion of doctoral degrees than master's, bachelor's, or associate's degrees (Appendix Table 2-33, Appendix Table 2-29, Appendix Table 2-18, and Appendix Table 2-23, respectively). The temporary residents' share of S&E doctorates rose from 31% in 2000 to 37% in 2013. In some fields, these students earned even larger shares of doctoral degrees. In 2013, they earned half or more of doctoral degrees awarded in engineering, computer sciences, and economics. They earned relatively lower proportions of doctoral degrees in some S&E fields—for example, 27% in biological sciences, 25% in medical sciences, 6% in psychology, and between 12% and 22% in most social sciences (except economics) (Appendix Table 2-33).

Countries and Economies of Origin

In the two decades since 1993, U.S. universities have awarded almost 210,000 S&E doctorates to temporary visa holders. Over that period, the top 10 countries and economies of origin accounted for 70% of all international recipients of these degrees (Table 2-13). Six out of those top 10 locations are in Asia.

Table 2-13 **Recipients of U.S. S&E doctorates on temporary visas, by country/economy of origin: 1993–2013**

Country/economy	Number	Percent
All recipients on temporary visas	208,861	100.0
Top 10 total	145,232	69.5
China	55,760	26.7
India	27,655	13.2
South Korea	20,899	10.0
Taiwan	14,184	6.8
Canada	6,160	2.9
Turkey	6,110	2.9
Thailand	4,346	2.1
Japan	3,497	1.7
Mexico	3,419	1.6
Germany	3,202	1.5
All others	63,629	30.5

NOTE: Data include non-U.S. citizens with unknown visa status.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the 2013 Survey of Earned Doctorates.

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Asia. From 1993 to 2013, students from four Asian locations (China, India, South Korea, and Taiwan, in descending order) earned more than half of all U.S. S&E doctoral degrees awarded to international students (119,000 of 209,000)—exceeding students from Europe (25,000) more than fourfold. By itself, China accounted for more than one-quarter of all these S&E doctorates (56,000), followed by India (28,000), South Korea (21,000), and Taiwan (14,000). Most of these degrees were awarded in engineering, biological sciences, and physical sciences (Table 2-14). A larger proportion of South Korean and Taiwanese doctorate recipients (exceeding 20%) than Chinese and Indian (approaching 10%) earned a doctorate in a non-S&E field.

Table 2-14 **Asian recipients of U.S. S&E doctorates on temporary visas, by field and country/economy of origin: 1993–2013**

Field	Asia	China	India	South Korea	Taiwan
All fields	157,823	59,798	30,182	26,740	17,981

Chapter 2. **Higher Education in Science and Engineering**

Field	Asia	China	India	South Korea	Taiwan
S&E	137,602	55,760	27,655	20,899	14,184
Engineering	51,879	20,006	12,220	8,316	5,785
Science	85,723	35,754	15,435	12,583	8,399
Agricultural sciences	4,795	1,565	755	759	508
Biological sciences	23,487	11,178	4,856	2,530	2,449
Computer sciences	8,228	3,385	2,303	985	666
Earth, atmospheric, and ocean sciences	2,657	1,400	331	352	249
Mathematics	6,861	3,805	757	947	548
Medical and other health sciences	4,837	1,123	1,219	622	878
Physical sciences	19,574	9,888	3,220	2,365	1,399
Psychology	1,946	409	260	450	325
Social sciences	13,338	3,001	1,734	3,573	1,377
Non-S&E	20,221	4,038	2,527	5,841	3,797

NOTES: Asia includes Afghanistan, Armenia, Azerbaijan, Bangladesh, Bhutan, Brunei, Burma/Myanmar, Cambodia, China, Georgia, Hong Kong, India, Indonesia, Japan, Kazakhstan, Kyrgyzstan, Laos, Macau, Malaysia, Maldives, Mongolia, Nepal, Pakistan, Philippines, Singapore, South Korea, Spratly Islands, Sri Lanka, Taiwan, Tajikistan, Thailand, Turkmenistan, Uzbekistan, and Vietnam. Data include temporary residents and non-U.S. citizens with unknown visa status.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the 2013 Survey of Earned Doctorates.

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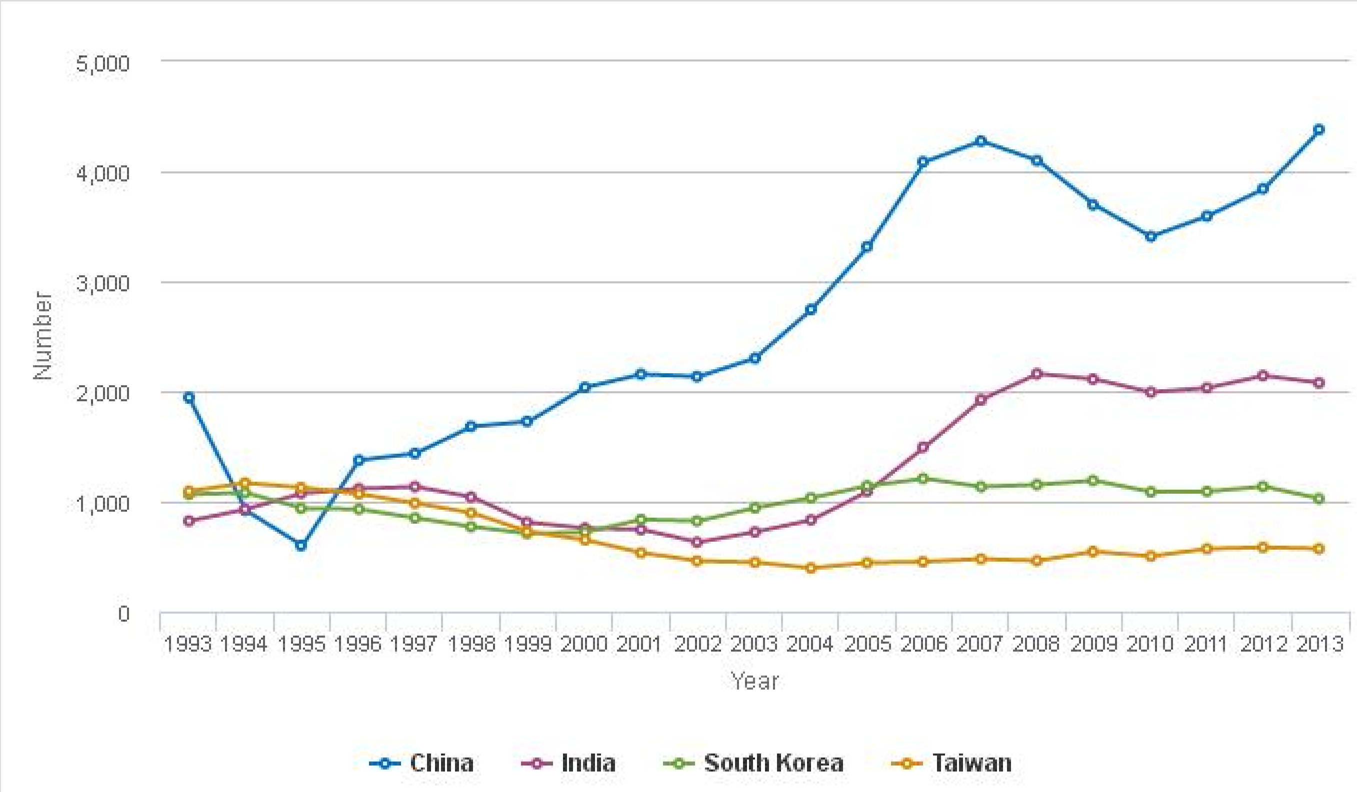
The number of S&E doctorates earned by students from China declined in the mid-1990s, increased through 2007, and dropped 16% in the following 3 years, but it rose nearly 30% since 2010, surpassing its peak in 2007 (Figure 2-24). Despite these fluctuations, the number of S&E doctorates earned by Chinese nationals more than doubled over the two decades. The number of S&E doctorates earned by students from India also declined in the late 1990s, and then increased almost every year since 2002 until it stabilized in 2009; it more than doubled over the last two decades. South Korea followed a similar trend but with a less dramatic increase in the early 2000s; since 2007, the number of S&E doctorates earned by South Koreans has been relatively stable. In contrast, Taiwan experienced a substantially different trajectory. In 1993, its students earned more U.S. S&E doctoral degrees than those from India or South Korea.[vi] As universities in Taiwan increased their capacity for advanced S&E education in the 1990s, the number of Taiwanese students earning U.S. S&E doctorates declined. Since 2004, however, their number has gradually risen.

[vi] The number of S&E doctorate recipients from China surpassed that of Taiwan in 1990. Up until that year, Taiwanese students earned more U.S. S&E doctorates than Chinese, Indian, or South Korean students (figure (NSB 2008) 2-25; figure (NSB 2010) 2-22).

Figure 2-24

U.S. S&E doctoral degree recipients, by selected Asian country/economy of origin: 1993–2013



NOTE: Degree recipients include temporary residents and non-U.S. citizens with unknown visa status.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the 2013 Survey of Earned Doctorates.

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Europe. European students earned far fewer U.S. S&E doctorates than Asian students between 1993 and 2013—a combined number broadly comparable with doctorates earned by students from India—and they tended to focus less on engineering than did their Asian counterparts (Table 2-14 and Table 2-15). European countries whose students earned the largest number of U.S. S&E doctorates from 1993 to 2013 were Germany, Russia, Greece, Italy, Romania, France, and the United Kingdom, in that order. Trends in doctorate recipients from individual Western European countries vary widely (Figure 2-25). The number of Central and Eastern European students earning S&E doctorates at U.S. universities nearly quadrupled between 1993 and 2013, to 390. Although their numbers almost reached the Western Europe total between 2005 and 2007, they have declined since then (Figure 2-26). A higher proportion of doctorate recipients from Russia, Romania, and Greece than from the United Kingdom, France, Italy, and Germany earned their doctorates in S&E. Russian and Romanian doctorate recipients were more likely than those from Western European countries to earn their doctorates in mathematics and physical sciences, and Greek and French doctorate recipients were more likely to earn doctoral degrees in engineering (Table 2-15).

Table 2-15 **European recipients of U.S. S&E doctorates on temporary visas, by field and region/country of origin: 1993–2013**

Chapter 2. **Higher Education in Science and Engineering**

Field	All European countries	Germany	Russia	Greece	Italy	Romania	France	United Kingdom
All fields	31,139	4,102	2,939	2,309	2,587	2,105	2,154	2,413
S&E	25,167	3,202	2,653	2,041	2,011	1,876	1,733	1,690
Engineering	4,956	521	390	737	446	301	568	177
Science	20,211	2,681	2,263	1,304	1,565	1,575	1,165	1,513
Agricultural sciences	654	91	17	55	53	21	58	36
Biological sciences	3,678	506	372	213	187	219	243	334
Computer sciences	1,535	196	120	239	88	234	58	47
Earth, atmospheric, and ocean sciences	960	154	93	34	79	34	86	129
Mathematics	2,581	280	340	138	199	359	73	144
Medical and other health sciences	537	80	12	51	22	17	33	74
Physical sciences	5,183	626	955	304	349	490	356	307
Psychology	696	146	38	40	41	33	20	98
Social sciences	4,387	602	316	230	547	168	238	344
Non-S&E	5,972	900	286	268	576	229	421	723

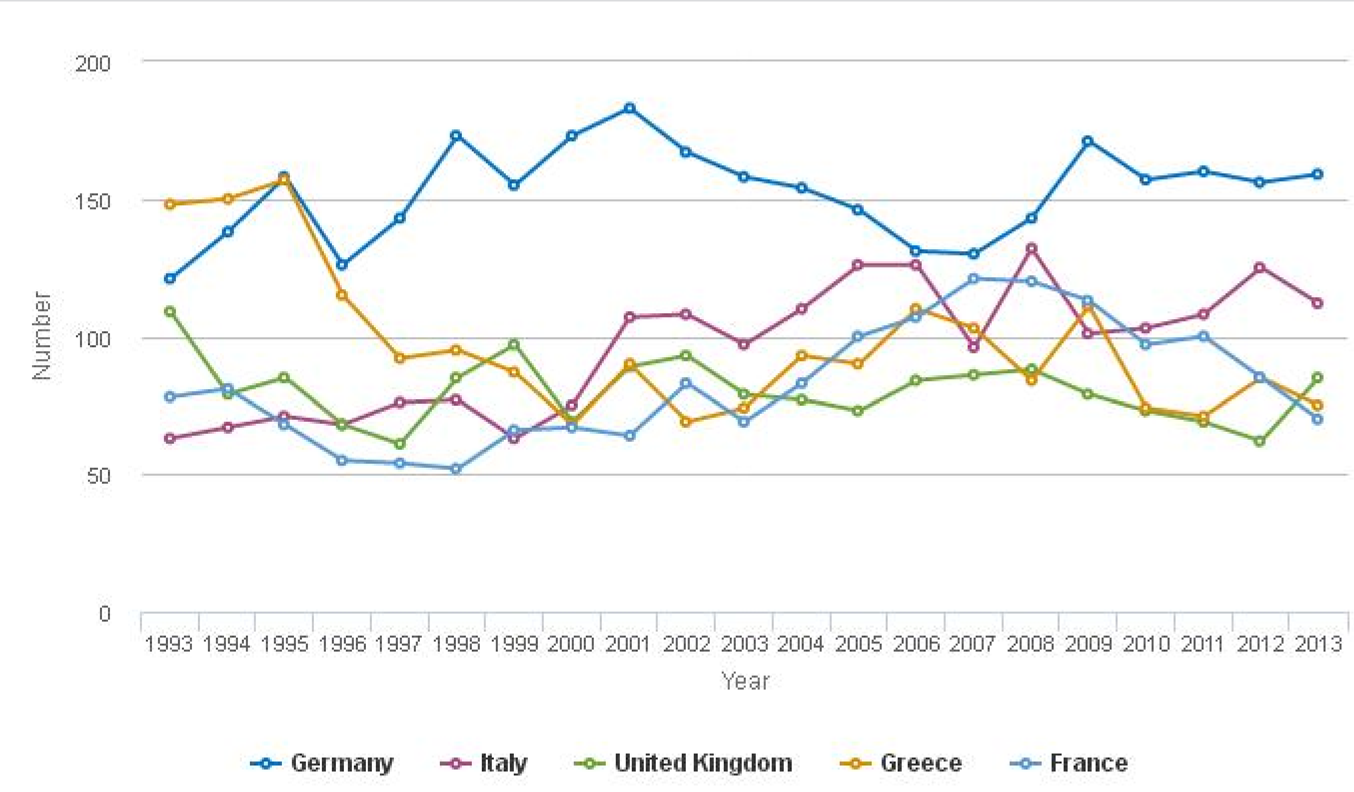
NOTE: Data include temporary residents and non-U.S. citizens with unknown visa status.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the 2013 Survey of Earned Doctorates.

Science and Engineering Indicators 2016

Figure 2-25

U.S. S&E doctoral degree recipients, by selected Western European country: 1993–2013



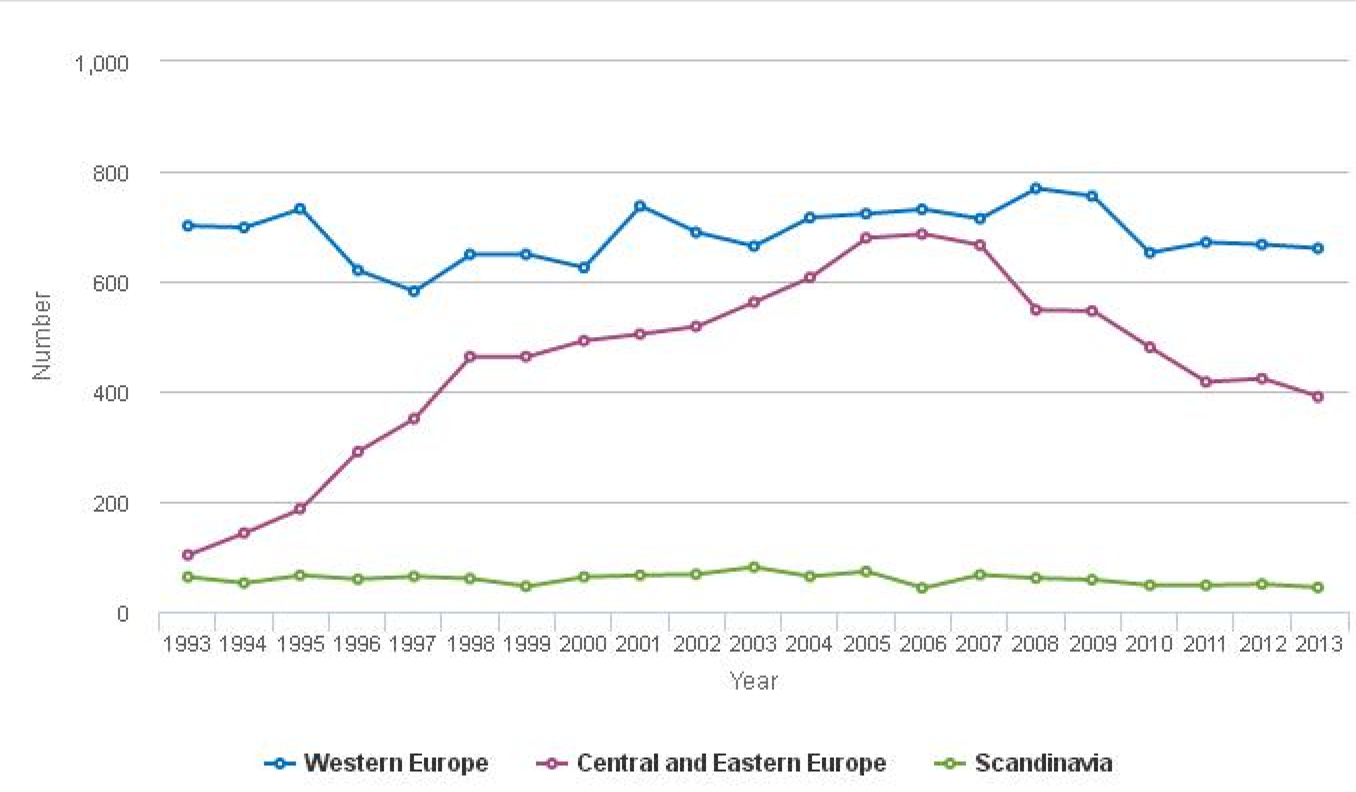
NOTE: Degree recipients include temporary residents and non-U.S. citizens with unknown visa status.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the 2013 Survey of Earned Doctorates.

Science and Engineering Indicators 2016

Figure 2-26

U.S. S&E doctoral degree recipients from Europe, by region: 1993–2013



NOTES: Degree recipients include temporary residents and non-U.S. citizens with unknown visa status. Western Europe includes Andorra, Austria, Belgium, France, Germany, Greece, Ireland, Italy, Liechtenstein, Luxembourg, Malta, Monaco, Netherlands, Portugal, San Marino, Spain, Switzerland, and United Kingdom. Central and Eastern Europe includes Albania, Belarus, Bosnia-Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Kosovo, Latvia, Lithuania, Macedonia, Moldova, Montenegro, Poland, Romania, Russia, Serbia, Slovakia, Slovenia, and Ukraine. Scandinavia includes Denmark, Finland, Iceland, Norway, and Sweden.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the 2013 Survey of Earned Doctorates.

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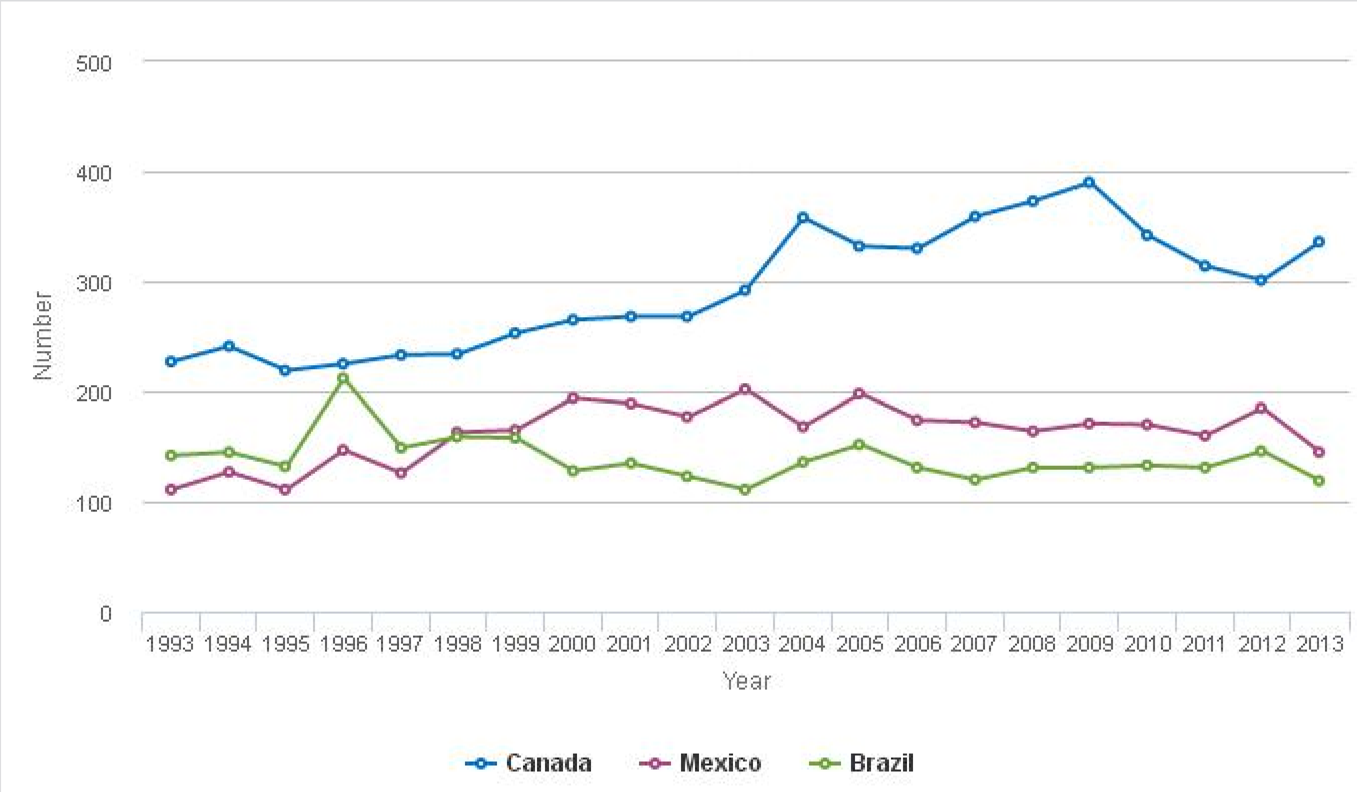
The Americas. Despite the proximity of Canada and Mexico to the United States, the shares of U.S. S&E doctoral degrees awarded to residents of these countries were small compared with those awarded to students from Asia and Europe. The number of U.S. doctoral S&E degrees earned by students from Canada increased from about 230 in 1993 to 390 in 2009, but it has mostly declined in the last 4 years. The overall numbers of doctoral degree recipients from Mexico and Brazil peaked earlier (2003 and 1996, respectively) and have been relatively stable in recent years (Figure 2-27).

Figure 2-27

U.S. S&E doctoral degree recipients from Canada, Mexico, and Brazil: 1993–2013



NOTE: Degree recipients include temporary residents and non-U.S. citizens with unknown visa status.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the 2013 Survey of Earned Doctorates.

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A higher proportion of Mexican and Brazilian students earned U.S. doctorates in S&E fields than the comparable proportion for Canadians (Table 2-16). In particular, higher proportions of Mexican and Brazilian students than Canadian students received U.S. doctoral degrees in engineering and agricultural sciences.

Table 2-16 North American, South American, and Middle Eastern recipients of U.S. S&E doctorates, by field and region/country of origin: 1993–2013

	North and South America[a]				Middle East[b]			
Field	All countries	Canada	Mexico	Brazil	All countries	Turkey	Iran	Jordan
All fields	24,518	8,994	3,989	3,503	17,558	7,242	2,560	1,790
S&E	19,076	6,160	3,419	2,924	14,440	6,110	2,450	1,551
Engineering	4,047	958	852	687	6,498	2,704	1,645	678
Science	15,029	5,202	2,567	2,237	7,942	3,406	805	873

	North and South America[a]				Middle East[b]			
Field	All countries	Canada	Mexico	Brazil	All countries	Turkey	Iran	Jordan
Agricultural sciences	1,872	220	536	403	536	241	38	77
Biological sciences	3,477	1,285	501	489	1,368	522	154	161
Computer sciences	676	217	111	161	923	365	122	105
Earth, atmospheric, and ocean sciences	686	208	139	111	232	94	24	11
Mathematics	985	314	201	155	687	306	112	83
Medical and other health sciences	810	387	81	164	496	45	40	144
Physical sciences	1,800	781	289	140	1,290	583	210	164
Psychology	901	683	39	59	316	124	12	6
Social sciences	3,822	1,107	670	555	2,094	1,126	93	122
Non-S&E	5,442	2,834	570	579	3,118	1,132	110	239

[a] North America includes Bermuda, Canada, and Mexico; South America includes Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay, and Venezuela.

[b] Middle East includes Bahrain, Gaza Strip, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, Turkey, United Arab Emirates, West Bank, and Yemen.

NOTE: Data include temporary residents and non-U.S. citizens with unknown visa status.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the 2013 Survey of Earned Doctorates.

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The Middle East. Between 1993 and 2013, Middle Eastern students earned far fewer U.S. S&E doctorates (about 14,000) than did students from Asia, Europe, or the Americas (Table 2-14, Table 2-15, and Table 2-16). Students from Turkey earned the largest number of U.S. S&E doctorates in this region, followed by those from Iran and Jordan. A larger proportion of Iranian (64%) than of Turkish (37%) or Jordanian (38%) doctorate recipients earned their doctorates in engineering.

International S&E Higher Education

In the 1990s, many countries, coming to view an educated population and workforce as a valuable national resource, expanded their higher education systems and eased access to higher education. At the same time, flows of students worldwide increased, often reflecting government incentives and programs. More recently, several countries have adopted policies to encourage the return of students who studied abroad, to attract international students, or both. As the world becomes more interconnected, students who enroll in tertiary (postsecondary) institutions outside their own countries have opportunities to expand their knowledge of other societies and languages and improve their employability in globalized labor markets.

Higher Education Expenditures

One indicator of the importance of higher education is the percentage of a nation's resources devoted to it as measured by the ratio of expenditures on tertiary education institutions to gross domestic product (GDP). This indicator varies widely among members of the OECD, an intergovernmental group of developed economies. Only about one-third of OECD members spend more than the average of 1.6% of a nation's GDP on tertiary education institutions, and only Canada, the United States, South Korea, and Chile spend more than 2%. According to the most recently available data from the OECD, in 2011, Canada spent the highest proportion of GDP on tertiary education institutions compared with all other OECD countries, followed by the United States, South Korea, and Chile (Appendix Table 2-34). Between 2000 and 2011, U.S. expenditures on tertiary education as a percentage of GDP were 60% higher than the OECD average and about 90% higher than the European Union (EU; see Glossary for member countries) average. Between 2000 and 2011, expenditures on tertiary education institutions as a percentage of GDP rose in most OECD countries, particularly in the United States, New Zealand, Turkey, the Czech Republic, Canada, and Estonia, as well as Russia. In the United Kingdom, expenditures on tertiary education institutions as a proportion of GDP rose between 2000 and 2009, but declined between 2009 and 2011.

Higher education financing data are not always fully comparable across different nations. They can vary between countries for reasons unrelated to actual expenditures, such as differences in measurement, types and levels of government funding included, types and levels of education included, and the prevalence of public versus private institutions. According to an international database compiled by the Program for Research on Private Higher Education at the State University of New York at Albany (2011), the United States and Japan have long-standing private higher education sectors, and Western Europe has an almost completely public higher education sector. Eastern and Central Europe and several African countries have recently seen growth in private higher education. In most countries in Latin America, more than half of all higher education institutions are private. In Asia, many governments have encouraged the expansion of private higher education as one of the strategies to deal with high enrollment growth (see sidebar, Trends in Higher Education in Asia). In 2011, about 80% of the students in South Korea and Japan and 60%–64% of the students in Singapore, the Philippines, Nepal, Indonesia, and Cambodia were enrolled in private institutions (UNESCO/UIS 2014).

Trends in Higher Education in Asia

Enrollment in higher education across Asia has grown considerably in the last two decades as a result of higher secondary school participation rates and a higher demand for an educated workforce in Asia's increasingly knowledge-oriented economies. According to a 2014 report by the United Nations Educational, Scientific and Cultural Organization Institute for Statistics (UNESCO/UIS 2014), to adapt to this enrollment growth, higher education systems had to "expand out" by building more campuses and universities. At the same time, higher education systems had to "expand up" by introducing new graduate programs to prepare and train qualified professors and researchers.

This expansion created a financial challenge for many governments. Their strategies for addressing this challenge include, for example, shifting some of the cost to students and their families by introducing fees or fee-based courses; encouraging public universities to find private funding; increasing the use of online instruction; and encouraging the expansion of private higher education, including the establishment of branch campuses of foreign universities.

In some Asian countries, this expansion also affected the quality of education because there were not enough qualified instructors to satisfy the demand. At the same time, increasing numbers of students meant heavier teaching loads, so student-instructor ratios also increased. For example, between 2000 and 2011, the student-instructor ratio increased in Bangladesh, Cambodia, China, Indonesia, Laos, Macau, and Vietnam. In the same period, however, the student-instructor ratio declined considerably in Thailand, Myanmar, South Korea, and Malaysia.

Many universities in Asia compete to obtain high placements in international university rankings. High rankings may influence public resource allocation and bring more government investment to top universities. High rankings may also attract more international students and thus increase revenues both for the university and the country where these students enroll. Publication rates in top-tier journals are a key component of these rankings, which implies that the competition for high rankings may put pressure on faculty to publish at top-tier international journals and in turn may affect teaching quality.

At the same time governments in Asia were trying to expand graduate education to meet the demand for university instructors, they also began to promote university-based research. University research is typically done at the graduate level, so expanding graduate education is viewed as a means to advance innovation and increase national competitiveness.

Educational Attainment

Higher education in the United States expanded greatly after World War II. As a result, the U.S. population led the world in educational attainment for several decades. Because of this, the United States offered clear advantages for firms whose work would benefit from the availability of a highly educated workforce. In the 1990s, however, many countries in Europe and Asia began to expand their higher education systems. Some of them have now surpassed the United States in the attainment of bachelor's degrees or higher in their younger cohorts. Over time, the expansion of higher education elsewhere has substantially diminished the U.S. educational advantage.

Although the United States continues to be among those countries with the highest percentage of the population ages 25–64 with a bachelor's degree or higher, several other countries have surpassed the United States in the percentage of the younger population (ages 25–34) with a bachelor's degree or higher (Figure 2-28).[i]

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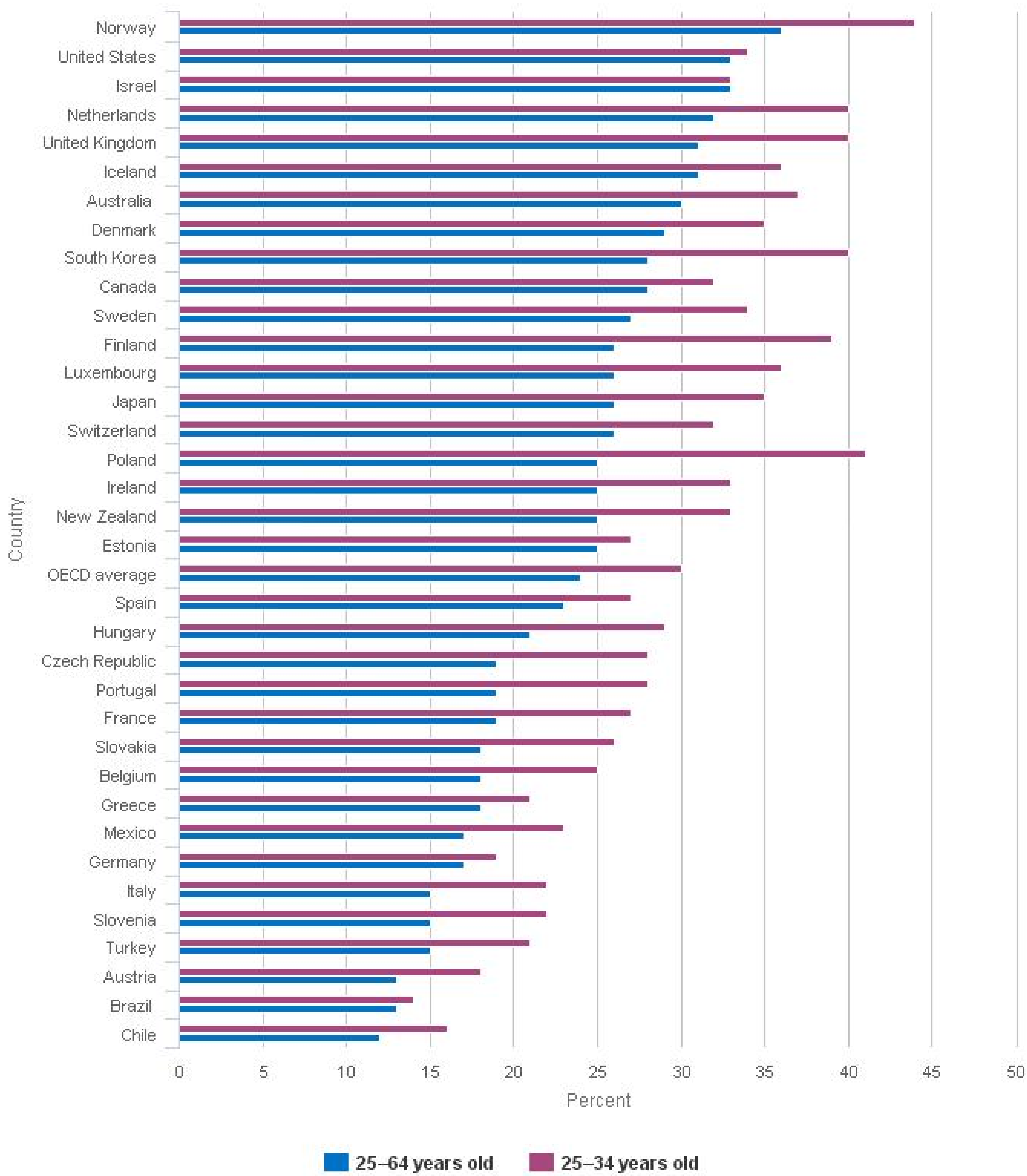
[i] These data are based on national labor force surveys and are subject to sampling error; therefore, small differences between countries may not be meaningful. The standard error for the U.S. percentage of 25–64-year-olds with a bachelor's or higher degree is roughly 0.1, and the standard error for the U.S. percentage of 25–34-year-olds with a bachelor's or higher degree is roughly 0.4.

Figure 2-28

Attainment of tertiary-type A and advanced research programs, by country and age group: 2012



OECD = Organisation for Economic Co-operation and Development.

NOTES: For Chile, the year of reference is 2011 instead of 2012. International Standard Classification of Education (ISCED) tertiary-type A programs, ISCED 5A, are largely theory based and designed to provide sufficient qualifications for entry to advanced research programs and professions with high-skill requirements such as medicine, dentistry, or architecture and have a minimum duration of 3 years' full-time equivalent, although they typically last 4 years or longer. In the United States, they correspond to bachelor's and master's degrees. Advanced research programs are tertiary programs leading directly to award of an advanced research qualification (e.g., doctorate).

SOURCE: OECD, *Education at a Glance 2014: OECD Indicators* (2014).

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First University Degrees in S&E Fields

More than 20 million students worldwide earned first university degrees (see Glossary) in 2012, with over 6 million of these in S&E fields (Appendix Table 2-35). These worldwide totals include only countries for which relatively recent data are available (primarily countries in Asia, Europe, and the Americas) and are therefore underestimates. Asian universities accounted for nearly 4 million of the world's S&E first university degrees in 2012, close to half of them in engineering. Students across Europe (including Eastern Europe and Russia) earned more than 1 million S&E first university degrees (nearly one-third of them in engineering),[i] and students in North America earned nearly 800,000 such degrees in 2012 (20% in engineering).

In several countries and economies around the world, the proportion of first university degrees in S&E fields was higher than in the United States. Nearly half or more of all first university degrees in China were in S&E fields, compared with about one-third in the United States. National differences in engineering degrees largely account for overall differences in the proportion of S&E degrees, given that the disparity was especially large in engineering. However, differences in the taxonomies and quality of engineering programs and level of reporting detail across countries make comparisons problematic. For example, according to Wadhwa and colleagues (2007), in China in the mid-2000s, the term "engineer" had no standard definition and did not translate well into different dialects, so the reports sent to the Ministry of Education from different Chinese provinces did not count degrees consistently. In the late 1990s, the Chinese government implemented top-down policy changes to increase enrollment in engineering. However, the total number of technical schools and the corresponding numbers of teachers and staff declined, which meant that degree awards were achieved by increasing class sizes and student-to-teacher ratios, leading to a decline in academic programs' quality.

China has traditionally awarded a large proportion of its first university degrees in engineering, although the percentage declined from 43% in 2000 to 32% in 2012 (Appendix Table 2-36). Other places with a high proportion of engineering degrees are Singapore, Taiwan, Iran, South Korea, Indonesia, Japan, Finland, Mexico, and Colombia (Appendix Table 2-35). In the United States, about 5% of all bachelor's degrees are in engineering. About 12% of all bachelor's degrees awarded in the United States and worldwide are in the natural sciences (physical, biological, computer, and agricultural sciences, as well as mathematics and statistics).

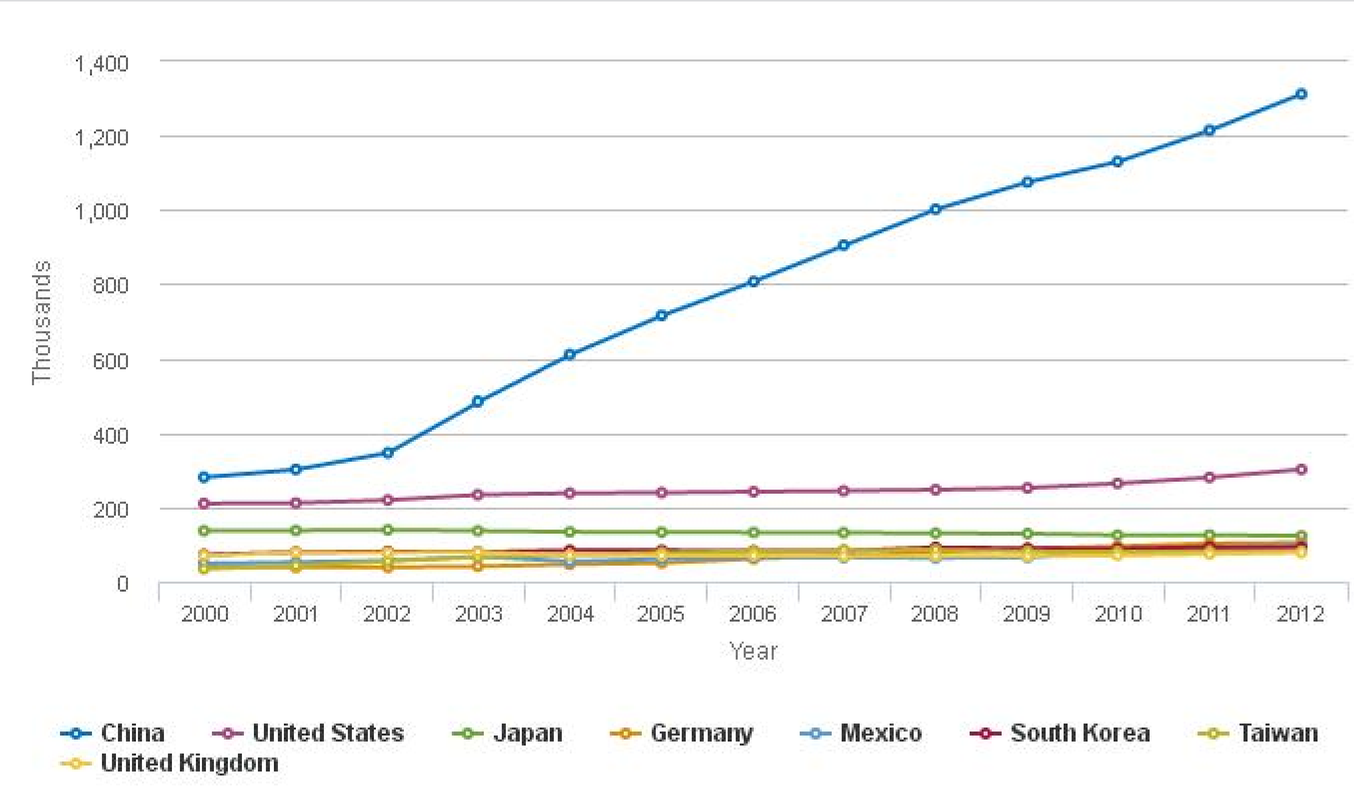
The number of S&E first university degrees awarded in China, Taiwan, Germany, Turkey, and Mexico doubled or more than doubled between 2000 and 2012. During this period, such degrees awarded in Australia grew by about two-thirds;[ii] those awarded in the United States and Poland increased by nearly 50%. S&E first university degrees awarded in France, Japan, and Spain declined by 24%, 10% and 3%, respectively. Growth in natural sciences and engineering degrees in China accounted for most of the country's increase in S&E first university degrees; about 1.3 million, up more than 300% from 2000 to 2012 (Figure 2-29; Appendix Table 2-36).

[i] For OECD countries, engineering includes "engineering and engineering trades" (International Standard Classification of Education [ISCED] 52), which is more specific than the code available in previous publications: "engineering, manufacturing, and construction" (ISC 5).

[ii] Comparison for Australia covers the 2000–11 period.

Figure 2-29

First university natural sciences and engineering degrees, by selected country: 2000–12



NOTE: Natural sciences include agricultural sciences; biological sciences; computer sciences; earth, atmospheric, and ocean sciences; and mathematics.

SOURCES: China—National Bureau of Statistics of China, *China Statistical Yearbook*, annual series (Beijing) (various years); Germany, Mexico, South Korea, and United Kingdom—Organisation for Economic Co-operation and Development, Online Education Database, http://stats.oecd.org/Index.aspx; Japan—Government of Japan, Ministry of Education, Culture, Sports, Science and Technology, Survey of Education;); Taiwan—Ministry of Education, Educational Statistics of the Republic of China (Taiwan): 2013 (2013); United States—National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; National Science Foundation, National Center for Science and Engineering Statistics, WebCASPAR database, http://webcaspar.nsf.gov.

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In 1999, 29 European countries, through the Bologna Declaration, initiated a system of reforms in higher education throughout Europe. The goal of the Bologna Process was to harmonize certain aspects of higher education within participating countries so that degrees were comparable; credits were transferable; and students, teachers, and researchers could move freely from institution to institution across national borders. Ten years later, the European Higher Education Area was launched, and higher education reform in Europe was extended to 47 participating countries. In recent years, countries have made considerable changes: they have modified higher education structures by implementing three degree cycles (bachelor's, master's, and doctorate), developed quality assurance systems, and established mechanisms to facilitate mobility (EACEA 2012). A recent report that examined data in the areas of access, retention, and employability across 36 education systems, however, indicated that most European countries have been slow to set clear goals or monitor progress in those areas (EACEA 2014).

S&E First University Degrees by Sex

Women earned half or more of first university degrees in S&E in many countries around the world in 2012, including the United States and several smaller countries. Most large countries in Europe are not far behind, with more than 40% of S&E first university degrees earned by women. In the Middle East, women earned nearly half or more of the S&E first university degrees in most countries in the region, except for Iraq. In several Asian countries, women generally earn about one-third or fewer of the first university degrees awarded in S&E fields. For example, in Taiwan, women earn 26% of the S&E first university degrees; in Japan, 28%; and in South Korea, 30% (Appendix Table 2-37).

In Canada, the United States, and many smaller countries, more than half of the S&E first university degrees earned by women were in the social and behavioral sciences. In contrast, in Singapore and Colombia, about half of the S&E first university degrees earned by women were in engineering, much higher proportions than in the United States or most countries in Europe. Other countries with relatively high proportion of women earning first university degrees in engineering include South Korea (31% of their S&E first university degrees), Malaysia (31%), Iran (30%), Taiwan (28%), Finland (28%), and India (27%),

Global Comparison of S&E Doctoral Degrees

Nearly 200,000 S&E doctoral degrees were awarded worldwide in 2012.[i] The United States awarded the largest number of S&E doctoral degrees of any country (about 35,000), followed by China (about 32,000), India (about 14,000), Germany (about 12,000), the United Kingdom (about 11,000), and France (about 8,000) (Appendix Table 2-38). About 60,000 S&E doctoral degrees were earned in the EU.

The number of S&E doctoral degrees awarded in China rose steeply between 2000 and 2009 and has leveled off since then. Although the rise was steeper in China, the trend was similar to the recent trend in doctoral production in the United States (Appendix Table 2-39 and Appendix Table 2-40). In 2007, China surpassed the United States as the world's largest producer of natural sciences and engineering doctoral degrees (Figure 2-30). The high growth of graduate education in China has been the result of large government investments in higher education over the last 20 years, intended to establish world-class universities in this country. Project 211 and Project 985 are examples of programs launched by the Chinese government in the mid-1990s to establish and strengthen institutions of higher education and key fields of study as a national priority (Lixu 2004) (see sidebar, Trends in Higher Education in Asia).

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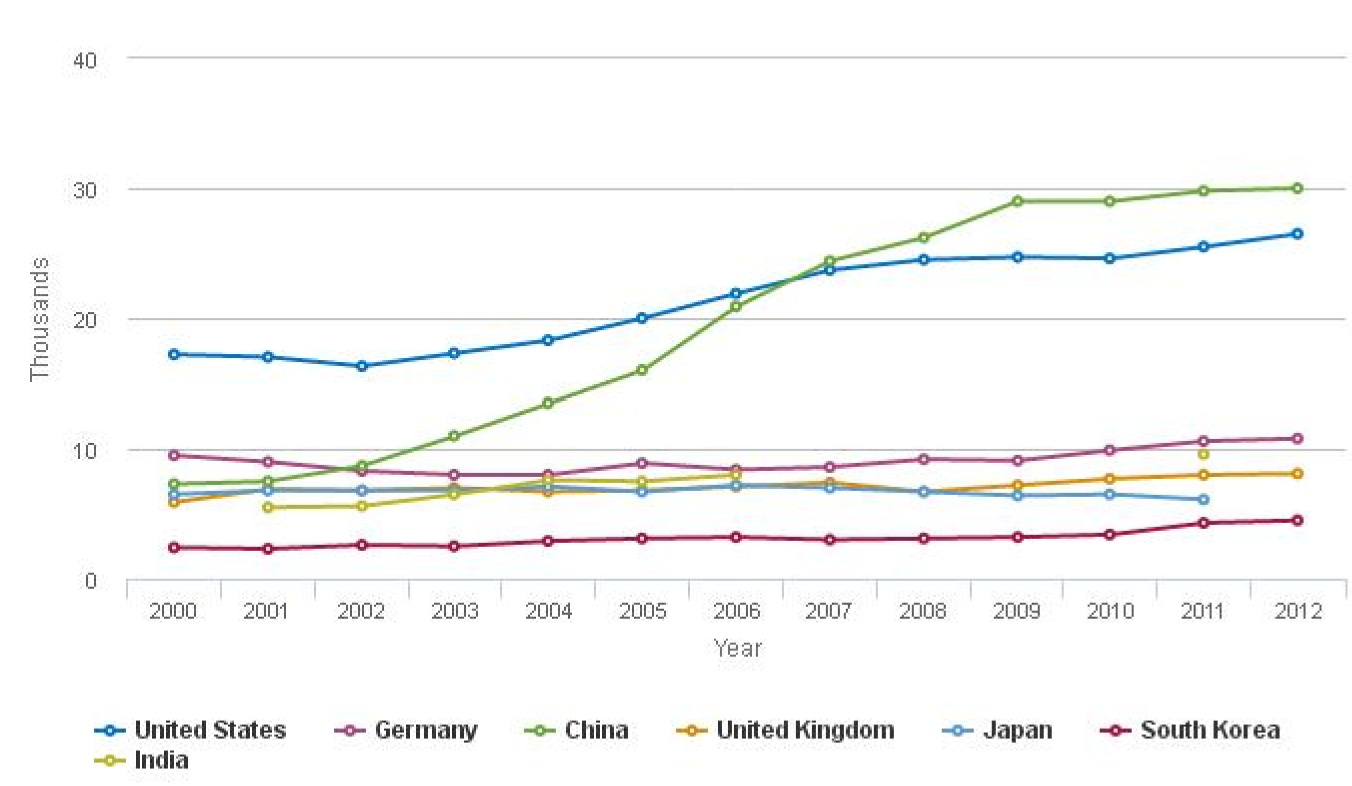
[i] In international degree comparisons, S&E does not include medical or other health fields. This is because international sources cannot separate the MD degrees from degrees in the health fields, and the MDs are professional or practitioner degrees, not research degrees.

Figure 2-30

Natural sciences and engineering doctoral degrees, by selected country: 2000–12



NA = not available.

NOTES: Natural sciences and engineering include biological, physical, earth, atmospheric, ocean, and agricultural sciences; computer sciences; mathematics; and engineering. Data for India are not available for 2007–10; data for Japan are not available for 2010.

SOURCES: China—National Bureau of Statistics of China, *China Statistical Yearbook*, annual series (Beijing) (various years); India—Department of Science and Technology; Japan—Government of Japan, Ministry of Education, Culture, Sports, Science and Technology, Survey of Education; Germany, South Korea, and United Kingdom—Organisation for Economic Co-operation and Development, Online Education Database, http://stats.oecd.org/; Russia—United Nations Educational, Scientific and Cultural Organization Institute for Statistics database, special tabulations (as of January 2015); United States—National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; National Science Foundation, National Center for Science and Engineering Statistics, WebCASPAR database, http://webcaspar.nsf.gov.

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In the United States, as well as in France, Germany, Italy, Spain, Switzerland, and the United Kingdom, the largest numbers of S&E doctoral degrees were awarded in the physical and biological sciences (Appendix Table 2-39). In Sweden, the number of doctorates awarded in the physical and biological sciences is similar to the number of doctorates awarded in engineering.

In Asia, China has been the largest producer of S&E doctoral degrees since 2000 (Appendix Table 2-40). As China's capacity for advanced S&E education increased, the number of S&E doctorates awarded rose from about 6,000 in 1998 to more than 32,000 in 2012. Despite the growth in the quantity of doctorate recipients, some question the quality of the doctoral programs in China (Cyranoski et al. 2011). The rate of growth in doctoral degrees in S&E and in all fields has slowed in 2010 (Appendix Table 2-40), after an announcement by the Chinese Ministry of Education indicating that China would begin to limit admissions to doctoral programs and focus more on quality of graduates (Mooney 2007).

Between 1998 and 2012 (2011 in the case of India), the number of S&E doctorates awarded in India, South Korea, and Taiwan more than doubled; in Japan, the numbers rose consistently through 2006 but declined through 2011 (the most recent data available). In China, Japan, South Korea, and Taiwan, more than half of S&E doctorates were awarded in engineering. In India, 40% of the S&E doctorates were awarded in the physical and biological sciences and 31% in the social and behavioral sciences (Appendix Table 2-40).

Women earned 41% of S&E doctoral degrees awarded in the United States in 2012, about the same percentage earned by women in Canada and the EU (Appendix Table 2-41).[ii] Women earned more than half of S&E doctoral degrees in Norway, Portugal, Latvia, Lithuania, and Ukraine but less than 20% of those in South Korea and Taiwan.

[ii] In the United States, women earned nearly half of the S&E doctoral degrees awarded to U.S. citizens and permanent residents in 2012 (Appendix Table 2-30).

Global Student Mobility

Governments around the world have increasingly come to regard movement toward a knowledge-based economy as key to economic progress. Realizing that this requires a well-trained workforce, they have invested in upgrading and expanding their higher education systems and broadening participation in them. In most instances, government spending underwrites these initiatives. Recent investments by several governments to send large numbers of their students to study abroad are a strategy for workforce and economic development. Examples include the Brazil Scientific Mobility Program (also known as Science without Borders), launched officially in July 2011, which provides scholarships to Brazilian students to study in STEM fields in universities in the United States.[i] Similarly, the government of Saudi Arabia has invested considerably in a scholarship program launched in 2005 that has supported study abroad programs for more than 100,000 Saudi students throughout the world, at an estimated cost of at least $5 billion since the program's inception (Knickmeyer 2012). In 2013, the Mexican government announced its Proyecta 100,000 program, which plans to send 100,000 students to study in the United States by 2018 (Lloyd 2014). The Chinese government has established the China Scholarship Council, a nonprofit affiliated with the Ministry of Education whose goal is to provide financial assistance to Chinese citizens to study abroad, as well as to foreign citizens to study in China (China Scholarship Council 2015).

Students have become more internationally mobile in the past two decades, and countries are increasingly competing for them. According to data from the OECD, the number of internationally mobile students who pursued a higher education degree more than doubled between 2000 and 2012, to 4.5 million (OECD 2014).[ii] In general, students migrate from developing countries to the more developed countries and from Europe and Asia to the United States. However, a few countries have emerged as regional hubs for certain geographic regions—for example, Australia, China, and South Korea for East Asia and South Africa for sub-Saharan Africa (UNESCO 2009; Bhandari, Belyavina, and Gutierrez 2011). In addition, several countries have set targets for increasing the numbers of international students they host; among these are Jordan (which plans to host 100,000 students by 2020), Singapore (150,000 by 2015), Japan (300,000 by 2025), and China (500,000 by 2020) (Bhandari and Belyavina 2012).

Some students migrate temporarily for education, whereas others remain abroad permanently after completing their studies. Some factors influencing the decision to seek a degree abroad include the policies of the countries of origin regarding sponsoring their citizens' studies abroad, the tuition fee policies of the countries of destination, the financial support the countries of destination offer to international students, the cost of living and exchange rates that affect the cost of international education, and the perceived value of obtaining a foreign credential. The long-term return on investment from international education also depends on how international degrees are recognized by the labor market in the country of origin (OECD 2010). For host countries, enrolling international students can help raise revenues from higher education and can be part of a larger strategy to attract highly skilled workers, particularly as demographic changes in many developed countries cause their own populations of college-age students to decrease (OECD 2012) (Appendix Table 2-42).

In recent years, many countries have expanded their provision of transnational education. One growing trend is the establishment of branch campuses: offshore programs established by higher education institutions in foreign countries. For local students, branch campuses provide the opportunity to earn degrees from foreign universities without leaving their home countries. For the institution venturing into a new country, meeting enrollment and financial goals without diluting quality standards is often a challenge. Branch campuses that bring in faculty from other countries can also fulfill some of the demand for highly qualified instructors that cannot be met by local higher education institutions (UNESCO/UIS 2014).

According to the State University of New York at Albany's Cross-Border Education Research Team (C-BERT) (Kinser and Lane 2015), a clearinghouse of information and research on transnational education, as of May 2015, there were 235 international branch campuses in operation and 23 with plans to open. C-BERT defines a branch campus as "an entity that is owned, at least in part, by a foreign education provider; is operated in the name of the foreign provider; engages in at least some face-to-face teaching; and provides access to an entire academic program that leads to a credential awarded by the foreign education provider." There were a total of 32 exporting countries (i.e., home countries of the institutions establishing branch campuses) and 73 importing countries (i.e., host countries for branch campuses). The largest exporters of branch campuses, in order of the number of branch campuses established, were the United States (83 branch campuses), the United Kingdom (34), Russia (20), Australia (17), and France (16). The largest importers of branch campuses, in order of the number of branch campuses they hosted, were the United Arab Emirates (33 branch campuses), China (28), Singapore (14), Qatar (11), and Malaysia (9). In some cases, branch campuses are a part of what countries designate as an international "education hub." Although there is no agreed-upon definition of "education hub," the term conveys the existence of cross-national education and research activities within a designated region. Examples of education hubs include Qatar, the United Arab Emirates, Abu Dhabi, Hong Kong, Malaysia, Singapore, and Botswana (Knight 2014; Kinser and Lane 2015).

More internationally mobile students (both undergraduate and graduate) go to the United States than to any other country (Figure 2-31). Other top destinations for international students include the United Kingdom (10%) Australia (6%), France (6%), and Germany (5%). Together with the United States, these countries receive about half of all internationally mobile students worldwide. Although the United States remains the destination for the largest number of internationally mobile students worldwide, its share in all fields has declined from 25% in 2000 to 19% in 2013 (OECD 2014).

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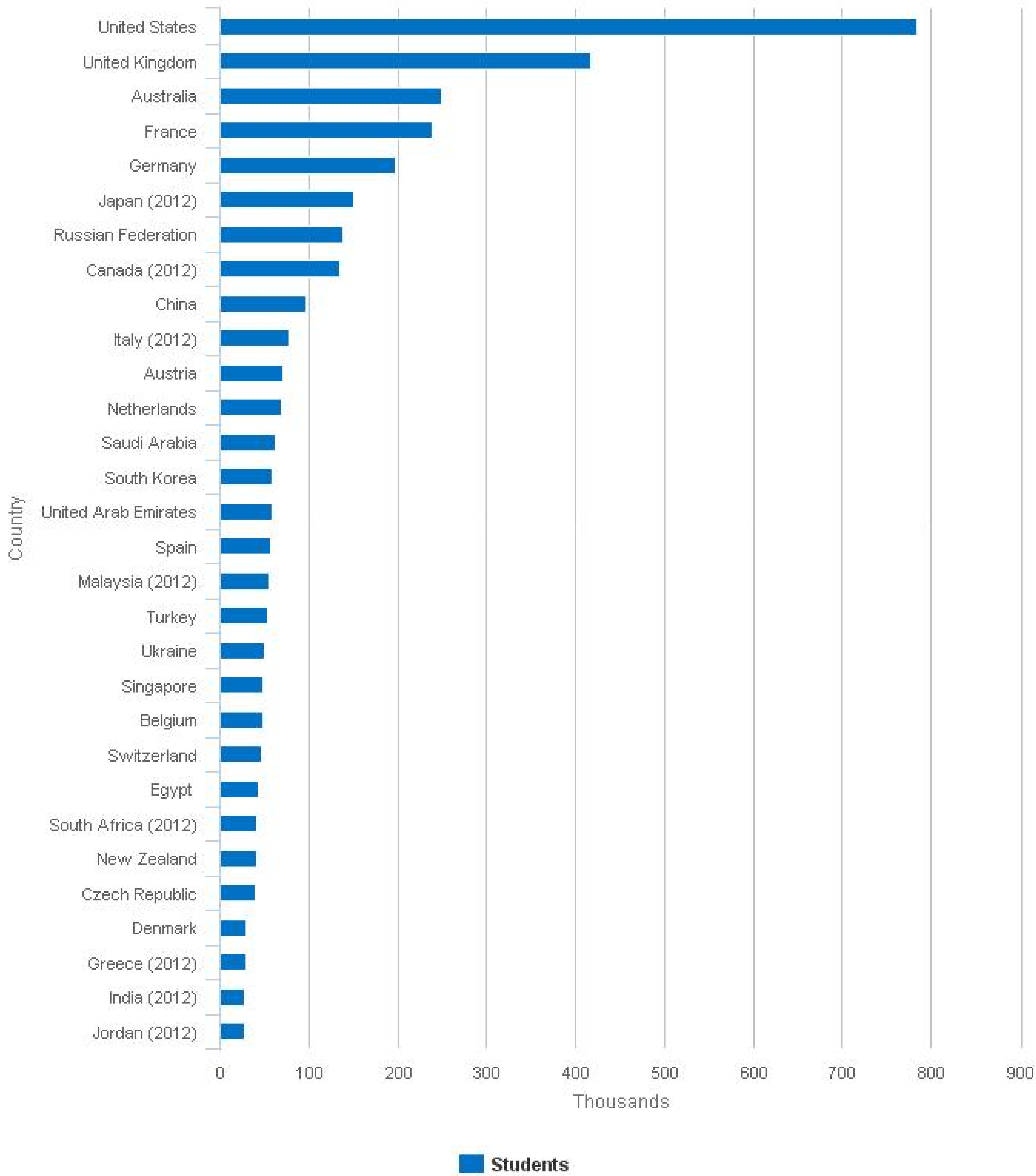
[i] This initiative is part of a broader effort from the Brazilian government to grant 100,000 scholarships to the best students to study abroad at the top universities around the world (IIE 2015a).

[ii] Internationally mobile students are those who have crossed a national or territorial border for the purposes of education and are now enrolled outside their country of origin. This concept is different from “foreign students,” which are those who are not citizens of the country where they are enrolled, but may, in some cases, be long-term residents or have been born in the country (OECD 2012).

Figure 2-31

Internationally mobile students enrolled in tertiary education, by selected country: 2013



NOTE: Data are based on the number of students who have crossed a national border and moved to another country with the objective of studying (i.e., mobile students).

SOURCE: United Nations Educational, Scientific and Cultural Organization Institute for Statistics database, special tabulations (2015).

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In the United States, international students are a small proportion (about 4%) of students enrolled in higher education (including both undergraduate and graduate levels); this proportion is higher at the graduate level. In other countries, the proportion of international students is much higher. Australia, with a much smaller higher education system than the United States, has a higher percentage of international students in tertiary-type A programs (19%) but a lower share (6%) of international students worldwide. Other countries with relatively high percentages of international students in tertiary-type A programs include the United Kingdom (18%), Austria (17%), Switzerland (17%), and New Zealand (13%).[iii] In Switzerland, more than 50% of doctoral students are international students, and in the United Kingdom, more than 41% of them are international students. Several other countries, including Belgium, New Zealand, Australia, the United States, Sweden, Canada, and Ireland have relatively high percentages (more than 20%) of doctoral students who are internationally mobile (OECD 2014).

Since the late 1990s, the United Kingdom has been actively working to improve its position in international education, by recruiting international students to study in the country and by expanding its provision of transnational education (British Council 2015; UKCISA 2013). Between 1995 and 2014, international student enrollment in S&E fields in the United Kingdom increased by nearly 51,000 international students at the undergraduate level and by close to 55,000 at the graduate level (Appendix Table 2-43), but the proportion of international students is much higher at the graduate than at the undergraduate level. For example, in 2013–14, international students were 14% of all undergraduates in the United Kingdom (an increase from 9% in 1994–95), compared with 48% at the graduate level (an increase from 29% in 1994–95). At the graduate level, international students accounted for 60% of graduate students in engineering and 56% in mathematics and computer sciences. Students from China accounted for most of the increase in international student enrollment, both at the graduate and the undergraduate levels. However, the number of undergraduate students from India, Hong Kong, Cyprus, and Nigeria, as well as the number of graduate students from Nigeria, India, Italy, Saudi Arabia, the United States, and Germany also increased considerably (Appendix Table 2-43).

In the context of slowing student enrollment in Japan, in 2008, the government announced plans to triple international enrollment within 12 years (McNeil 2008, 2010). Although Japan succeeded in increasing its enrollment of international students between 2004 and 2014 (in S&E and in all fields), growth has slowed considerably in the last 4 years (Appendix Table 2-44; appendix table [NSB 2012] 2-41; appendix table [NSB 2014] 2-45), perhaps caused in part by the March 2011 earthquake and tsunami (McNeil 2012). In 2014, nearly 70,000 international students were enrolled in S&E programs in Japanese universities, similar to the preceding 4 years and up from 57,000 in 2004. The number of international students in Japan was larger at the undergraduate than at the graduate level; however, international students accounted for a smaller proportion of students at the undergraduate than at the graduate level in 2014 (3% of undergraduate and 17% of graduate S&E students). The vast majority of the international students were from Asian countries. In 2014, Chinese students accounted for 65% of the international S&E undergraduate students and 56% of the international S&E graduate students in Japan. South Koreans were 18% of the international undergraduates and 7% of the international graduate students. Vietnam, Malaysia, Indonesia, Thailand, Taiwan, and Nepal were among the top 10 locations of origin for both undergraduates and graduate students (Appendix Table 2-44).

International students in Canada constitute a larger share of enrollment at the graduate than at the undergraduate level (Appendix Table 2-45). The proportion of international enrollment in Canadian universities has been growing, from 6% in 2002 to 8% in 2012 at the undergraduate level and from 20% to 24% at the graduate level. In 2012, at the undergraduate and graduate levels, the highest percentages of international S&E students were in mathematics and computer sciences and in engineering. At the undergraduate level, China was the top country of origin of international S&E students in Canada, accounting for 22% of international undergraduate students, followed by France and the United States (11% and 9%, respectively). The proportion of international undergraduate S&E students in Canada from China and France increased considerably between 2002 and 2012, while the proportion of students from the United States declined. At the graduate level, the top country of origin of international S&E students was also China (15%), followed by Iran and France (13% and 11%, respectively). The proportion of international graduate students from China declined, and the proportion of those from France and the United States remained stable. The proportion of Iranian S&E graduate students studying in Canada grew from 3% in 2002 to 13% in 2012; growth was higher in the natural sciences and in engineering.

Although the United States hosts the largest number of international students worldwide, U.S. students constitute a relatively small share of international students worldwide. About 70,000 U.S. students (in all fields) were reported as international students by OECD and OECD partner countries in 2012, far fewer than the number of international students from China, India, South Korea, Germany, Turkey, or France. The main destinations of U.S. students were the United Kingdom (16,600), Canada (9,600), Germany (4,300), France (3,900), New Zealand (3,200), and Australia (2,900)—mostly English-speaking OECD countries (OECD 2014). Given the relatively low number of U.S. students who study abroad and the importance of international experience in a globalized world, in 2014, IIE established Generation Study Abroad. This 5-year initiative has the goal to increase the number of U.S. students studying abroad, in credit and degree programs, to 600,000 by 2019 (IIE 2015b).

Nearly 290,000 U.S. university students enrolled in study abroad programs in the 2012–13 academic year (credit mobility—see Glossary), a 2% increase from the preceding year but an 88% rise from 2000–01 (IIE 2014). Nearly 40% were enrolled in programs during the summer term; about one-third enrolled in programs lasting one semester, 15% in short-term programs lasting up to 8 weeks, 3% for the academic or the calendar year, and the rest for one or two quarters or a month. Nearly three-quarters were undergraduates, primarily juniors and seniors; about 8% were master’s students, and 1% were doctoral students. Nearly two-thirds of the U.S. students studying abroad were women, and more than three-quarters were white. Nearly 40% were studying in S&E fields: 22% in social sciences, 9% in physical or life sciences, 4% in engineering, 2% in mathematics or computer sciences, and 1% in agricultural sciences; these proportions have been stable since 2000–01. The leading destinations for study abroad programs in the 2012–13 academic year were the United Kingdom, Italy, and Spain, followed by France and China.

According to a recent study conducted by IIE and Project Atlas (Belyavina, Li, and Bhandari 2013), in 2011–12, nearly 47,000 U.S. students were enrolled in academic degree programs in the 14 countries represented (degree mobility—see Glossary).[iv] The most frequent host countries for U.S. students pursuing degrees abroad were the United Kingdom (17,000), Canada (9,000), France (4,000), and Germany (4,000). Most students were enrolled in undergraduate or master’s degree programs (42% each), followed by doctoral programs (16%). Almost two-thirds of these students studied in anglophone countries; the top destination was the United Kingdom. Humanities, social sciences, business and management, and physical and life sciences were the most popular broad fields of study for students pursuing a degree abroad.

[iii] Luxembourg has a very high proportion of international students enrolled in tertiary-type A programs (34%) mostly because of the high level of integration with neighboring countries (OECD 2014).

[iv] The 14 countries represented in the study were Australia, Canada, China, Denmark, France, Germany, Ireland, Japan, Malaysia, New Zealand, the Netherlands, Spain, Sweden, and the United Kingdom.

Conclusion

S&E higher education in the United States is attracting growing numbers of students. The number of associate's, bachelor's, master's, and doctoral degrees awarded in all fields and in S&E fields continues to rise, having reached new peaks in 2013. Most of the growth in undergraduate S&E education occurred in science fields, particularly in the social and behavioral sciences and in the biological sciences. In engineering, bachelor's degrees have increased consistently for the last 10 years and have surpassed the record high numbers attained in the mid-1980s; graduate enrollment in engineering has reached record numbers. Computer sciences degree awards have increased continuously since 2009, after a steep decline in the mid- to late 2000s. The number of master's and doctoral degrees awarded grew in all major S&E fields. In the last decade, growth in doctoral degrees awarded occurred mostly in the natural sciences and engineering fields.

Community colleges play a key role in increasing access to higher education for all citizens. Many U.S. citizen and permanent resident degree holders report earning college credit from a community college. Nearly half of Hispanic undergraduates are enrolled in them. The expected demographic growth in number of Hispanic students between 20 and 24 years of age will affect community colleges and HHEs.

Over the last two decades, higher education spending and revenue patterns and trends have undergone substantial changes, which intensified during the recent economic downturn. Public institutions faced competing demands in a tight budget environment, caught between declining state appropriations and the need to maintain educational quality and access. Despite the decline in enrollment in 2011–12, net tuition per FTE student continued to increase with the decrease in revenues from state and local appropriations in public institutions, so challenges remain.

International student enrollment in S&E has recovered since the post-9/11 decline. In recent years, international student enrollment has increased considerably at the undergraduate and graduate levels, in both S&E and non-S&E fields.

Globalization of higher education continues to expand. Universities in several other countries have expanded their enrollment of international S&E students. The United States continues to attract the largest number and fraction of internationally mobile students worldwide, although its share of international students in all fields has decreased in recent years.

Higher education is undergoing rapid transformation. The growth of distance and online education through MOOCs and similar innovations expands access to knowledge and has the potential to decrease the cost of some degrees, at the same time as pressures have been increasing to reduce rising costs. However, it is too early to assess whether MOOCs will be widely adopted by different types of institutions, whether increased access will be accompanied by increased learning, and what consequences distance and online innovations will bring to the higher education landscape.

Glossary

Baccalaureate-origin institution: The college or university from which an S&E doctorate recipient earned a bachelor's degree.

Credit mobility: Temporary tertiary education within the framework of enrollment in a tertiary education program at a home institution (usually) for the purpose of gaining academic credit (i.e., credit that will be recognized in that home institution). It is mostly used for study, but it can also take other forms, such as traineeships.

Degree mobility: The physical crossing of a national border to enroll in a degree program at the tertiary level in the country of destination. The degree program would require the students' presence for the majority of courses taught.

European Union (EU): As of September 2015, the EU comprised 28 member nations: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom. Unless otherwise noted, Organisation for Economic Co-operation and Development data on the EU include all of these 28 members.

First university degree: A terminal undergraduate degree program; these degrees are classified as "level 5A first university degree" in the International Standard Classification of Education, which is developed by UNESCO, although individual countries use different names for the first terminal degree (e.g., *corso di Laurea* in Italy, *diplom* in Germany, *licence* in France, and *bachelor's degree* in the United States and in Asian countries).

Internationally mobile students: Students who have crossed a national or territorial border for purposes of education and are now enrolled outside their countries of origin. This term refers to degree mobility in data collected by UNESCO/UIS, OECD, and Eurostat and excludes students who travel for credit mobility.

Natural sciences: Include agricultural; biological; computer; earth, atmospheric, and ocean; and physical sciences and mathematics.

Net price: The published price of an undergraduate college education minus the average grant aid and tax benefits that students receive.

Net tuition revenue: Total revenue from tuition and fees (including grant and loan aid used by students to pay tuition); excludes institutional student aid that is applied to tuition and fees.

Tertiary-type A programs: Higher education programs that are largely theory based and designed to provide sufficient qualifications for entry to advanced research programs and to professions with high skill requirements, such as medicine, dentistry, or architecture. These programs have a minimum duration of 3 years, although they typically last 4 or more years and correspond to bachelor's or master's degrees in the United States.

Tertiary-type B programs: Higher education programs that focus on practical, technical, or occupational skills for direct entry into the labor market and have a minimum duration of 2 years. These programs correspond to associate's degree programs in the United States.

Underrepresented minorities: Blacks, Hispanics, and American Indians and Alaska Natives are considered to be underrepresented minorities in S&E.

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Chapter 3.

Science and Engineering Labor Force

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Highlights

U.S. S&E Workforce: Definition, Size, and Growth

The S&E workforce can be defined in several ways: by workers in S&E occupations, by holders of S&E degrees, or by the use of S&E technical expertise on the job. The estimated size of the S&E workforce varies depending on the definitional criteria chosen.

- In 2013, estimates of the size of the S&E workforce ranged from approximately 6 million to more than 21 million depending on the definition used.
- In 2013, an estimated 5.7 million college graduates were employed in S&E occupations in the United States. The largest S&E occupations were computer and mathematical sciences (2.6 million), followed by engineering (1.6 million). Occupations in life sciences (638,000), social sciences (581,000), and physical sciences (319,000) combined to about the size of the engineering component.
- In 2013, about 21.1 million individuals in the United States had a bachelor's or higher level degree in an S&E field of study. The majority (15.8 million) held their highest level of degree (bachelor's, master's, professional, or doctorate) in an S&E field. Of these highest degrees, the most common fields were social sciences (6.4 million) and engineering (3.4 million). Computer and mathematical sciences (2.6 million), life sciences (2.4 million), and physical sciences (956,000) together were slightly less than the size of the social sciences component.
- Not all S&E degree holders work in jobs formally designated as S&E occupations. The number of college-educated individuals reporting that their jobs require at least a bachelor's degree level of technical expertise in S&E (17.7 million) is substantially higher than the number employed in S&E occupations (nearly 6 million), suggesting that the application of S&E knowledge and skills is widespread across the technologically sophisticated U.S. economy and not limited to jobs classified as S&E.

The S&E workforce has grown steadily over time.

- Between 1960 and 2013, the number of workers in S&E occupations grew at an average annual rate of 3%, compared to the 2% growth rate for the total workforce.
- Data from more recent years indicate that trends in S&E employment compared favorably to overall employment trends during and after the 2007–09 economic downturn. Between 2008 and 2014, the number of workers employed in S&E occupations rose by about half a million, whereas the total workforce stayed relatively steady.

S&E Workers in the Economy

Scientists and engineers work for all types of employers.

- The vast majority of scientists and engineers (individuals trained or employed in S&E) are employed in the business sector (70%), followed by the education (19%) and government (11%) sectors. Within the business sector, for-profit businesses employ the bulk of scientists and engineers.
- Among individuals with S&E doctorates, the proportion working in the business sector (46%) is similar to the proportion working in the education sector (45%). Within the education sector, over 90% work in 4-year colleges and universities, including those in postdoctoral and other temporary positions.

- The vast majority of educational institutions and government entities that employ scientists and engineers are large employers (i.e., having 100 or more employees). In contrast, scientists and engineers working in the business sector are distributed across firms of different sizes.
- Within the business sector, the industry with the largest number of workers in S&E occupations is professional, scientific, and technical services.
- Employment in S&E occupations is geographically concentrated in the United States. The 20 metropolitan areas with the largest proportion of the workforce employed in S&E occupations in 2014 accounted for 18% of nationwide S&E employment, compared to 8% of all employment.

S&E Labor Market Conditions

Whether measured by S&E occupation or degree, S&E workers have higher earnings than other comparable workers.

- Half of the workers in S&E occupations earned $81,000 or more in 2014, which is more than double the median salaries ($36,000) of the total workforce.
- Employed college graduates with a highest degree in S&E earn more than those with non-S&E degrees (median salaries in 2013 were $65,000 and $52,000, respectively). For the most part, the earnings premium associated with an S&E degree is present across early, mid, and later career stages.

The S&E labor force is less likely than others to experience unemployment.

- Unemployment rates for college-educated individuals in S&E occupations tend to be lower than those for all college graduates and much lower than those for the overall labor force: In February 2013, about 3.8% of scientists and engineers and 4.3% of all college-educated individuals in the labor force were unemployed, about half the official unemployment rate for the entire U.S. labor force (8.1%).
- Unemployment rates for S&E doctorate holders (2.3%) are even lower than for those at other degree levels (4.2% and 3.7% among S&E bachelor's and master's degree holders, respectively).

Demographics of the S&E Workforce

Mirroring U.S. population trends, the S&E labor force is aging. Additionally, a larger proportion of older scientists and engineers remain in the labor force in 2013 than in 1993.

- The median age of scientists and engineers in the labor force was 43 years in 2013, compared to 41 years in 1993.
- Between 1993 and 2013, an increasing percentage of scientists and engineers in their 60s reported that they were still in the labor force. Whereas 54% of scientists and engineers between the ages of 60 and 69 were in the labor force in 1993, the comparable percentage rose to 64% in 2013.

Women remain underrepresented in the S&E workforce, but less so than in the past.

- In 2013, women constituted 50% of the college-educated workforce, 39% of employed individuals whose highest degree was in an S&E field, and 29% of those in S&E occupations. The corresponding 1993 shares were 43%, 31%, and 23%, respectively.

- Women employed in S&E occupations are concentrated in different occupational categories than men, with relatively high proportions in social sciences (62%) and life sciences (48%) and relatively low proportions in engineering (15%), physical sciences (31%), and computer and mathematical sciences (25%).

Historically underrepresented racial and ethnic groups, particularly blacks and Hispanics, continue to be part of the S&E workforce at rates lower than their presence in the U.S. population, whereas Asians and foreign-born individuals are represented in the S&E workforce at higher rates.

- Hispanics, blacks, and American Indians or Alaska Natives together make up 27% of the U.S. population age 21 and older but a much smaller proportion of the S&E workforce: 14% of S&E highest degree holders and 11% of workers in S&E occupations.
- Conversely, Asians make up 5% of the U.S. population age 21 and older but account for 17% of those employed in S&E occupations. Asians have a large presence in engineering and computer sciences occupations, particularly among computer software and hardware engineers, software developers, bioengineers or biomedical engineers, and postsecondary teachers in engineering.
- About 70% of workers in S&E occupations are non-Hispanic whites, which is comparable to their overall representation in the U.S. population age 21 and older (66%).
- Foreign-born individuals account for 27% of all workers in S&E occupations, which is substantially higher than their share of the entire college-educated workforce (15%).
- Foreign-born workers employed in S&E occupations tend to have higher levels of education than their U.S. native-born counterparts.

A variety of indicators point to a decline, albeit temporary, in the immigration of scientists and engineers during the 2007–09 economic downturn.

- Declines in temporary work visas issued to high-skill workers during the 2007–09 economic downturn have reversed in recent years. Issuance of new H-1B visas has shown continued increase since 2009 and by 2014 exceeded the pre-recession levels. In some other temporary work visa categories, however, the issuance of new visas in 2014 remained below pre-recession levels.
- After rising for most of the decade 2000–09, the number of foreign recipients of U.S. S&E doctoral degrees declined in 2009 and 2010. It has risen since 2011 and now exceeds pre-recession levels.
- About two-thirds of temporary visa holders earning a U.S. S&E doctorate remain in the United States at least 5 years. This proportion reached 67% in 2005, declined during the economic downturn, and then rose to 66% in 2011.

Global S&E Labor Force

Worldwide, the number of workers engaged in research has been growing.

- Among countries with large numbers of researchers—defined as workers engaged in the creation and development of new knowledge, products, and processes—growth since 2000 has been most rapid in China and South Korea.
- The United States and the European Union experienced steady growth but at lower rates than China or South Korea.
- Russia and, to some extent, Japan were exceptions to the worldwide trend. Between 2000 and 2013, the number of researchers in Japan rose very slightly; in Russia, the number declined.

Introduction

Chapter Overview

Policymakers and scholars consistently emphasize innovation based on S&E research and development as a vehicle for a nation's economic growth and global competitiveness. In the increasingly interconnected 21st century world, workers with S&E expertise are integral to a nation's innovative capacity because of their high skill level, their creative ideas, and their ability not only to advance basic scientific knowledge but also to transform advances in fundamental knowledge into tangible and useful products and services. As a result, these workers make important contributions to improving living standards and accelerating the pace of a nation's economic and productivity growth.

Chapter Organization

The U.S. workforce includes both individuals employed in S&E occupations and individuals educated in S&E fields but employed in a variety of non-S&E occupations. Many more individuals have S&E degrees than work in S&E occupations. Indicative of a knowledge-based economy, many individuals in non-S&E occupations reported that their work nevertheless requires a bachelor's degree level of S&E expertise. Therefore, the first section in this chapter, "U.S. S&E Workforce: Definition, Size, and Growth," discusses the S&E workforce based on three measures: workers in S&E occupations, holders of S&E degrees, and use of S&E technical expertise on the job. This section also discusses the interplay between educational background and occupational choice.

The second section in this chapter, "S&E Workers in the Economy," examines the distribution of S&E workers across employment sectors. It describes the distribution of S&E workers across sectors (e.g., business, education, government) as well as within particular sectors (e.g., local, state, and federal government). This section also presents data on geographic distribution of S&E employment in the United States. Data on R&D activity and work-related training by S&E workers are also discussed.

The third section, "S&E Labor Market Conditions," looks at labor market outcomes for S&E workers. Data in this section focus on earnings and unemployment, with a particular focus on recent S&E graduates.

The next three sections cover labor force demographics. "Age and Retirement of the S&E Workforce" presents data on the age distribution and retirement patterns of S&E workers. "Women and Minorities in the S&E Workforce" focuses on S&E participation by women and by racial and ethnic minorities; this section also presents data on salary differences by sex and by race and ethnicity. "Immigration and the S&E Workforce" presents data on S&E participation by foreign-born individuals in the United States.

The final section in this chapter is "Global S&E Labor Force." Although there are indications that the global S&E labor force has grown, international data on the characteristics of this broader labor force are particularly limited and are not always comparable with data for the United States. In this final section, data from the Organisation for Economic Co-operation and Development (OECD) are used to present indicators of worldwide R&D employment.

This chapter uses a variety of data sources, including, but not limited to, the National Science Foundation's (NSF's) Scientists and Engineers Statistical Data System (SESTAT), the Census Bureau's American Community Survey (ACS), the Occupational Employment Statistics (OES) survey administered by the Bureau of Labor Statistics (BLS), and the Current Population Survey (CPS) sponsored jointly by the Census Bureau and BLS. Different sources cover different segments of the population and different levels of detail on the various topics. (See Table 3-1 and sidebar, NSF's Scientists and Engineers Statistical Data System) Although data collection methods and definitions can differ across surveys in ways that affect estimates, combining data from different sources facilitates an accurate and comprehensive picture of the very specialized S&E workforce. A particular measure or categorization of the workforce may be better suited for addressing some questions than others, and a particular data source may not include information in every category. Analyses of long-term trends, international trends, and comparison of S&E and non-S&E workers are discussed whenever data are available.

NSF's Scientists and Engineers Statistical Data System

NSF's Scientists and Engineers Statistical Data System (SESTAT) provides detailed employment, education, and demographic data for scientists and engineers under age 76 residing in the United States. SESTAT currently defines scientists and engineers as individuals who have college degrees in S&E or S&E-related fields or who are working in S&E or S&E-related occupations. (See Table 3-2 for definitions of S&E and S&E-related occupations.) Unless otherwise noted, this chapter uses the term "scientists and engineers" to refer to this broad SESTAT population and the term "college graduates" to refer to the population with at least a bachelor's level degree. Data available through SESTAT are collected by two large demographic and workforce surveys of individuals conducted by NSF: the National Survey of College Graduates (NSCG) and the Survey of Doctorate Recipients (SDR). SESTAT integrates the data from the two surveys, and together the data provide a comprehensive picture of scientists and engineers in the United States.

The NSCG is the central component of SESTAT, providing data that detail the characteristics of the entire bachelor's degree holder population in the United States (regardless of their S&E background). Its population of college graduates includes individuals trained as scientists and engineers who hold at least a bachelor's degree. Because it covers the entire college graduate population residing in the United States, the NSCG provides information on individuals educated or employed in S&E fields as well as those educated or employed in non-S&E fields. The data presented in this chapter for all college graduates (regardless of S&E background) are mostly based on the NSCG.

Whereas NSCG data cover the general college-educated population, the SDR data add to SESTAT doctoral scientists and engineers who earned their research doctoral degree in a science, engineering, or health (SEH) field from a U.S. academic institution. The SDR is a longitudinal biennial survey that has been conducted since 1973. The survey follows a sample of SEH doctoral degree holders from the year of their U.S. doctoral degree award until age 76. The panel is refreshed each survey cycle with a sample of new SEH doctoral degree recipients.

For more information on SESTAT, see http://www.nsf.gov/statistics/sestat/

Table 3-1 Major sources of data on the U.S. labor force

Data source	Data collection agency	Data years	Major topics	Respondent	Coverage
			Worker occupation		All full-time and part-time wage and

Data source	Data collection agency	Data years	Major topics	Respondent	Coverage
Occupational Employment Statistics (OES), http://www.bls.gov/oes/	Department of Labor, Bureau of Labor Statistics	Through 2014	Salary Industry Employer location (national, state, metropolitan statistical area)	Employing organizations	salary workers in nonfarm industries; does not cover self-employed, owners and partners in unincorporated firms, household workers, or unpaid family workers
Scientists and Engineers Statistical Data System, http://sestat.nsf.gov. See sidebar "NSF's Scientists and Engineers Statistical Data System"	National Science Foundation, National Center for Science and Engineering Statistics	Through 2013	Employment status Occupation Job characteristics (work activities, technical expertise) Salary Detailed educational history Demographic characteristics	Individuals	Individuals with bachelor’s degree or higher in S&E or S&E-related field or with non-S&E degrees but working in S&E or S&E-related occupation
American Community Survey (ACS), http://www.census.gov/acs/www/	Department of Commerce, Census Bureau	Through 2013	Employment status Occupation First bachelor’s degree field Educational attainment Demographic characteristics	Households	U.S. population
			Employment status		

Data source	Data collection agency	Data years	Major topics	Respondent	Coverage
Current Population Survey (CPS), http://www.census.gov/cps/	Department of Labor, Bureau of Labor Statistics	Through 2015	Occupation Educational attainment Demographic characteristics	Households	Civilian noninstitutional population age 16 or over

Science and Engineering Indicators 2016

U.S. S&E Workforce: Definition, Size, and Growth

Definition of the S&E Workforce

Because there is no standard definition of S&E workers, this section presents multiple categorizations for measuring the size of the S&E workforce.[i] In general, this section defines the S&E workforce to include people who either work in S&E occupations or hold S&E degrees. However, the application of S&E knowledge and skills is not limited to jobs classified as S&E; the number of workers reporting that their jobs require at least a bachelor's degree level of knowledge in one or more S&E fields exceeds the number of jobs in the economy with a formal S&E label. Therefore, this section also presents data on the use of S&E technical expertise on the job to provide an estimate of the S&E workforce. The estimated number of scientists and engineers varies based on the criteria applied to define the S&E workforce.

U.S. federal occupation data classify workers by the activities or tasks they primarily perform in their jobs. The NSF and Census Bureau occupational data in this chapter come from federal statistical surveys in which individuals or household members provide information about job titles and work activities. This information is used to classify jobs into standard occupational categories based on the Standard Occupational Classification (SOC) system.[ii] In contrast, the BLS-administered OES survey relies on employers to classify their workers using SOC definitions. Differences between employer- and individual-provided information can affect the content of occupational data.

NSF has developed a widely used set of SOC categories that it calls *S&E occupations*. Very broadly, these occupations include life scientists, computer and mathematical scientists, physical scientists, social scientists, and engineers. NSF also includes postsecondary teachers of these fields in S&E occupations. A second category of occupations, *S&E-related occupations*, includes health-related occupations, S&E managers, S&E technicians and technologists, architects, actuaries, S&E precollege teachers, and postsecondary teachers in S&E-related fields. The S&E occupations are generally assumed to require at least a bachelor's degree level of education in an S&E field. The vast majority of S&E-related occupations also require S&E knowledge or training, but an S&E bachelor's degree may not be a required credential for employment in some of these occupations. Examples include health technicians and computer network managers. Other occupations, although classified as *non-S&E occupations,* may include individuals who use S&E technical expertise in their work. Examples include technical writers who edit scientific publications and salespeople who sell specialized research equipment to chemists and biologists. The NSF occupational classification of S&E, S&E-related, and non-S&E occupations appears in Table 3-2 along with the NSF educational classification of S&E, S&E-related, and non-S&E degree fields.

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[i] The standard definition of the term *labor force* is a subset of the population that includes both those who are employed and those who are not working but seeking work (unemployed); other individuals are not considered to be in the labor force. Unless otherwise noted, when data refer only to employed persons, the term *workforce* is used. For data on unemployment rates by occupation, calculations assume that unemployed individuals are seeking further employment in their most recent occupation.

[ii] The SOC is used by federal statistical agencies to classify workers into occupational categories for the purpose of collecting, calculating, and disseminating data. Detailed information on the SOC is available at http://www.bls.gov/SOC/.

Table 3-2 **Classification of degree fields and occupations**

			Occupation classification	
Classification	Degree field	Occupation	STEM	S&T
S&E	Biological, agricultural, and environmental life sciences	Biological, agricultural, and environmental life scientists	X	X
	Computer and mathematical sciences	Computer and mathematical scientists	X	X
	Physical sciences	Physical scientists	X	X
	Social sciences	Social scientists	X	X
	Engineering	Engineers	X	X
		S&E postsecondary teachers		
S&E-related	Health fields	Health-related occupations		
	Science and math teacher education	S&E managers	X	
		S&E precollege teachers		
	Technology and technical fields	S&E technicians and technologists	X	X
	Architecture	Architects		
	Actuarial science	Actuaries		
		S&E-related postsecondary teachers		
Non-S&E	Management and administration	Non-S&E managers		
		Management-related occupations		
	Education (except science and math teacher education)	Non-S&E precollege teachers		
		Non-S&E postsecondary teachers		
	Social services and related fields	Social services occupations		
	Sales and marketing	Sales and marketing occupations		
	Arts and humanities	Arts and humanities occupations		
	Other fields	Other occupations		

NOTES: S&T = science and technology; STEM = science, technology, engineering, and mathematics.
The designations STEM and S&T refer to occupations only. For more detailed classification of occupations and degrees by S&E, S&E-related, and non-S&E, see National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT), http://sestat.nsf.gov.

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Indicative of a knowledge-based economy, the number of individuals who have S&E training or who reported applying S&E technical expertise in their jobs exceeds the number of individuals employed in jobs that are categorized as S&E. As such, a relatively narrow definition of the S&E workforce consists of workers in occupations that NSF designates as S&E occupations. In comparison, a much broader definition of an S&E worker, utilized by NSF's SESTAT, includes any individual with a bachelor's or higher level degree in an S&E or S&E-related field of study or a college graduate in any field employed in an S&E or S&E-related occupation. (See sidebar, NSF's Scientists and Engineers Statistical Data System.) As noted earlier, the S&E workforce may also be defined by the technical expertise or training required to perform a job. Unlike information on occupational categories or educational credentials, information on the use of technical knowledge, skills, or expertise in a person's job reflects that individual's subjective opinion about the content and characteristics of the job.[iii] The next section provides estimates of the size of the S&E workforce using all three definitions.

Other general terms, including science, technology, engineering, and mathematics (STEM), science and technology (S&T), and science, engineering, and technology (SET), are often used to designate the part of the labor force that works with S&E. These terms are broadly equivalent and have no standard definition.

[iii] As expected, this subjective measure varies across occupations. For example, in 2013, among postsecondary teachers of chemistry, 96% said that their job required at least a bachelor's degree level of knowledge in engineering, computer sciences, mathematics, or natural sciences. Among postsecondary teachers of business commerce or marketing, 84% said that their job required at least this level of expertise in other fields such as health, business, or education. Among the SESTAT population whose occupation is secretary/receptionist/typist, only about 5% said that their job required a bachelor's degree level of knowledge in engineering, computer sciences, mathematics, or natural sciences; about 5% said that their job required at least a bachelor's degree level of knowledge in social sciences; and 17% said that their job required at least a bachelor's degree level of expertise in other fields such as health, business, or education.

Size of the S&E Workforce

When defined by occupation, the S&E workforce totals between 6.2 million and 6.3 million people according to the most recent estimates (Table 3-3). Those in S&E occupations who had at least a bachelor's degree are estimated at between 4.6 million and 5.7 million (Table 3-3).[i] By far the largest categories of S&E occupations are in computer and mathematical sciences and engineering, which together account for about 73% (among college-educated workers) to 84% (among workers of all education levels) of all employed workers in S&E occupations (Figure 3-1). Occupations in life, social, and physical sciences each employ a smaller proportion of S&E workers.

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[i] Estimates of the size of the S&E workforce may vary across the different surveys because of differences in the scope of the data collection (SESTAT surveys collect data from individuals with at least a bachelor's degree); because of the type of survey respondent (SESTAT surveys collect data from individuals, OES collects data from employers, and ACS collects data from households); or because of the level of detail collected on an occupation, which aids in classifying a reported occupation into a standard occupational category. For example, the SESTAT estimate of the number of workers in S&E occupations includes postsecondary teachers of S&E fields; however, postsecondary teachers in ACS are grouped under a single occupation code regardless of field and are therefore not included in the ACS estimate of the number of workers in S&E occupations.

Table 3-3 Measures and size of U.S. S&E workforce: 2013 and 2014

Measure	Education coverage	Data source	Number of individuals
Occupation			
Employed in S&E occupations	All education levels	2014 BLS OES Survey	6,319,000
Employed in S&E occupations	Bachelor's and above	2013 NSF/NCSES SESTAT	5,749,000
Employed in S&E occupations	All education levels	2013 Census Bureau ACS	6,197,000
Employed in S&E occupations	Bachelor's and above	2013 Census Bureau ACS	4,630,000
Education			
At least one degree in S&E field	Bachelor's and above	2013 NSF/NCSES SESTAT	21,121,000
Highest degree in S&E field	Bachelor's and above	2013 NSF/NCSES SESTAT	15,811,000
Job closely related to highest degree	Bachelor's and above	2013 NSF/NCSES SESTAT	5,847,000
S&E occupation	Bachelor's and above	2013 NSF/NCSES SESTAT	3,033,000
Other occupation	Bachelor's and above	2013 NSF/NCSES SESTAT	2,814,000
Job somewhat related to highest degree	Bachelor's and above	2013 NSF/NCSES SESTAT	3,716,000
S&E occupation	Bachelor's and above	2013 NSF/NCSES SESTAT	1,050,000
Other occupation	Bachelor's and above	2013 NSF/NCSES SESTAT	2,665,000
Job requires S&E technical expertise at bachelor's level			
In one or more S&E fields	Bachelor's and above	2013 NSF/NCSES SESTAT NSCG	17,655,000
Engineering, computer science, mathematics, or natural sciences	Bachelor's and above	2013 NSF/NCSES SESTAT NSCG	12,649,000
Social sciences	Bachelor's and above	2013 NSF/NCSES SESTAT NSCG	8,094,000

NOTES: ACS = American Community Survey; BLS = Bureau of Labor Statistics; NSCG = National Survey of College Graduates; NSF/NCSES = National Science Foundation, National Center for Science and Engineering Statistics; OES = Occupational Employment Statistics; SESTAT = Scientists and Engineers Statistical Data System.

Estimates of the S&E workforce vary across the example surveys because of differences in the scope of the data collection (SESTAT surveys collect data from individuals with bachelor's degrees and above only);

	because of the survey respondent (SESTAT surveys collect data from individuals, OES collects data from establishments, and ACS collects data from households); or because of the level of detail collected on an occupation, which aids in classifying a reported occupation into a standard occupational category. All of these differences can affect the estimates. For example, the SESTAT estimate of the number of workers in S&E occupations includes postsecondary teachers of S&E fields; however, postsecondary teachers in ACS are grouped under a single occupation code regardless of field and are therefore not included in the ACS estimate of the number of workers in S&E occupations. The total for "at least one degree in S&E field" and "highest degree in S&E field" includes individuals who are employed as well as those who are unemployed and out of the labor force.
SOURCES:	BLS, OES Survey (2014); Census Bureau, ACS (2013); NSF/NCSES, NSCG (2013) and SESTAT (2013) integrated file.
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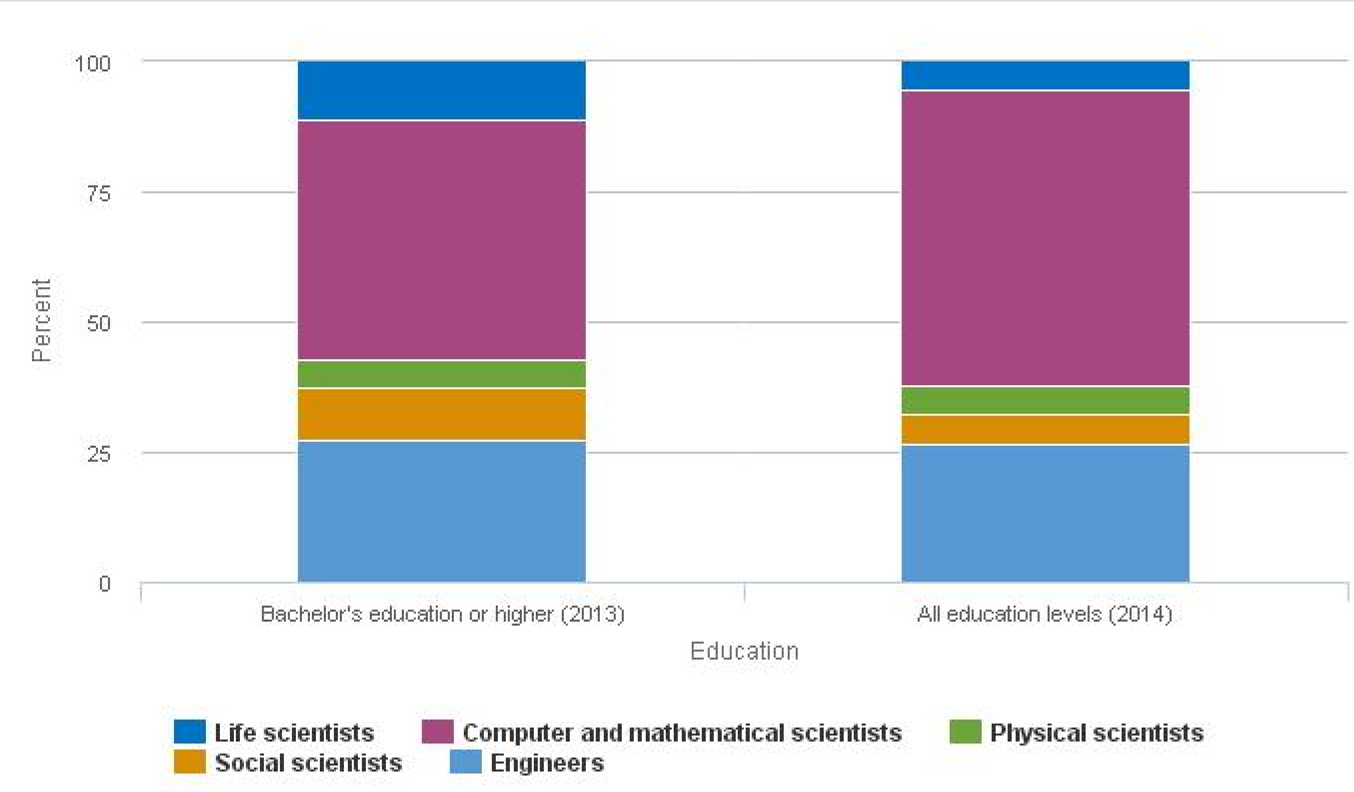
Figure 3-1

Employment in S&E occupations, by broad occupational category: 2013 and 2014



SOURCES: Bureau of Labor Statistics, Occupational Employment Statistics Survey, 2014; National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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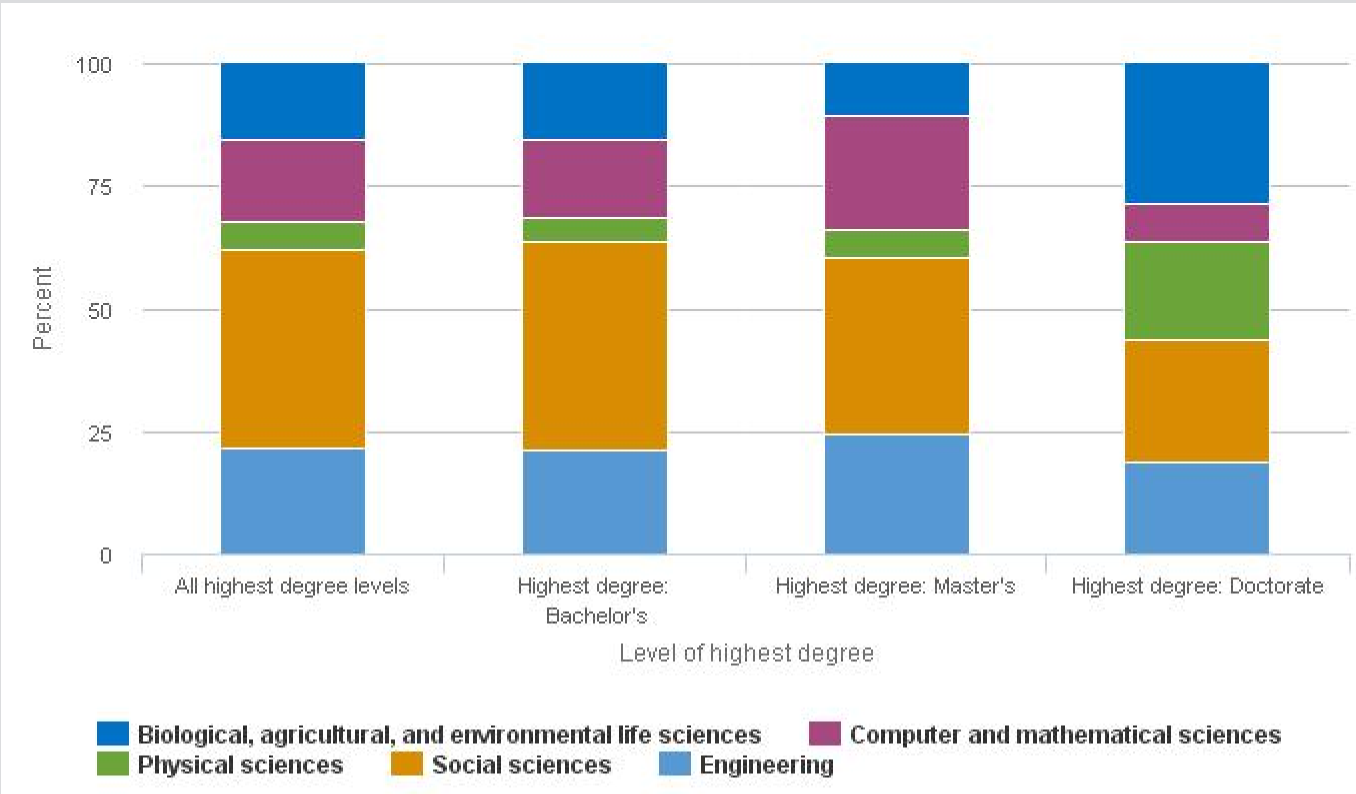
As noted earlier, S&E degree holders greatly outnumber those currently employed in S&E occupations. In 2013, about 21 million college graduates in the United States had a bachelor's or higher level degree in an S&E field of study (Table 3-3). About three-fourths of these college graduates (15.8 million) attained their highest degree—a bachelor's, master's, professional, or doctorate—in an S&E field (in this chapter, these individuals are referred to as S&E highest degree holders). An individual's highest degree is often an accurate representation of the skills and credentials that one employs in the labor market, which is why the data presented in this chapter by educational attainment are generally provided for highest degree. Overall, across all S&E highest degrees, social sciences and engineering were the most common degree fields (Figure 3-2).[ii] The 15.8 million with an S&E highest degree includes 11.4 million with bachelor's degrees, 3.3 million with master's degrees, 1.0 million with doctorates, and 52,000 with professional degrees.

[ii] Among those with doctorates in an S&E field, life sciences and social sciences were the most common fields, followed by physical sciences, engineering, and computer and mathematical sciences.

Figure 3-2

S&E degrees among college graduates, by field and level of highest degree: 2013



NOTE: All degree levels includes professional degrees not shown separately.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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A majority of S&E degree holders (60%) reported that their job was either closely or somewhat related to their field of highest degree (Table 3-3). Because many of these individuals were employed in occupations not categorized as S&E, this suggests that the application of S&E knowledge and skills is widespread across the U.S. economy and not limited to occupations classified as S&E.

The extensive use of S&E expertise in the workplace is also evident from the number of college graduates who indicate that their job requires technical expertise at the bachelor's degree level in S&E fields. According to the 2013 National Survey of College Graduates (NSCG), nearly 17.7 million college graduates reported that their jobs required at least this level of technical expertise in one or more S&E fields (Table 3-3); this figure is almost three times as large as the nearly 6 million college graduates employed in S&E occupations.

Growth of the S&E Workforce

The S&E workforce has grown faster over time than the overall workforce. According to Census Bureau data, employment in S&E occupations grew from about 1.1 million in 1960 to about 6.2 million in 2013 (Figure 3-3).[i] This represents an average annual growth rate of 3%, compared to a 2% growth rate in total employment during this period. S&E occupational employment as a share of total employment doubled: from about 2% in 1960 to about 4% in 2013. See sidebar, Projected Growth of Employment in S&E Occupations for BLS data on occupational projections for the period 2012–22.

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[i] The data on S&E employment levels for 1960 and 2013 are calculated using the Census Bureau's 1960 Decennial Census and 2013 American Community Survey (ACS) microdata, respectively, adjusted by the Integrated Public Use Microdata Series (IPUMS) from the University of Minnesota's Minnesota Population Center (http://www.ipums.org). Occupational classification systems have changed over time, which limits the comparability of occupational counts over time. For example, computer occupations were not present in the occupational classification system used in 1960. For more information on the change in occupational classification systems, see Wyatt and Hecker's report, "Occupational Changes During the 20th Century" (*Monthly Labor Review*, March 2006). S&E employment levels for 1960 and 2013 include workers at all education levels and do not include S&E postsecondary teachers. Although the 1960 Decennial Census data allow for separate identification of S&E postsecondary teachers, the 2013 ACS data aggregate all postsecondary teachers into one occupation code and therefore do not allow for separate identification of S&E postsecondary teachers. For 1960, including S&E postsecondary teachers would increase the number of workers employed in S&E occupations to nearly 1.2 million. See Appendix Table 3-1 for a list of S&E occupations in the 1960 Decennial Census and 2013 ACS.

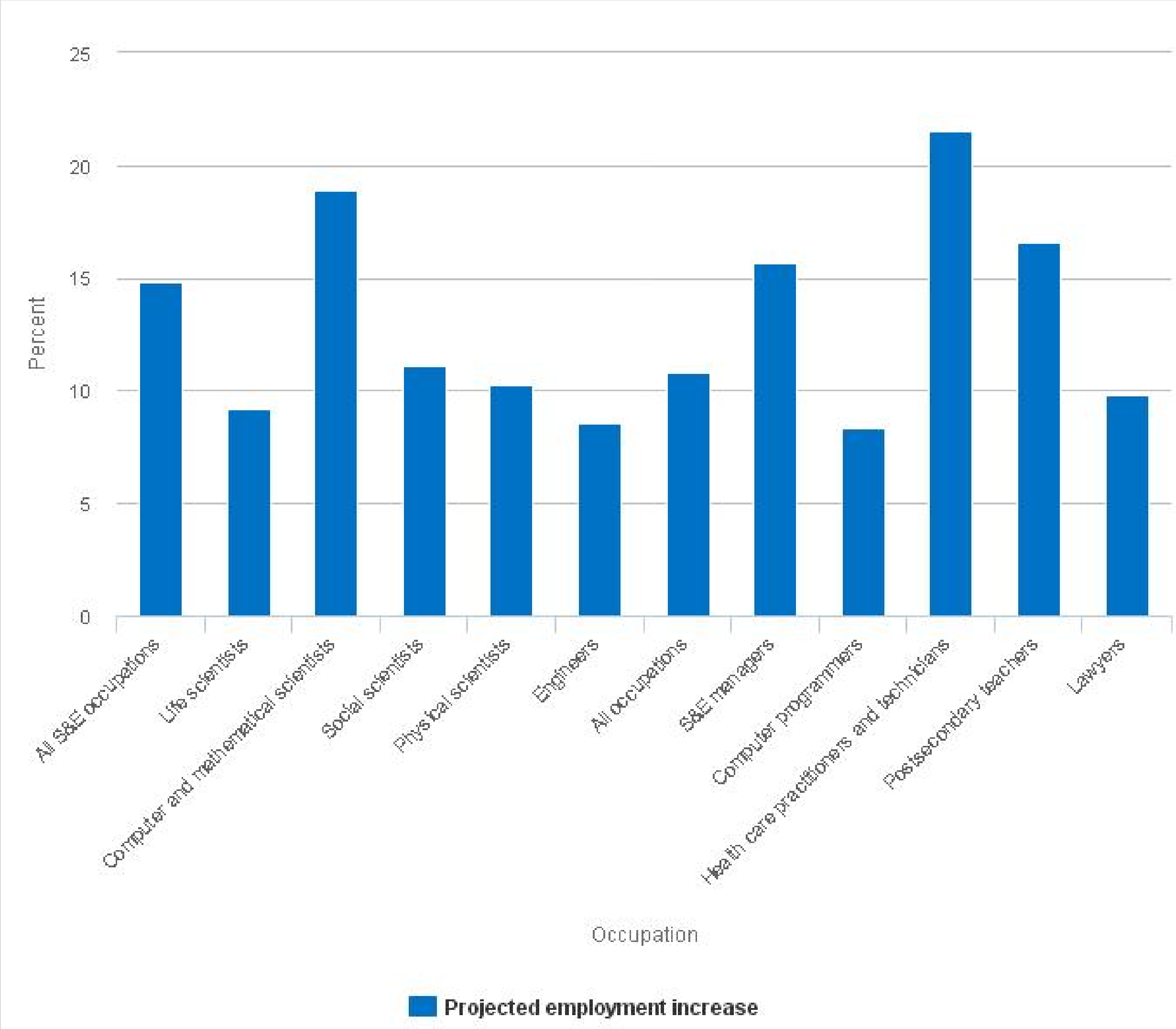
Projected Growth of Employment in S&E Occupations

This sidebar presents the most recent data from the Bureau of Labor Statistics (BLS) on occupational projections for the period 2012–22. While interpreting the data, it should be kept in mind that employment projections are uncertain. Many industry and government decisions that affect hiring are closely linked to national and global fluctuations in aggregate economic activity, which are difficult to forecast long in advance. In addition, technological and other innovations will influence demand for workers in specific occupations. The assumptions underlying projections are sensitive to fundamental empirical relationships, and, as a result, may become less accurate as overall economic conditions change.*

BLS occupational projections for the period 2012–22 suggest that total employment in occupations that NSF classifies as S&E will increase at a faster rate (15%) than employment in all occupations (11%) (Figure 3-A; Table 3-A). These projections are based only on the demand for narrowly defined S&E occupations and do not include the wider range of occupations in which S&E degree holders often use their training.

Figure 3-A

Projected increases in employment for S&E and other selected occupations: 2012–22



SOURCE: Bureau of Labor Statistics, Employment Projections program, 2012–22, special tabulations of 2012–22 Employment Projections. See appendix table 3-2.

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Table 3-A Bureau of Labor Statistics projections of employment and job openings in S&E and other selected occupations: 2012–22

(Thousands)

Occupation	BLS National Employment Matrix 2012 estimate	BLS projected 2022 employment	Job openings from growth and net replacements, 2012–22	10-year growth in total employment (%)	10-year job openings as percentage of 2012 employment
All occupations	145,356	160,984	50,557	10.8	34.8
All S&E	5,914	6,791	2,047	14.8	34.6
Computer and mathematical scientists	3,445	4,096	1,177	18.9	34.2
Life scientists	295	322	105	9.2	35.6
Physical scientists	297	328	111	10.3	37.2
Social scientists	287	319	110	11.1	38.3
Engineers	1,590	1,726	544	8.6	34.2
S&E-related occupations					
S&E managers	894	1,034	321	15.7	35.9
S&E technicians and technologists	1,126	1,183	331	5.1	29.4
Computer programmers	344	372	118	8.3	34.4
Health care practitioners and technicians	8,050	9,783	3,378	21.5	42.0
Selected other occupations					
Postsecondary teachers	1,831	2,135	579	16.6	31.6
Lawyers	760	835	197	9.8	25.9

NOTES: BLS = Bureau of Labor Statistics.

Estimates of current and projected employment for 2012–22 are from BLS's National Employment Matrix; data in the matrix are from the Occupational Employment Statistics (OES) Survey and the Current Population Survey (CPS). Together, these sources cover paid workers, self-employed workers, and unpaid family workers

	in all industries, agriculture, and private households. Because data are derived from multiple sources, they can often differ from employment data provided by OES Survey, CPS, or other employment surveys alone. BLS does not make projections for S&E occupations as a group and some of the S&E and S&E-related occupational categories as defined by the National Science Foundation (NSF); numbers in the table are based on the sum of BLS projections for occupations that the NSF includes in the respective categories. See appendix table 3-2.
SOURCE:	BLS, Employment Projections program, 2012–22, special tabulations of 2012–22 Employment Projections.
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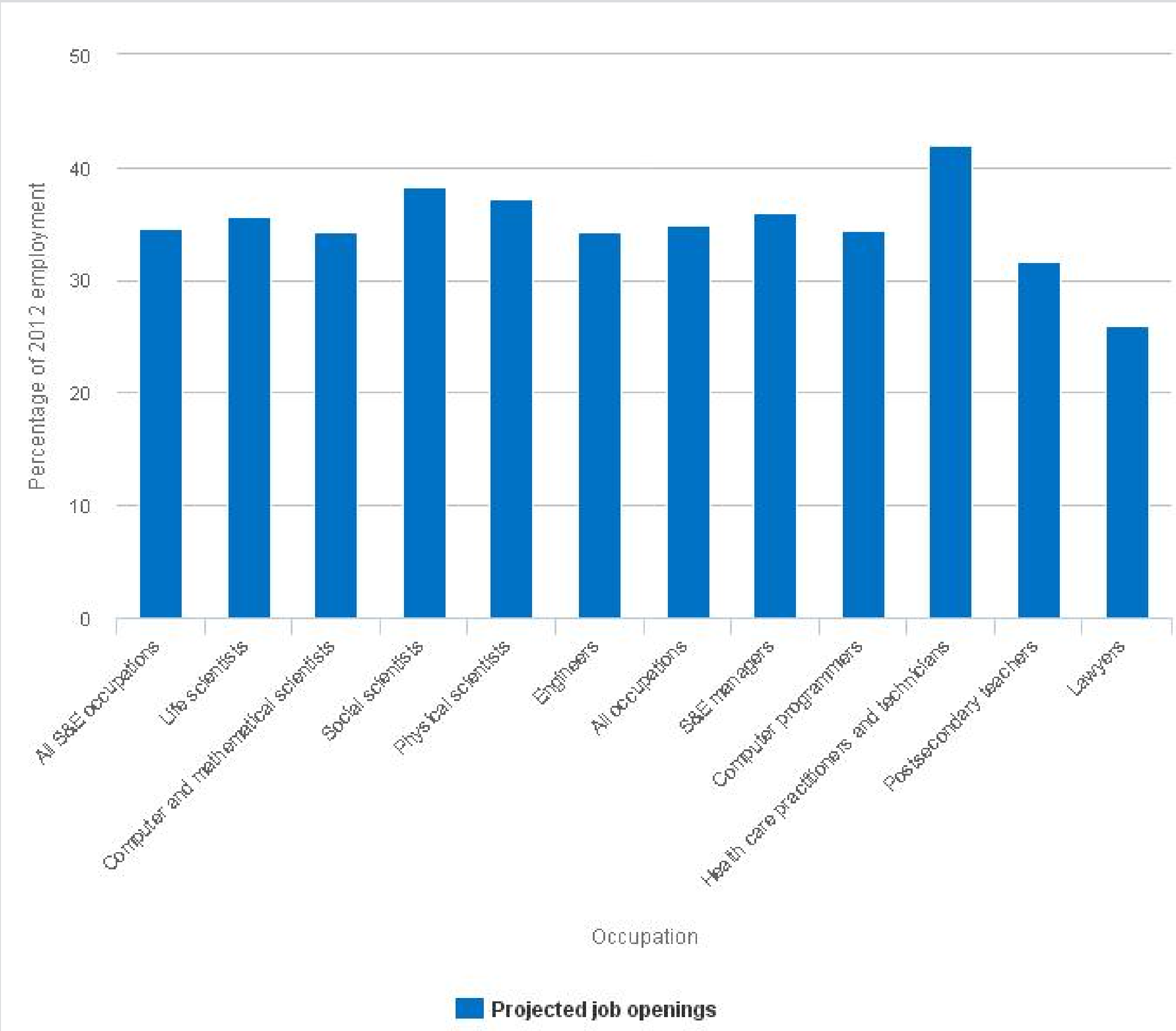
During the period 2012–22, job openings in NSF-identified S&E occupations are projected to represent about one-third (35%) of current employment in 2012, which is similar to the proportion of job openings in all occupations (35%) (Figure 3-B). Job openings include both new jobs and openings caused by workers permanently leaving the occupations.

Figure 3-B

Projected job openings in S&E and other selected occupations: 2012–22



SOURCE: Bureau of Labor Statistics, Employment Projections program, 2012–22, special tabulations of 2012–22 Employment Projections. See appendix table 3-2.

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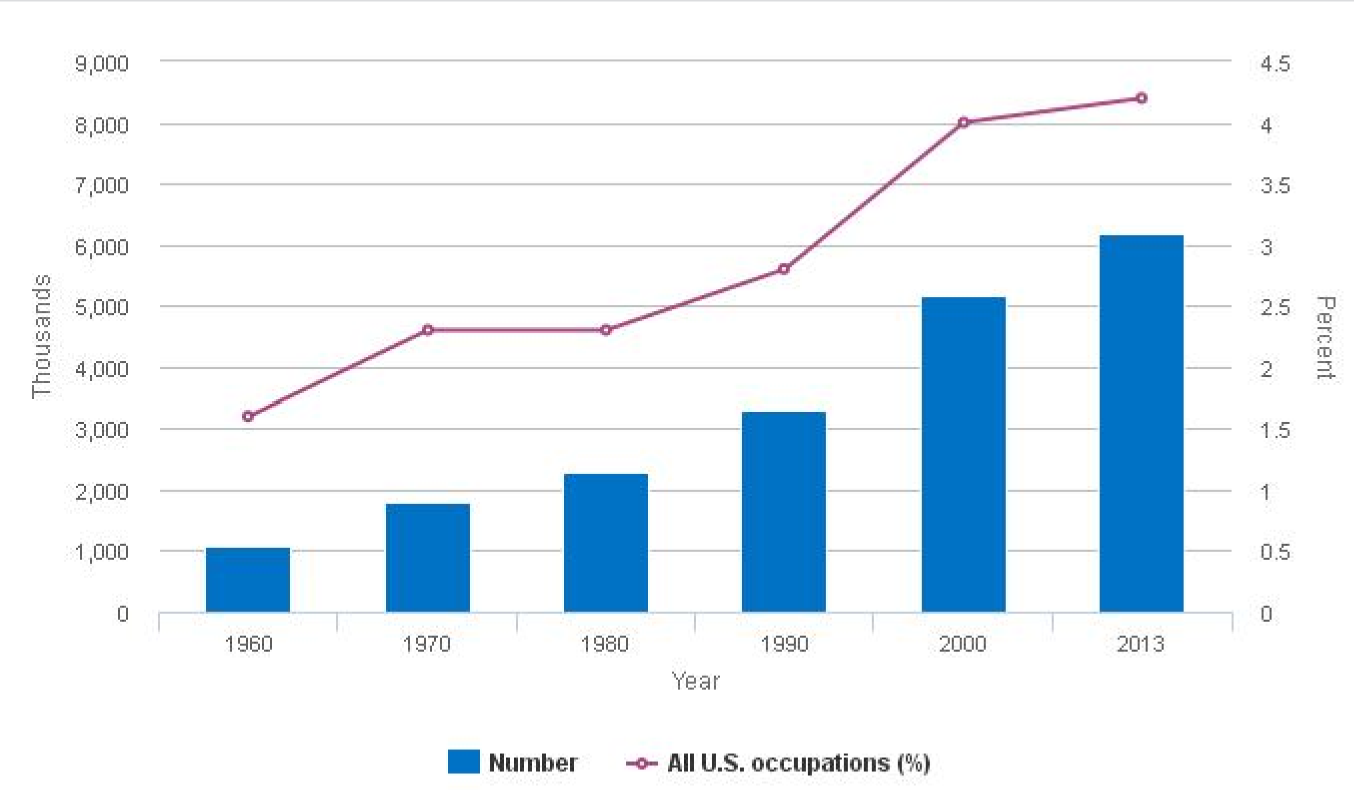
Of the BLS-projected net job openings in NSF-identified S&E occupations, 57% are projected to be in computer and mathematical sciences occupations, the largest subcategory of S&E occupations (Table 3-A). This occupational group also has the largest projected growth rate (19%) among NSF-identified S&E groups. Engineering occupations, the second largest subcategory of S&E occupations, are expected to generate about one-fourth (27%) of all job openings in S&E occupations during the period 2012–22; however, the growth rate in these occupations (9%) is projected to be lower than the growth rate for all occupations (11%). The other broad categories of S&E occupations—life sciences, social sciences, and physical sciences occupations—account for much smaller proportions of S&E occupations and are projected to have a growth rate between 9% and 11%. Job openings in the broad categories of S&E occupations are projected to represent relatively similar proportions of current employment in their respective fields, ranging from 34% to 38%.

In addition to S&E occupations, Table 3-A also shows selected other occupations that contain significant numbers of S&E-trained workers. Among these occupations, the health care practitioners and technicians group, which employs more workers than all S&E occupations combined, is projected to grow 22%, double the growth rate for all occupations. The postsecondary teachers group, which includes all fields of instruction, and the S&E managers group are projected to grow 17% and 16%, respectively, both of which are slightly higher than the 15% projected growth rate for all S&E occupations. In contrast, BLS projects that the computer programmers group and the S&E technicians and technologists group will grow more slowly than all S&E occupations.

*The mean absolute percentage error in the 1996 BLS projection of 2006 employment in detailed occupations was 17.6% (Wyatt 2010). The inaccuracies in the 1996 projection of 2006 employment were primarily the result of not anticipating the housing bubble or increases in oil prices (Wyatt 2010).

Figure 3-3

Individuals employed in S&E occupations in the United States: Selected years, 1960–2013



NOTE: Data include people at all education levels.

SOURCES: Census Bureau, Decennial Census (1960–2000) and American Community Survey (2013) microdata, downloaded from the Integrated Public Use Microdata Series (IPUMS), University of Minnesota (http://www.ipums.org).

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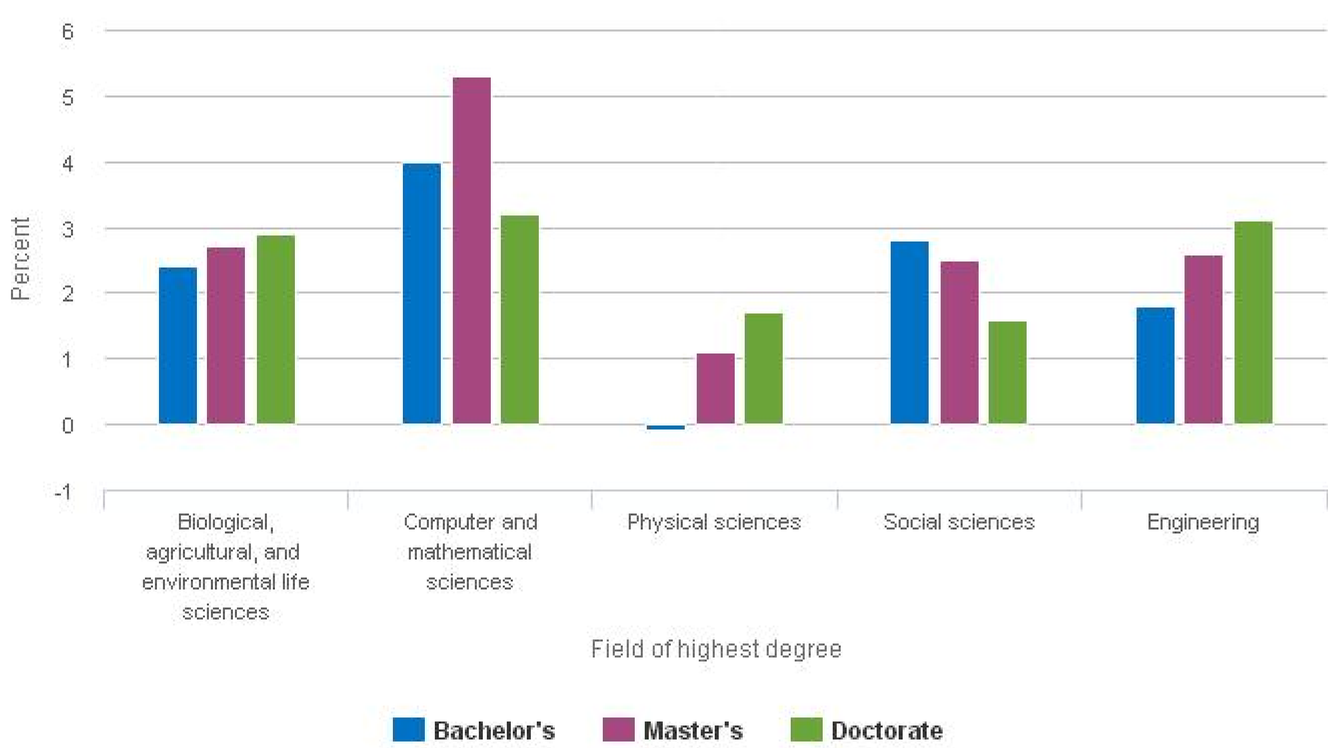
Data from recent years indicate that trends in S&E employment compared favorably to overall employment trends during and after the 2007–09 economic downturn. Occupation-based estimates from BLS indicate that the size of the S&E workforce stayed relatively steady between May 2008 (5.8 million) and May 2011 (5.8 million) and then rose to 6.3 million by May 2014. The broader STEM workforce—including S&E technicians and managers—by May 2014 (8.2 million) had surpassed its previous 2008 (7.9 million) high. In contrast, the total workforce declined from 135 million in May 2008 to 128 million in May 2011 and then rose to 135 million by May 2014, similar to the 2008 level.

The growth in the number of individuals with S&E degrees in recent years can be examined using data from SESTAT. The total number of S&E highest degree holders employed in the United States grew from 9.6 million to 12.4 million between 2003 and 2013, reflecting a 2.7% annual average growth rate. Most broad S&E degree fields exhibited growth (Figure 3-4). (See chapter 2 for a fuller discussion of S&E degrees.)

Figure 3-4

Average annual growth in the total number of employed individuals with highest degree in S&E, by field and level of highest degree: 2003–13



SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Science and Engineering Statistical Data System (SESTAT) (2003, 2013), http://sestat.nsf.gov.

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A number of factors have contributed to the growth in the S&E labor force over time: the rising demand for S&E skills in a global and highly technological economic landscape; increases in U.S. S&E degrees earned by women, by racial and ethnic minority groups, and by foreign-born individuals; temporary and permanent migration to the United States of those with foreign S&E educations; and the rising number of scientists and engineers who are delaying their retirement. The demographic sections of this chapter provide data on aging and retirement patterns of scientists and engineers as well as on S&E participation by women, by racial and ethnic minorities, and by foreign-born individuals.

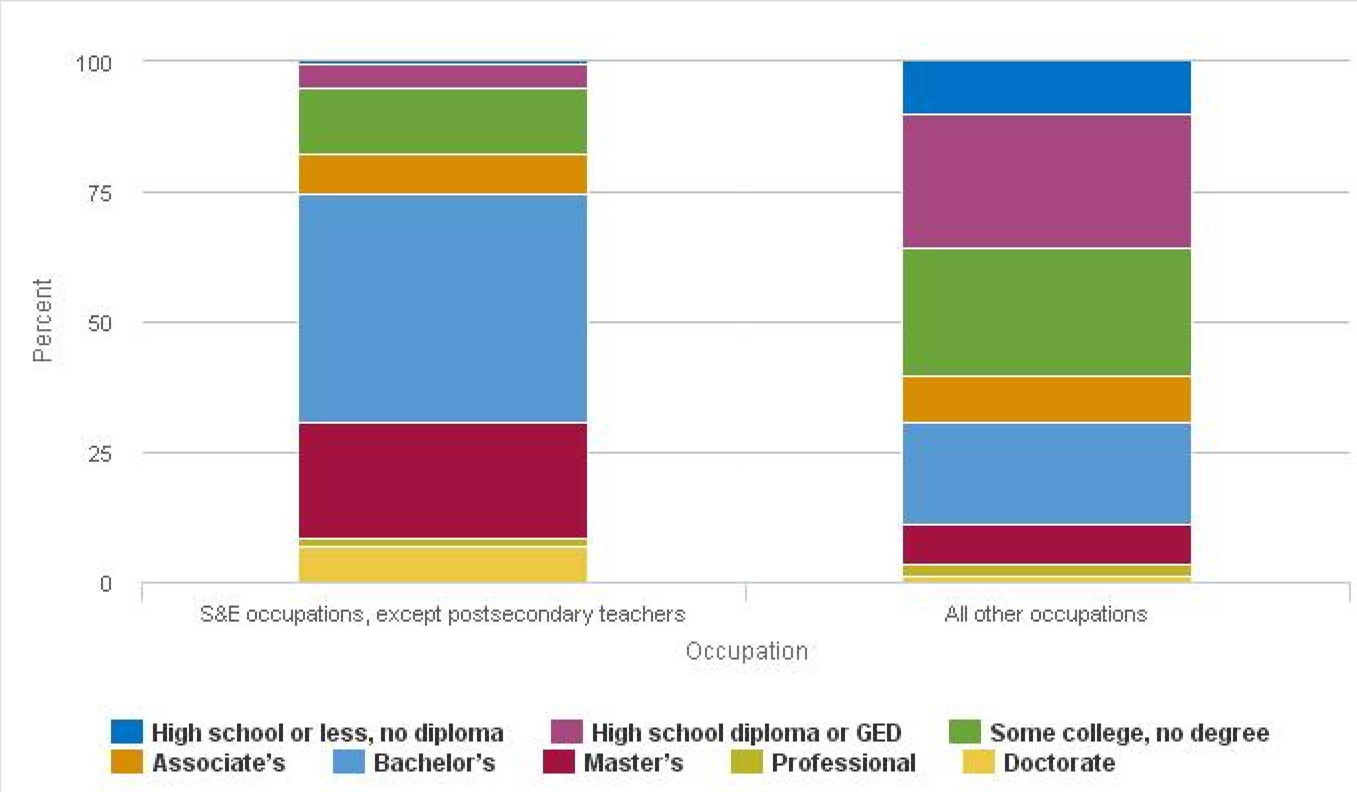
Educational Distribution of Workers in S&E Occupations

Workers in S&E occupations have undergone more formal training than the general workforce (Figure 3-5). Data from the 2013 ACS indicate that a larger proportion of workers in S&E occupations (75%) (excluding postsecondary teachers) hold a bachelor's or higher degree than workers in all other occupations (31%).[i] The proportion of workers with advanced degrees beyond the bachelor's level is 31% in S&E occupations, compared to 11% in all other occupations. About 7% of all S&E workers (again excluding postsecondary teachers) have doctorates.

[i] Many comparisons using Census Bureau data on occupations are limited to looking at all S&E occupations except postsecondary teachers because the Census Bureau aggregates all postsecondary teachers into one occupation code. NSF surveys of scientists and engineers and some BLS surveys collect data on postsecondary teachers by field.

Figure 3-5

Educational attainment, by type of occupation: 2013



GED = General Equivalency Diploma.

SOURCE: Census Bureau, American Community Survey (2013).

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Compared with the rest of the workforce, very few of those employed in S&E occupations have only a high school degree. However, many individuals enter the S&E workforce with marketable technical skills from technical or vocational schools (with or without an earned associate's degree) or college courses; some also acquire these skills through workforce experience or on-the-job training. In information technology, and to some extent in other occupations, employers frequently use certification exams, not formal degrees, to judge skills. (See sidebar, S&E Workers Without a Bachelor's Degree and the discussion on community college in chapter 2 section "Institutions Providing S&E Education".)

S&E Workers Without a Bachelor's Degree

Although the Scientists and Engineers Statistical Data System (SESTAT) provides detailed information on college graduate scientists and engineers, it lacks similar data on individuals who do not have a bachelor's degree. In 2013, about 5.7 million workers age 25 and older without a bachelor's degree were employed in an S&E or S&E-related occupation. Using nationally representative data from the Census Bureau's American Community Survey (ACS), this sidebar looks at the demographic, employment, and educational backgrounds of workers without a bachelor's degree.*

In 2013, about one-quarter of all S&E jobs (1.4 million) and 41% of all S&E-related jobs (4.3 million) were held by individuals without a bachelor's degree. Relative to college-educated workers in S&E or S&E-related occupations, disproportionate numbers of those without a bachelor's degree were black or Hispanic. In 2013, about 12% of sub-baccalaureate workers in these occupations were black, 10% were Hispanic, and 4% were Asian. About 11% of sub-baccalaureate workers in these occupations were foreign born. The corresponding shares among college-educated workers in these occupations were 6% black, 5% Hispanic, 16% Asian, and 23% foreign born.

Among the 1.4 million workers without a bachelor's degree and employed in S&E occupations, 71% were concentrated in computer occupations; computer support specialists accounted for the largest subset (30%) of these workers. In comparison, 46% of the college-educated workers in S&E occupations held computer jobs; software developers represented the largest subset (42%) of these workers.

Health occupations accounted for the largest subset of workers in S&E-related occupations (74%). However, workers without a bachelor's degree were concentrated in different categories of health occupations than those with a bachelor's degree. For example, about 56% of health workers without a college degree were employed as a health technician or technologist; only 12% of health workers with a college degree were employed in these occupations. On the contrary, a similar proportion of health workers with (and without) a bachelor's degree were employed as registered nurses (34% and 37%, respectively).

Relative to other occupations, S&E and S&E-related occupations provide sound employment for workers without a college degree. In 2013, the median earnings of sub-baccalaureate workers in S&E ($60,000) or S&E-related ($45,000) occupations were significantly higher than the median earnings in other occupations ($28,000). The unemployment rate among these workers in S&E (4%) or S&E-related (4%) occupations was lower than the rate in other occupations (9%). Among sub-baccalaureate workers in S&E or S&E-related occupations, median salaries ranged from about $35,000 among health care technicians and technologists to $50,000 among S&E technicians, $52,000 among registered nurses, and $57,000 among computer workers; the unemployment rate ranged from 2% among registered nurses to 4% among health care technicians and 5% among computer workers.

Workers employed in S&E or S&E-related occupations received more formal training (even if they did not have a bachelor's degree) than those employed in other occupations; therefore, it is not surprising that salaries were higher in these jobs. Among workers without a bachelor's degree, 70% of those employed in S&E occupations and 74% of those employed in S&E-related occupations had an associate's degree or 1 or more years of college credit, compared to 36% of those employed in other occupations.

*This sidebar defines the S&E workforce by workers in S&E occupations (except postsecondary teachers in S&E fields). The ACS data do not allow for separate identification of postsecondary teachers by fields. See Appendix Table 3-1 for a list of S&E occupations in the 2013 ACS.

According to the 2013 SESTAT, the vast majority (82%) of college graduates employed in S&E occupations have at least a bachelor's or higher level degree in an S&E field (Table 3-4), suggesting that formal S&E training is the usual pathway for obtaining employment in these occupations. However, the importance of formal S&E training in the same broad field as one's S&E occupation varies across occupational categories. For example, among computer and mathematical scientists, less than one-half (46%) have a bachelor's or higher level degree in that broad field of study and nearly one-fourth (23%) do not have any S&E or S&E-related degree. In contrast, 75% of life scientists, 73% of physical scientists, 75% of social scientists, and 82% of engineers have a bachelor's or higher level degree in their respective broad field. The next section presents data on the proportion of S&E degree holders who are employed in S&E and non-S&E occupational categories.

Table 3-4 **Educational background of college graduates employed in S&E occupations, by broad S&E occupational category: 2013**

(Percent)

Educational background	All S&E occupations	Biological, agricultural, and environmental life scientists	Computer and mathematical scientists	Physical scientists	Social scientists	Engineers
Total (*n*)	5,749,000	638,000	2,647,000	319,000	581,000	1,564,000
At least one S&E degree	82.1	89.3	73.3	96.6	81.6	91.2
At least one S&E degree in field	82.1	75.1	46.1	73.4	75.2	81.5
Highest degree in field	75.5	68.5	42.3	67.4	65.4	74.5
All degrees in S&E	70.7	75.1	63.8	88.1	55.4	82.6
No S&E degrees but at least one S&E-related degree	4.3	6.3	4.3	1.6	2.9	4.5
No S&E or S&E-related degree but at least one non-S&E degree	13.7	4.5	22.5	1.9	15.5	4.3

NOTES: At least one S&E degree in field is the proportion of workers in a particular S&E occupational category with at least one bachelor's or higher-level degree in the same broad field. Highest degree in field is the proportion of workers in a particular S&E occupational category with highest degree in the same broad field. For example, among computer and mathematical scientists, these data refer to the proportion with at least one bachelor's or higher-level degree in the broad field of computer and mathematical sciences and the proportion with highest degree in the broad field of computer and mathematical sciences, respectively. Detail may not add to total because of rounding.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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Occupational Distribution of S&E Degree Holders and Relationship between Jobs and Degrees

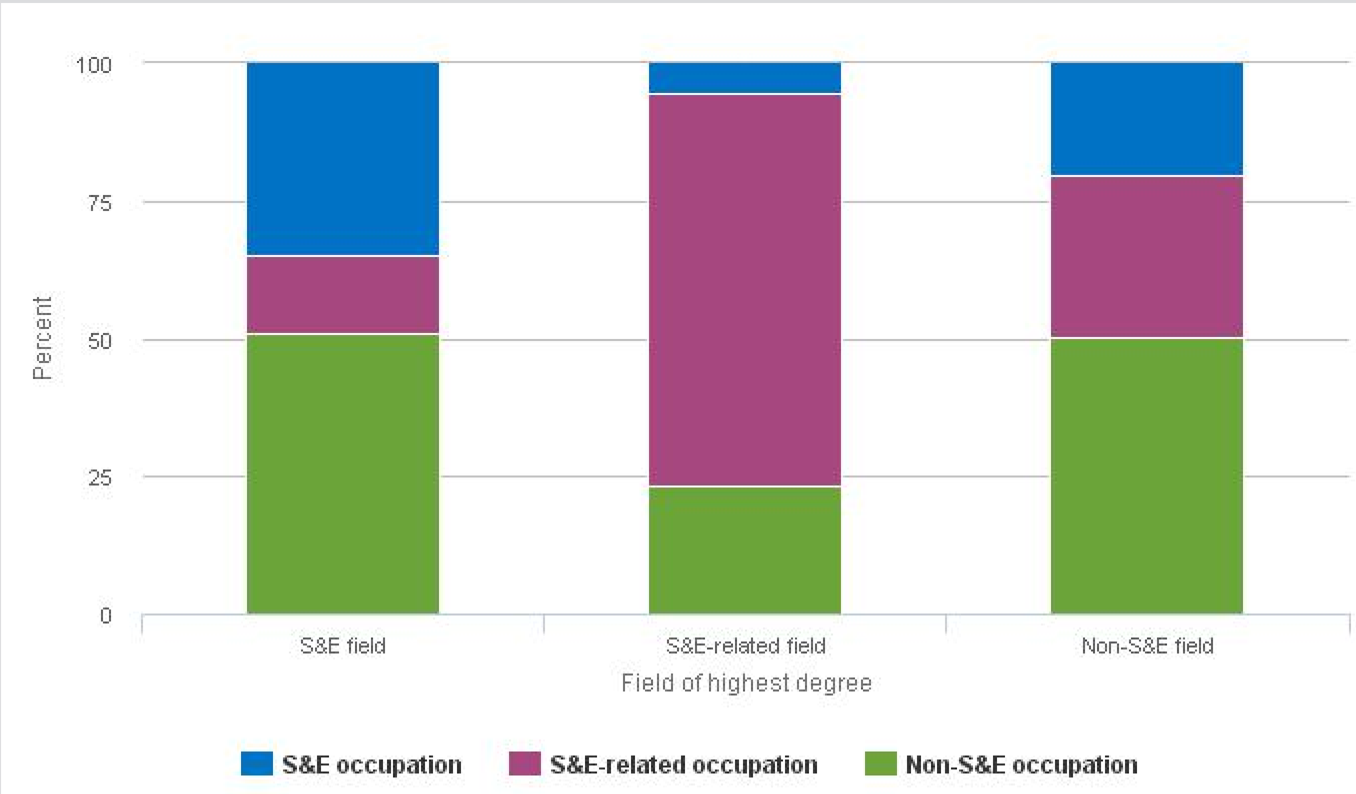
SESTAT provides joint information on both degree achievement and occupational employment of scientists and engineers in the United States, thus enabling a direct comparison of the interplay between degree and occupation for individuals who earned a highest degree in an S&E discipline and those who earned a highest degree in a non-S&E discipline.

Although an S&E degree is often necessary to obtain S&E employment, many individuals with S&E degrees pursue careers in non-S&E fields. However, a majority of workers with S&E training who work in non-S&E jobs reported that their work is related to their S&E training, suggesting that the application of S&E skills and expertise extends well beyond jobs formally classified as S&E occupations. (The next section, "S&E Workers in the Economy," provides data on R&D activity of scientists and engineers employed in S&E and non-S&E occupations.)

Only about half of those with a highest degree in S&E are employed in an S&E (35%) or S&E-related (14%) occupation; the other 51% are employed in non-S&E occupations. Figure 3-6 shows the occupational distribution of the S&E workforce with S&E, S&E-related, and non-S&E highest degrees. The largest category of non-S&E jobs for these S&E degree holders is management and management-related occupations (2.2 million workers), followed by sales and marketing (1.1 million workers) (Appendix Table 3-3). Other non-S&E occupations with a large number of S&E-trained workers include social services (457,000) and college and precollege teaching in non-S&E areas (421,000). S&E degree holders also work in S&E-related jobs such as health (558,000), S&E management (450,000), S&E technician or technologist (501,000), and precollege teaching in S&E areas (219,000).

Figure 3-6

Occupational distribution of scientists and engineers, by broad field of highest degree: 2013



NOTE: Scientists and engineers include those with one or more S&E or S&E-related degrees at the bachelor's level or higher or those who have only a non-S&E degree at the bachelor's level or higher and are employed in an S&E or S&E-related occupation.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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Most individuals with a highest degree in S&E but working in non-S&E occupations do not see S&E as irrelevant. Rather, most indicate that their jobs are either closely (35%) or somewhat (33%) related to their highest degree field (Table 3-5). For example, among S&E degree holders in non-S&E management and management-related occupations, about three-quarters indicate that their jobs are either closely (32%) or somewhat (42%) related to their S&E degree. Among those in social services and related occupations, these numbers are higher (92%); among those in sales and marketing, these numbers are lower (51%).

Table 3-5 **Relationship of highest degree to job among S&E highest degree holders not in S&E occupations, by degree level: 2013**

		Degree related to job (%)		
Highest degree	Workers (*n*)	Closely	Somewhat	Not
All degree levels	8,105,000	34.7	32.9	32.4

		Degree related to job (%)		
Highest degree	Workers (*n*)	Closely	Somewhat	Not
Bachelor's	6,451,000	30.0	34.3	35.7
Master's	1,405,000	54.4	25.8	19.8
Doctorate	232,000	47.0	35.8	17.2

NOTE: All degree levels includes professional degrees not broken out separately. Detail may not add to total because of rounding.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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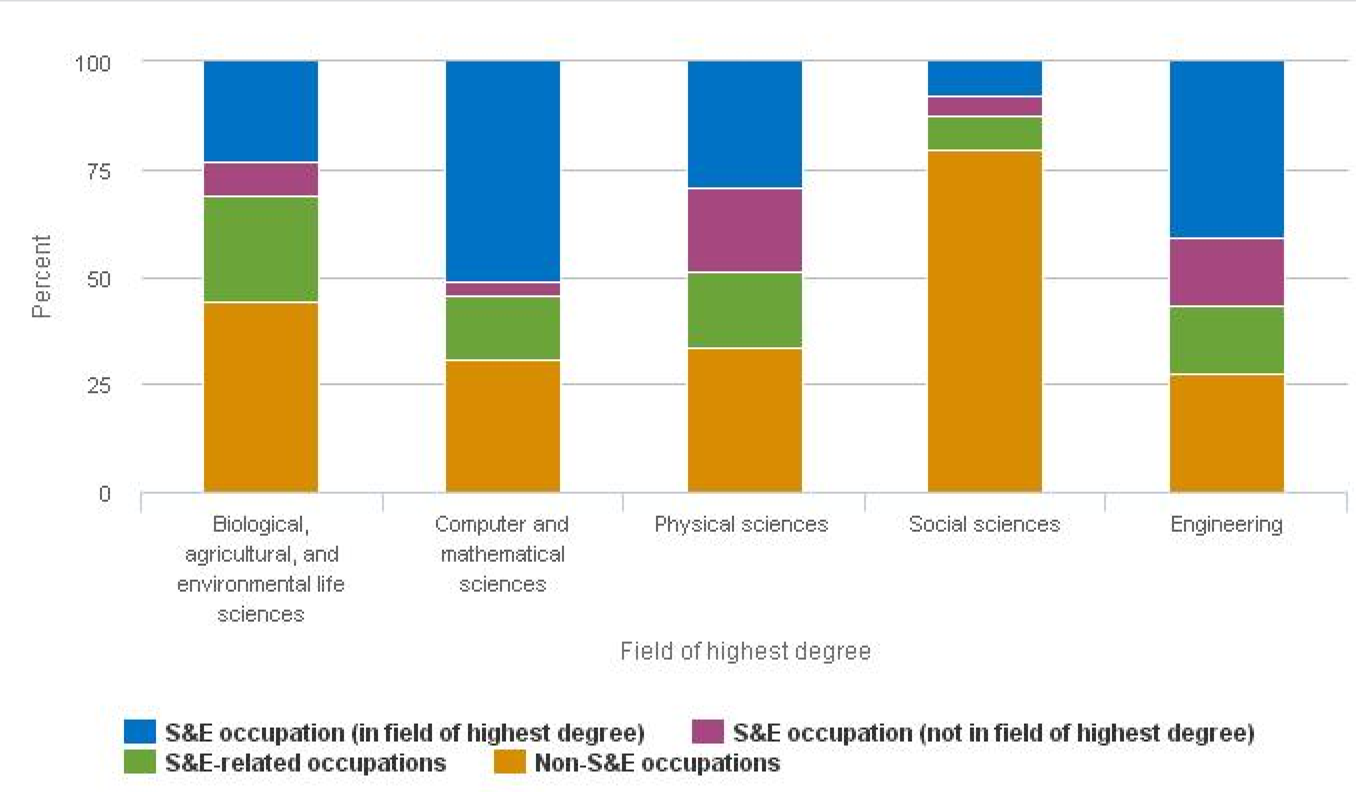
Unlike individuals with an S&E highest degree, at least half of those whose highest degrees are either in S&E-related or non-S&E fields are employed in their corresponding broad occupational categories (Figure 3-6). For those with an S&E-related highest degree, the largest category of jobs is health occupations (3.4 million); for those with a non-S&E highest degree, the largest category of jobs is non-S&E management and management-related occupations (873,000) (Appendix Table 3-3). Significant numbers of individuals with a non-S&E highest degree work in computer and information sciences (671,000), in health (590,000), in precollege teaching in S&E areas (556,000), or as lawyers or judges (562,000).

The pattern that a large proportion of individuals with a highest degree in S&E are employed in areas other than S&E occupations has been robust over time. SESTAT data from 1993 indicate that 36% of all scientists and engineers with S&E highest degrees were employed in S&E occupations, and the rest held positions in areas other than S&E. The comparable proportion in 2013 was 35%.

The proportion of S&E highest degree holders who go on to work in S&E occupations varies substantially by S&E degree fields and levels of degree and is heavily influenced by those in social sciences. Individuals with social sciences degrees are the least likely to work in S&E occupations (12%); these individuals work primarily in non-S&E occupations (80%) (Figure 3-7). In contrast, at least half of individuals with a highest degree in computer and mathematical sciences (54%), physical sciences (49%), or engineering (57%) report working in S&E occupations. This general pattern between study field of degrees and occupations is similar at the bachelor's and master's level but not at the doctoral level, where S&E doctorates most often work in an S&E occupation similar to their doctoral field (Figure 3-8).

Figure 3-7

Occupational distribution of S&E highest degree holders, by field of highest degree: 2013



NOTES: Detail may not add to total because of rounding. For each broad S&E highest degree field, S&E occupation (in field of highest degree) includes individuals who report being employed in an occupation in the same broad category. For example, for highest degree holders in computer and mathematical sciences, S&E occupation (in field of highest degree) includes those who report the broad field of computer and mathematical sciences as their occupation, and S&E occupation (not in field of highest degree) includes those who report an S&E occupation other than computer and mathematical sciences occupations.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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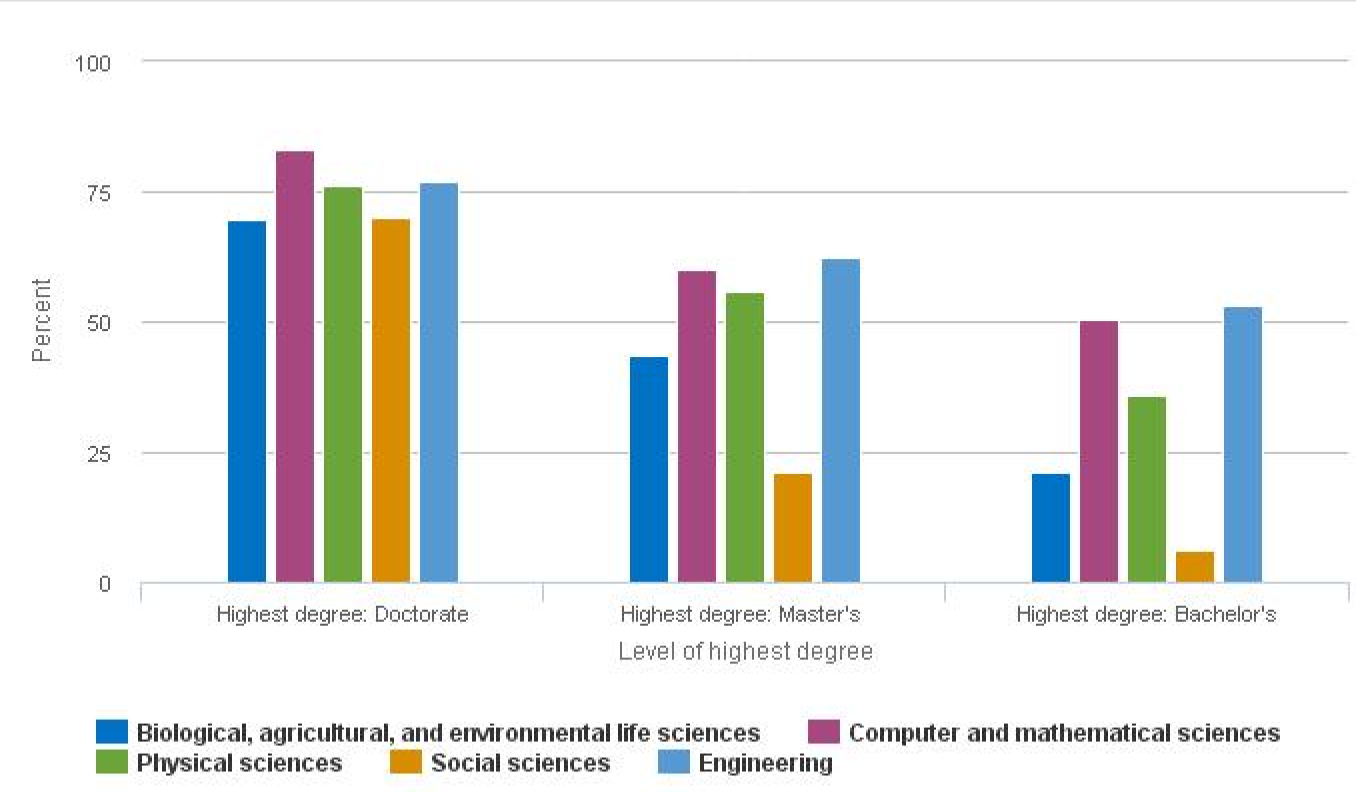
Figure 3-8

S&E degree holders working in S&E occupations, by level and field of S&E highest degree: 2013



NOTE: Individuals may have degrees in more than one S&E degree field.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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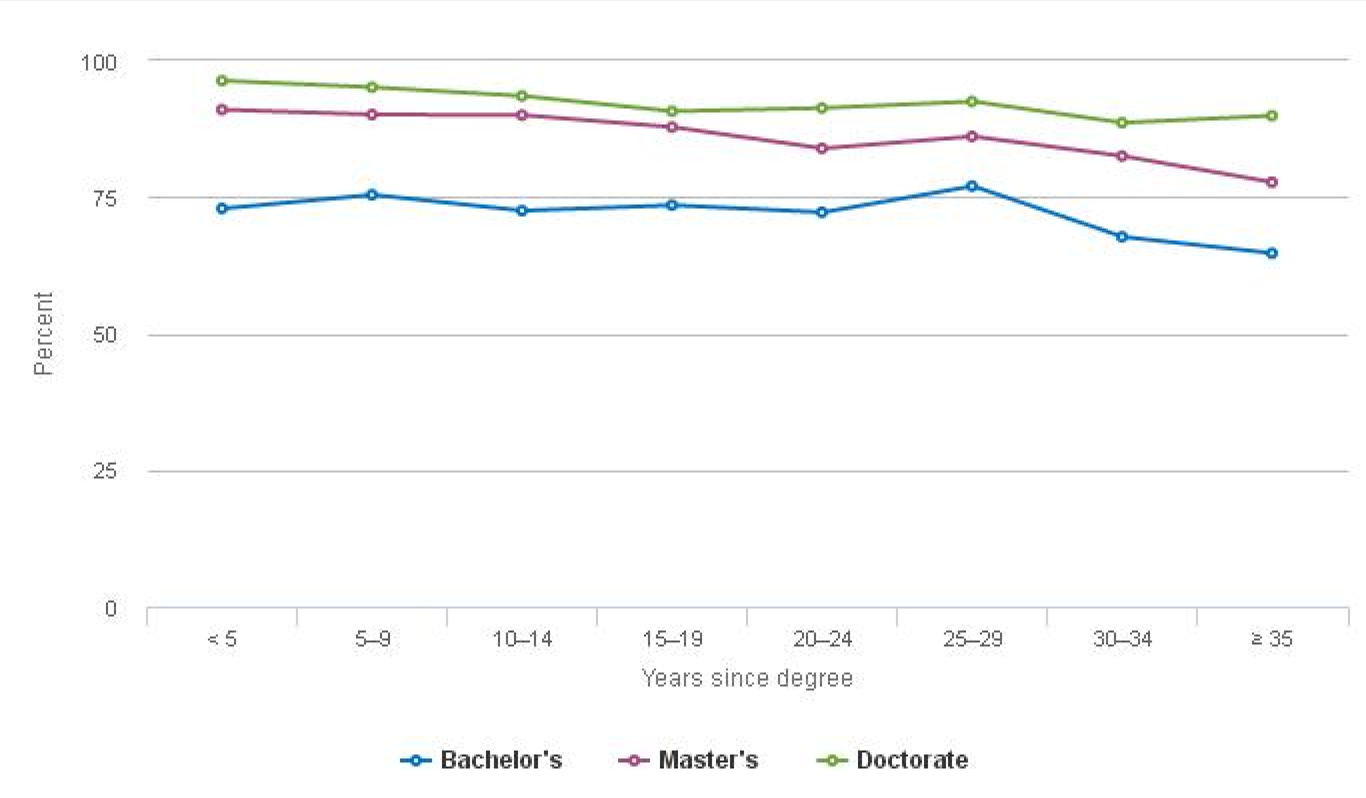
Whereas Figure 3-8 shows the proportion of S&E degree holders employed in S&E occupations, Figure 3-9 shows what proportions of S&E degree holders reported that their work is related (closely or somewhat) to their S&E degree. Workers with more advanced S&E training were more likely than those with only bachelor's level degrees to work in a job related to their degree field. Irrespective of degree level, the bulk of degree holders in life sciences (74%), physical sciences (78%), and computer and mathematical sciences (88%), along with engineering (88%), considered their jobs to be related to their degree field. The corresponding percentage of social scientists was 66%.

Figure 3-9

S&E degree holders employed in jobs related to highest degree, by level of and years since highest degree: 2013



NOTE: Data include those who report their job is either closely or somewhat related to the field of their highest degree.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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The pattern of a stronger relationship between S&E jobs and S&E degrees among master's degree or doctorate holders compared with bachelor's degree holders is robust across career stages, as seen in comparisons among groups of bachelor's, master's, and doctoral degree holders at comparable numbers of years since receiving their degrees (Figure 3-9). For each group, the relationship between job and field of highest degree becomes weaker over time, particularly toward the later career stages. Possible reasons for this decline include changes in career interests, development of skills in different areas, promotion to general management positions, or realization that some of the original training has become obsolete. Despite these potential factors, the career-cycle decline in the relevance of an S&E degree appears modest.

S&E Workers in the Economy

To understand the economic and scientific contributions of scientists and engineers, it is important to know how they are distributed across the economy and what kind of work they perform. This section examines the economic sectors, size, and other characteristics of organizations that employ scientists and engineers (defined both by occupation and field of education). It also describes the distribution of S&E workers within particular sectors. The analysis covers all sectors: private and public educational institutions; for-profit businesses and nonprofit organizations; and federal, state, and local governments. It also examines self-employed scientists and engineers and the concentration of S&E workers by industry sectors and by geography.

The S&E labor force is a national resource in the continuous productivity increases and innovative capacities that fuel long-term economic growth and raise public welfare. The chapter concludes with examinations of R&D activity and work-related training as indicators of worker skill level, productivity, and innovative capacity. It distinguishes between analyses based on S&E degree field and S&E occupation.

Employment Sectors

The business sector is by far the largest employer of the broad S&E workforce (including those with at least an S&E or S&E-related bachelor's degree and those working in an S&E or S&E-related occupation regardless of an S&E degree). In 2013, the business sector—mostly for-profit businesses—employed about 70% of such individuals (Table 3-6). The education sector, including private and public institutions, employed another 19%, the bulk in 2-year and precollege institutions. The government sector—federal, state, and local—employed another 11%. This distribution pattern has been quite stable for decades, except a small rise in the nonprofit segment and a small decline in government (Appendix Table 3-4).

Table 3-6 **Employment sector of scientists and engineers, by broad occupational category and degree field: 2013**

Employment sector	All employed scientists and engineers	Highest degree in S&E	S&E occupations	S&E-related occupations	Non-S&E occupations
Total (*n*)	23,557,000	12,446,000	5,749,000	7,439,000	10,368,000
Business/industry (%)	70.1	71.9	69.7	68.8	71.1
For-profit businesses	52.4	58.2	61.6	45.3	52.4
Nonprofit organizations	11.1	7.2	4.8	18.5	9.2
Self-employed, unincorporated businesses	6.6	6.4	3.3	5.0	9.5
Education (%)	18.9	15.6	18.1	22.6	16.8
4-year institutions	7.9	8.3	14.5	7.2	4.8
2-year and precollege institutions	11.0	7.3	3.7	15.4	12.0
Government (%)	11.0	12.5	12.2	8.6	12.1

Employment sector	All employed scientists and engineers	Highest degree in S&E	S&E occupations	S&E-related occupations	Non-S&E occupations
Federal	4.3	5.1	6.4	3.3	4.0
State/local	6.7	7.4	5.8	5.3	8.1

NOTE: Scientists and engineers include those with one or more S&E or S&E-related degrees at the bachelor's level or higher or those who have only a non-S&E degree at the bachelor's level or higher and are employed in an S&E or S&E-related occupation.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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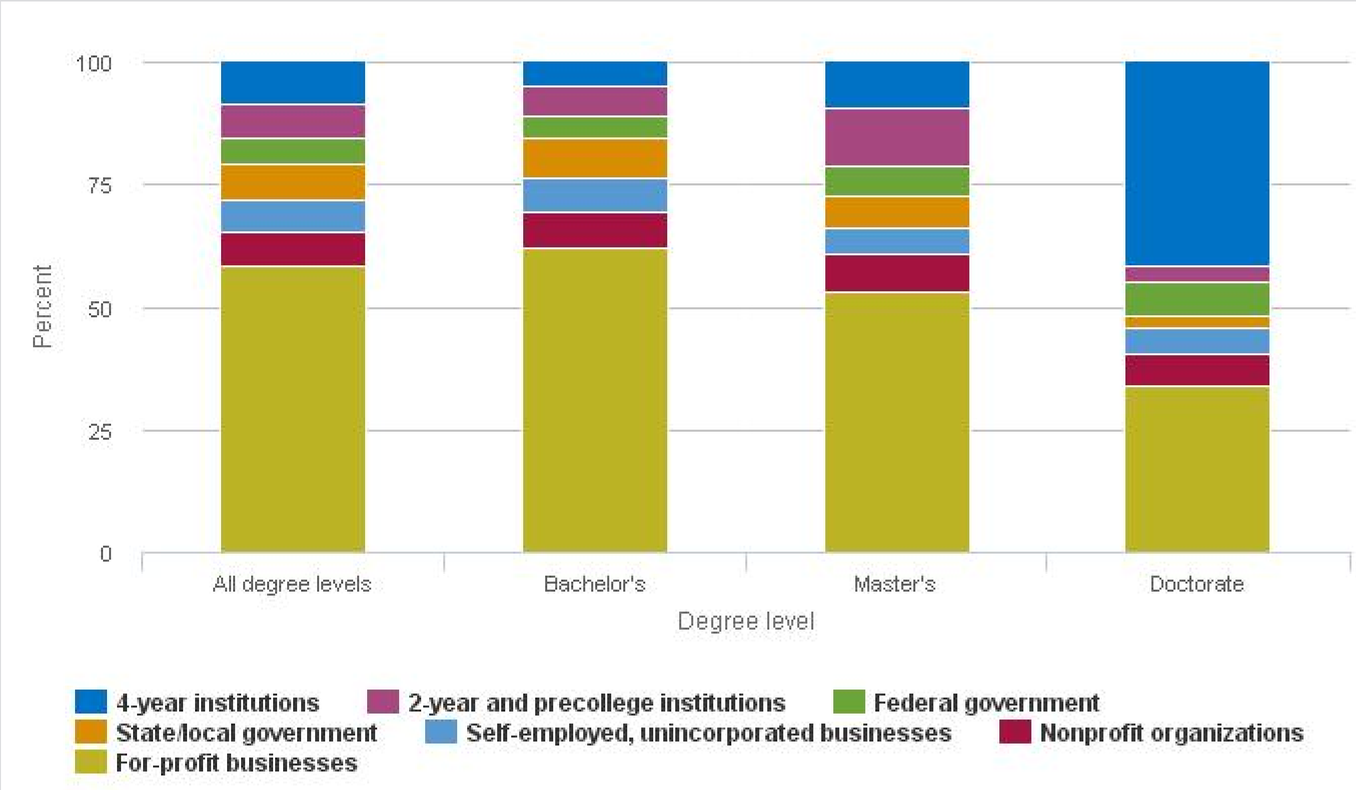
Some differences exist in the concentration of particular groups of S&E workers across employment sectors. For example, academic institutions are the largest employer of the SESTAT population with doctorates, although the business sector is the largest employer of the overall SESTAT population. Whereas individuals employed in engineering occupations and computer and mathematical sciences occupations are largely concentrated in the business sector, those employed as life scientists, physical scientists, and social scientists are more evenly distributed between the business and education sectors. The following discussion provides a deeper analysis of the economic sectors in which scientists and engineers work.

Education Sector

The education sector employs nearly one-fifth of the S&E workforce but is segmented by level of S&E education (Table 3-6). The vast majority of S&E doctorate holders in this sector work in 4-year institutions as faculty, postdocs, research staff, and a variety of other full- and part-time positions. The majority of bachelor's level scientists and engineers work in 2-year and precollege institutions (Figure 3-10; Appendix Table 3-5). (See chapter 5 for additional detail on academic employment of science, engineering, and health [SEH] doctorates.)

Figure 3-10

S&E highest degree holders, by degree level and employment sector: 2013



NOTE: All degree levels includes professional degrees not reported separately.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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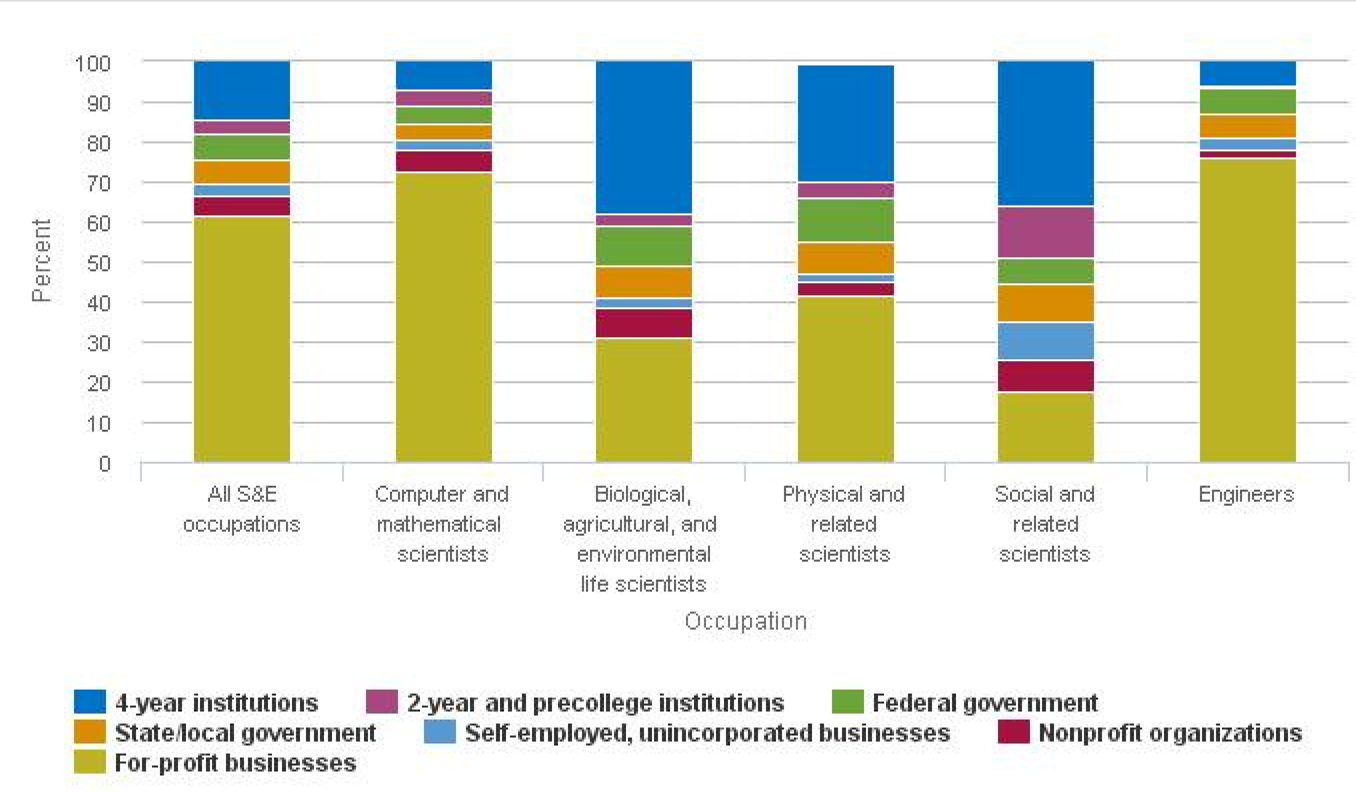
The subsectoral employment distribution also differs for those in S&E occupations. Larger proportions of life, physical, and social scientists work in the education sector compared with engineers or computer and mathematical scientists (Figure 3-11). Within the education sector, the vast majority (80%) of those in S&E occupations are concentrated in 4-year institutions. In contrast, the great majority of workers in S&E-related or non-S&E occupations in the education sector are found in 2-year and precollege institutions (68% and 71%, respectively), and the bulk of them are employed as teachers.

Figure 3-11

Broad S&E occupational categories, by employment sector: 2013



SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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Business Sector

For-profit businesses. For-profit businesses employ the largest proportion of scientists and engineers (Table 3-6). At the doctorate level, however, for-profit businesses employ fewer S&E doctorates than 4-year educational institutions (Figure 3-10; Appendix Table 3-5). About three-fourths of those working in computer and mathematical sciences occupations (73%) and in engineering occupations (76%) are employed by for-profit businesses, but the proportions are much lower for those in other S&E occupations, ranging from 17% for social scientists to 41% for physical scientists (Figure 3-11).

Nonprofit organizations. Employment of scientists and engineers in nonprofit organizations has grown (Appendix Table 3-4), with particularly strong growth among S&E-related occupations, which include health-related jobs. Continuing the trend seen in the broader economy, the number of health-related jobs in nonprofit organizations has risen dramatically from 97,000 in 1993 to 1.2 million in 2013. As a result, the total share of all health-related occupations in nonprofit organizations has risen from 13% in 1993 to 27% in 2013. The majority of such workers are employed as registered nurses, dieticians, therapists, physician assistants, and nurse practitioners.

Among those in S&E occupations, the proportion employed by nonprofit organizations is much smaller (5%) (Table 3-6), with substantial variation among different fields, ranging from 2% of engineers to 8% of social scientists and life scientists (Figure 3-11).

Self-employment. In 2013, almost 4.1 million scientists and engineers (17%) reported being self-employed in either an unincorporated or incorporated business, professional practice, or farm (Table 3-7).[i] Those working in S&E-related or non-S&E occupations reported higher levels of self-employment (16% and 22%, respectively) than those working in S&E occupations (11%). Among those with a highest degree in S&E, individuals with professional degrees reported substantially higher rates of self-employment (38%) than those with a bachelor's degree (18%), master's degree (14%), or doctorate (11%) as their highest degree.

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[i] The data on self-employment from SESTAT include those who report being self-employed or employed by a business owner in either an unincorporated or incorporated business, professional practice, or farm. As a result, the data may capture both self-employed individuals in their own businesses as well as those whose principal employer is a business owner. This is a major reason why the SESTAT estimate of self-employed workers in S&E occupations is higher than those from other surveys (e.g., the Census Bureau's ACS).

Table 3-7 **Self-employed scientists and engineers, by education, occupation, and type of business: 2013**

(Percent)

Characteristic	Total	Unincorporated business	Incorporated business
All employed scientists and engineers	17.4	6.6	10.9
Highest degree in S&E field	16.8	6.4	10.3
Biological, agricultural, and environmental life sciences	18.6	7.5	11.1
Computer and mathematical sciences	13.4	4.6	8.7
Physical sciences	14.6	5.7	8.9
Social sciences	18.4	8.2	10.1
Engineering	16.1	4.3	11.8
S&E highest degree level			
Bachelor's	18.1	6.8	11.4
Master's	13.9	5.5	8.4
Doctorate	10.8	5.3	5.5
Professional	37.8	24.4	13.3
Occupation			
S&E occupation	10.7	3.3	7.3
Biological, agricultural, and environmental life scientists	5.8	2.2	3.8
Computer and mathematical scientists	10.3	2.9	7.5
Physical scientists	7.8	2.2	5.3
Social scientists	15.5	9.5	6.0

Characteristic	Total	Unincorporated business	Incorporated business
Engineers	12.0	2.6	9.5
S&E-related occupations	15.7	5.0	10.7
Non-S&E occupations	22.4	9.5	12.9

NOTE: Scientists and engineers include those with one or more S&E or S&E-related degrees at the bachelor's level or higher or those who have only a non-S&E degree at the bachelor's level or higher and are employed in an S&E or S&E-related occupation.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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Incorporated businesses account for at least half of self-employed scientists and engineers in most fields. However, most of those whose highest degree was a professional one worked in unincorporated businesses (Table 3-7). This was also the case for individuals in social sciences occupations, whose level of unincorporated self-employment was largely driven by psychologists: In 2013, among the 208,000 employed psychologists, 31% were self-employed, mostly in unincorporated businesses. In addition, 38% of professional degree holders in a field of psychology were self-employed, divided almost evenly between unincorporated and incorporated businesses.

Government Sector

Federal government. According to data from the U.S. Office of Personnel Management (OPM), in 2014 the federal government employed approximately 319,000 people in S&E occupations, which represents about 16% of the federal civilian workforce.[ii],[iii] Federal workers in S&E occupations are almost evenly distributed among computer and mathematical sciences occupations (32%); engineering occupations (31%); and life sciences, physical sciences, and social sciences occupations (36%). The vast majority (81%) of the federal workers in S&E occupations have a bachelor's or higher level degree.

The five federal agencies with the largest proportions of their workforce in S&E jobs are those with strong scientific missions: the National Aeronautics and Space Administration (65%), the Nuclear Regulatory Commission (62%), the Environmental Protection Agency (61%), NSF (41%), and the Department of Energy (33%). The Department of Defense has the largest number of workers in S&E occupations (147,000), accounting for 46% of the federal workforce in S&E occupations.[iv]

State and local government. In 2013, about 1.6 million scientists and engineers (7%) were working in state and local governments in the United States (Table 3-6). Public educational institutions are included in the education sector and excluded here. State and local governments employ about 8% of S&E bachelor's degree holders and 7% of S&E master's degree holders, compared to only 2% of S&E doctorate holders (Figure 3-10). Among those employed in S&E occupations, larger proportions of life scientists, physical scientists, and social scientists work in state and local governments compared with engineers and computer and mathematical scientists (Figure 3-11).

[ii] The source of the federal S&E employment data is OPM's Enterprise Human Resources Integration Statistical Data Mart. Coverage is limited to federal civilian employees on pay status with certain exclusions. For information on specific exclusions and inclusions, see the coverage definition on OPM's Federal Human Resources Data (FedScope) Web page: http://www.fedscope.opm.gov/datadefn/aehri_sdm.asp#cpdf3

[iii] Employment in the federal government is largely limited to those with U.S. citizenship. Many federal workers with S&E employment are in occupations that, nationwide, include relatively large concentrations of foreign-born persons, some of whom are not U.S. citizens, rendering them ineligible for many federal jobs.

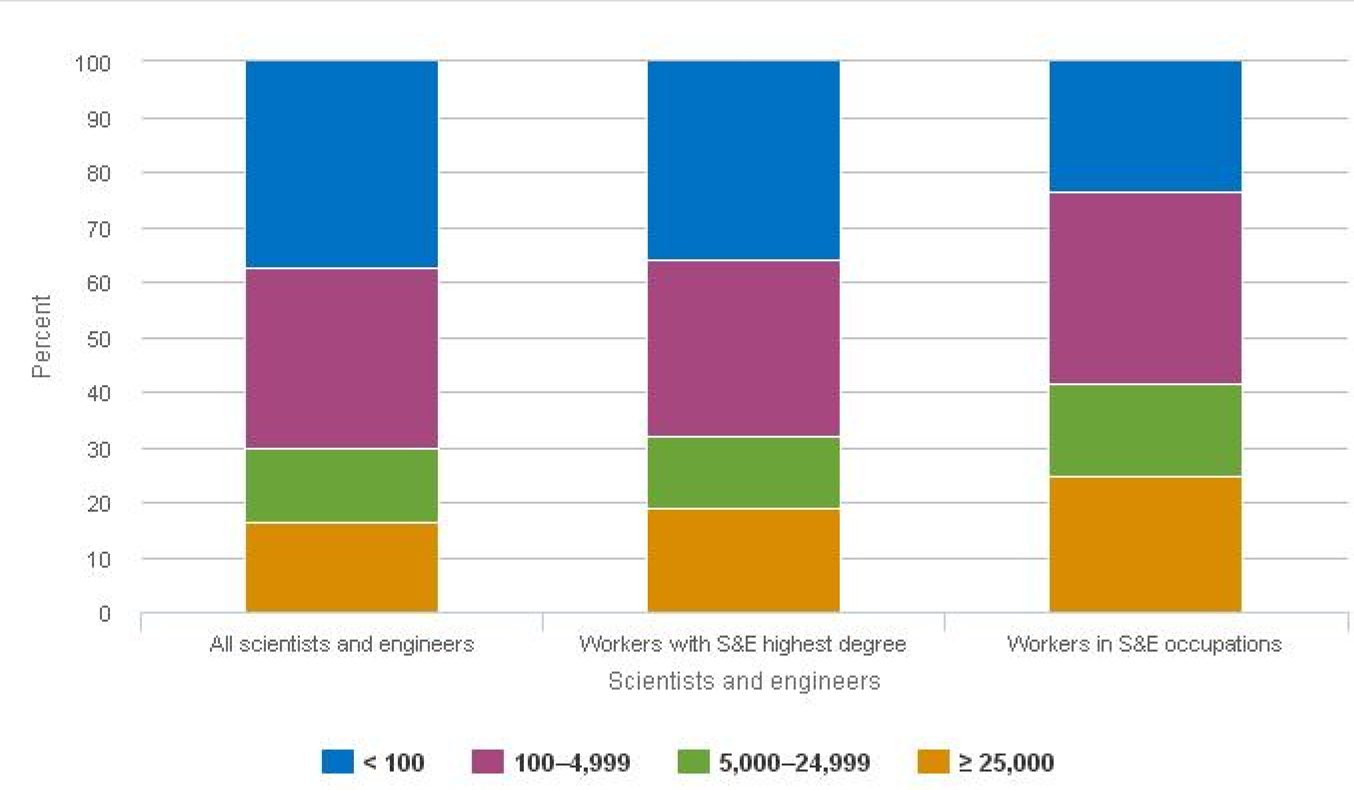
[iv] This list does not include the National Institutes of Health, which is a part of the Department of Health and Human Services (DHHS). S&E employment accounted for 19% of total DHHS employment in 2014.

Employer Size

The vast majority of educational institutions and government entities that employ individuals trained in S&E fields or working in S&E occupations are large employers (i.e., having 100 or more employees). These large organizations employ 87% of scientists and engineers in the education sector and 91% of those in the government sector. In contrast, scientists and engineers working in the business sector are more broadly distributed across firms of different sizes (Figure 3-12).

Figure 3-12

Scientists and engineers employed in the business sector, by employer size: 2013



NOTE: Scientists and engineers include those with one or more S&E or S&E-related degrees at the bachelor's level or higher or those who have only a non-S&E degree at the bachelor's level or higher and are employed in an S&E or S&E-related occupation.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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Many scientists and engineers who are self-employed work in businesses with 10 or fewer employees. In all, 85% of self-employed individuals in unincorporated businesses and 45% of self-employed individuals in incorporated businesses work in businesses with 10 or fewer employees. In contrast, only 5% of all other scientists and engineers work in businesses with 10 or fewer employees. Many of these scientists and engineers likely think of themselves as independent professionals rather than small business owners.

Industry Employment

The OES survey provides detailed estimates for employment in S&E occupations by type of industry; however, it excludes self-employed individuals, those employed in private households, and some individuals employed in agriculture. Industries vary in their proportions of S&E workers (Table 3-8). In 2014, the industry group with the largest S&E employment was professional, scientific, and technical services[i] (2 million), followed by manufacturing (911,000) (Table 3-8). The government sector, which includes federal, state, and local governments, employed 636,000 S&E workers; educational services, including private and public educational institutions, employed another 696,000 S&E workers. These four industry groups—professional, scientific, and technical services; manufacturing;

government; and educational services—had a disproportionate concentration of S&E workers and together accounted for about 67% of S&E employment, compared with 31% of total employment.

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[i] The establishments in this sector provide professional, scientific, and technical services to clients in a variety of industries as well as households. The services provided by S&E workers in this industry sector may include computer services; engineering and specialized design services; consulting services; research services; advertising services; and other professional, scientific, and technical services.

Table 3-8 **Employment in S&E occupations, by major industry: May 2014**

	Workers employed (n)		
Industry	All occupations	S&E occupations	Industry workforce in S&E occupations (%)
U.S. total—all industries	135,128,260	6,318,580	4.7
Agriculture, forestry, fishing, and hunting	409,720	1,250	0.3
Mining	824,260	61,630	7.5
Utilities	547,980	56,560	10.3
Construction	6,094,090	55,930	0.9
Manufacturing	12,100,740	911,290	7.5
Wholesale trade	5,780,070	236,950	4.1
Retail trade	15,472,510	44,210	0.3
Transportation and warehousing	5,202,640	40,590	0.8
Information	2,735,590	507,080	18.5
Finance and insurance	5,618,720	314,930	5.6
Real estate, rental, and leasing	2,017,970	13,470	0.7
Professional, scientific, and technical services	8,231,540	1,972,220	24.0
Management of companies and enterprises	2,206,620	275,840	12.5
Administrative and support and waste management and remediation	8,627,320	236,180	2.7
Educational services	12,758,610	696,180	5.5
Health care and social assistance	18,341,690	199,980	1.1
Arts, entertainment, and recreation	2,198,590	11,570	0.5
Accommodation and food services	12,548,660	3,680	0.0
Other services (except federal, state, and local government)	3,937,990	43,320	1.1
Federal, state, and local government (OES designation)	9,472,980	635,730	6.7

	OES = Occupational Employment Statistics.
NOTES:	Industries are defined by the North American Industry Classification System (NAICS). The OES Survey does not cover employment among self-employed workers and employment in private households (NAICS 814). In the employment total for agriculture, forestry, fishing, and hunting, only the following industries are included: logging (NAICS 1133), support activities for crop production (NAICS 1151), and support activities for animal production (NAICS 1152). As a result, the data do not represent total U.S. employment. Differences between any two industry groups may not be statistically significant.
SOURCE:	Bureau of Labor Statistics, OES Survey (May 2014).
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S&E employment intensity, defined by an industry's S&E employment as a proportion of its total employment, was highest in professional, scientific, and technical services (24%), followed by information (19%) and management of companies and enterprises (13%) (Table 3-8). The broad industry sectors with S&E employment intensity below the national average (4.7%) together employed 60% of all workers in 2014 but only 14% of workers in S&E occupations. These sectors with S&E employment intensity below the national average include large employers such as health care and social assistance, retail trade, and accommodation and food services. The health care and social assistance industry employed a large number of health workers who fall under NSF's category of S&E-related occupations (Table 3-2).

Employment by Metropolitan Area

The availability of a skilled workforce is an important indicator of a region's population, productivity, and technological growth (Carlino, Chatterjee, and Hunt 2001; Glaeser and Saiz 2003). The federal government uses standard definitions to describe geographical regions in the United States for comparative purposes. It designates very large metropolitan areas, sometimes dividing them into smaller metropolitan divisions that can also be substantial in size (Office of Management and Budget 2009).

This section presents the following indicators of the availability of S&E workers in a metropolitan area: (1) the number of S&E workers in the metropolitan area or division, and (2) the proportion of the entire metropolitan area workforce in S&E occupations. Data on the metropolitan areas with the largest proportion of workers in S&E occupations in 2014 appear in Table 3-9. These estimates are affected by the geographic scope of each metropolitan area, which can vary significantly. In particular, comparisons between areas can be strongly affected by how much territory outside the urban core is included in the metropolitan area.

Table 3-9 **Metropolitan areas with largest proportion of workers in S&E occupations: May 2014**

	Workers employed (*n*)		
Metropolitan area	All occupations	S&E occupations	Metropolitan area workforce in S&E occupations (%)
U.S. total	135,128,260	6,318,580	4.7
San Jose–Sunnyvale–Santa Clara, CA	973,480	163,460	16.8
Boulder, CO	167,200	22,620	13.5
Huntsville, AL	208,480	27,820	13.3
Framingham, MA, NECTA Division	162,170	21,010	13.0
Corvallis, OR	33,450	3,920	11.7

	Workers employed (*n*)		
Metropolitan area	All occupations	S&E occupations	Metropolitan area workforce in S&E occupations (%)
Durham–Chapel Hill, NC	284,480	33,020	11.6
Washington-Arlington-Alexandria, DC-VA-MD-WV, Metropolitan Division	2,378,260	259,080	10.9
Seattle-Bellevue-Everett, WA, Metropolitan Division	1,492,650	154,480	10.3
Bethesda-Rockville-Frederick, MD, Metropolitan Division	566,300	55,860	9.9
San Francisco–San Mateo–Redwood City, CA, Metropolitan Division	1,086,660	105,430	9.7
Ithaca, NY	49,430	4,380	8.9
Ames, IA	42,250	3,740	8.9
Boston-Cambridge-Quincy, MA, NECTA Division	1,795,230	157,300	8.8
Lowell-Billerica-Chelmsford, MA-NH, NECTA Division	118,980	10,420	8.8
Ann Arbor, MI	204,840	17,810	8.7
Columbus, IN	48,120	4,090	8.5
Fort Collins–Loveland, CO	139,530	11,810	8.5
Austin–Round Rock–San Marcos, TX	886,620	72,820	8.2
State College, PA	66,660	5,420	8.1
Madison, WI	347,750	27,250	7.8

NOTES: NECTA = New England City and Town Area.
The data exclude metropolitan statistical areas where S&E proportions were suppressed. Larger metropolitan areas are broken into component metropolitan divisions. Differences between any two areas may not be statistically significant.

SOURCE: Bureau of Labor Statistics, Occupational Employment Statistics Survey (May 2014).
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S&E employment in the United States is geographically concentrated; that is, a small number of geographic areas account for a significant proportion of S&E jobs. For example, the 20 metropolitan areas listed in Table 3-9 account for 18% of nationwide employment in S&E jobs, compared to about 8% of employment in all occupations.

Scientists and Engineers and Innovation-Related Activities

Who Performs R&D?

R&D creates new types of goods and services that can fuel economic and productivity growth and enhance living standards. Thus, the status of the nation’s R&D workforce is a policy area of concern nationally, regionally, and, increasingly, locally. This section uses SESTAT data to examine the R&D activity of scientists and engineers. In this section, the R&D workforce is defined as the proportion of workers who reported basic research, applied research, design, or development as a primary or secondary work activity in their principal job (i.e., activities that rank first or second in total work hours from a list of 14 activities).[i]

Overall, 27% of employed scientists and engineers in 2013 reported R&D as a primary or secondary work activity; the proportions who did so vary substantially across occupations and degrees (Figure 3-13). The majority of individuals in S&E occupations (55%) reported performing R&D, but so did a considerable proportion of those in S&E-related occupations (21%) and non-S&E occupations (15%). This indicates that although R&D activity spans a broad range of occupations, it is concentrated in S&E occupations. Among those with a non-S&E highest degree but working in an S&E occupation, a sizeable proportion reported R&D activity (44%), although this proportion is lower than for their colleagues with a highest degree in an S&E field (58%).

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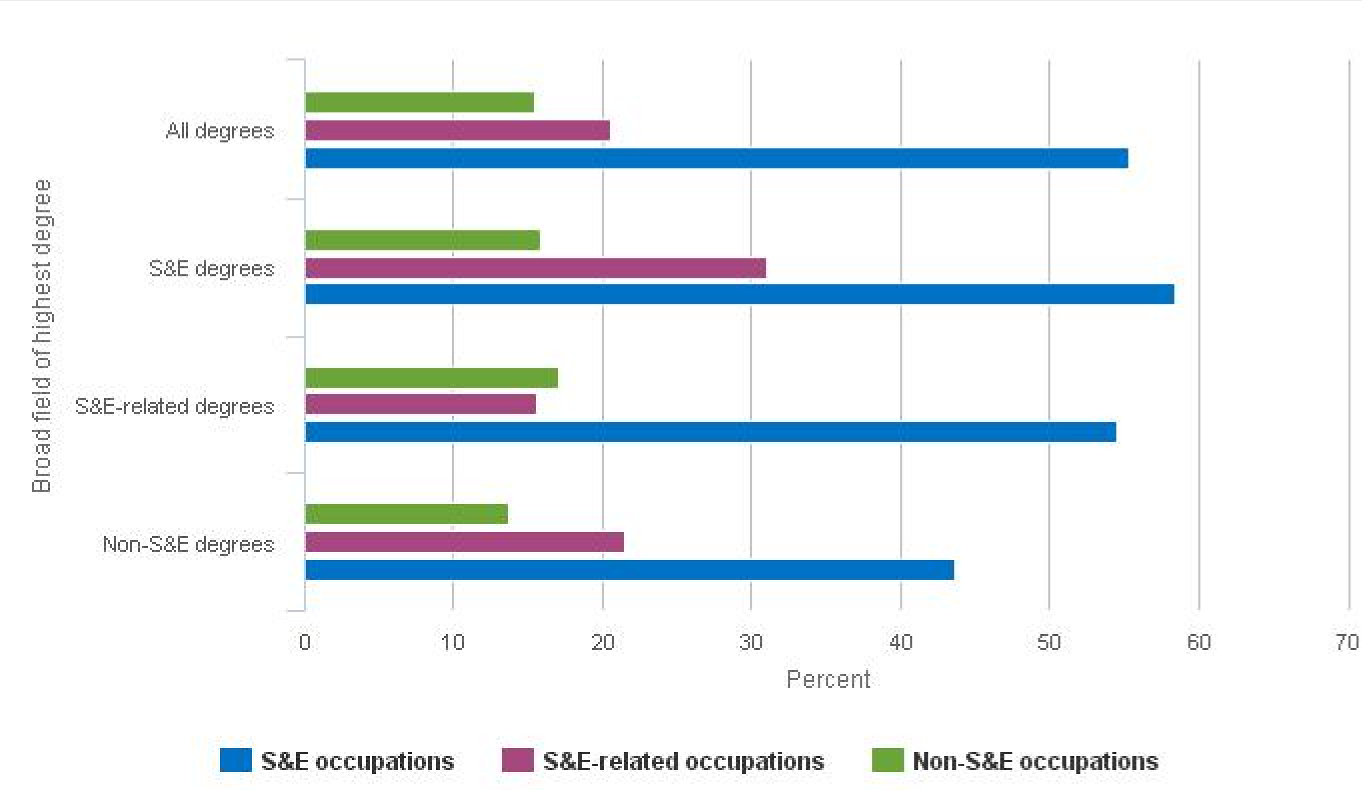
[i] The other 10 activities are used to define four additional broad categories of primary/secondary work activities, including teaching; management and administration; computer applications; and professional services, production workers, or other work activities not specified.

Figure 3-13

Employed scientists and engineers with R&D activity, by broad field of highest degree and broad occupational category: 2013



NOTES: Scientists and engineers include those with one or more S&E or S&E-related degrees at the bachelor's level or higher or those who have only a non-S&E degree at the bachelor's level or higher and are employed in an S&E or S&E-related occupation. R&D activity here refers to the share of workers reporting basic research, applied research, design, or development as a primary or secondary work activity in their principal job—activities ranking first or second in work hours.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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Many S&E degree holders subsequently earn degrees in fields such as medicine, law, or business. In 2013, the majority of S&E bachelor's degree holders who subsequently obtained an advanced degree (60%) earned it in an S&E-related field (18%) or non-S&E field (42%). Additionally, among S&E bachelor's degree holders who reported a second major for their bachelor's degree, about 56% designated an S&E-related field (2%) or non-S&E field (54%) as their second major.

Most individuals in the S&E workforce who reported performing R&D have a bachelor's (54%) or master's (31%) degree as their highest degree; those with doctorates account for 11% of researchers but only 5% of the S&E workforce. In most occupations, those with doctorates indicated higher rates of R&D activity than those with a bachelor's or master's degree as their highest degree (table 3-10).[ii] Overall, among those employed in S&E occupations, life scientists (74%) reported the highest rates of R&D activity, whereas social scientists (47%) and computer and mathematical scientists (44%) reported the lowest rates (Table 3-10).

[ii] Social scientists were exceptions. In 2013, a larger proportion of social scientists with doctorates reported R&D activity than social scientists with master's degrees; however, the difference in R&D activity rates between social scientists with doctorates and social scientists with bachelor's degrees was not statistically significant.

Table 3-10 **R&D activity rate of scientists and engineers employed in S&E occupations, by broad occupational category and level of highest degree: 2013**

(Percent)

Highest degree level	Biological, agricultural, and environmental life scientists	Computer and mathematical scientists	Physical scientists	Social scientists	Engineers
All degree levels	73.8	44.4	69.9	47.0	66.6
Bachelor's	68.9	41.4	60.2	47.6	64.4
Master's	69.6	48.7	72.3	45.0	66.9
Doctorate	83.7	64.5	79.4	54.0	84.7

NOTES: All degree levels includes professional degrees not broken out separately. R&D activity rate is the proportion of workers who report that basic research, applied research, design, or development is a primary or secondary work activity in their principal job—activities ranking first or second in work hours.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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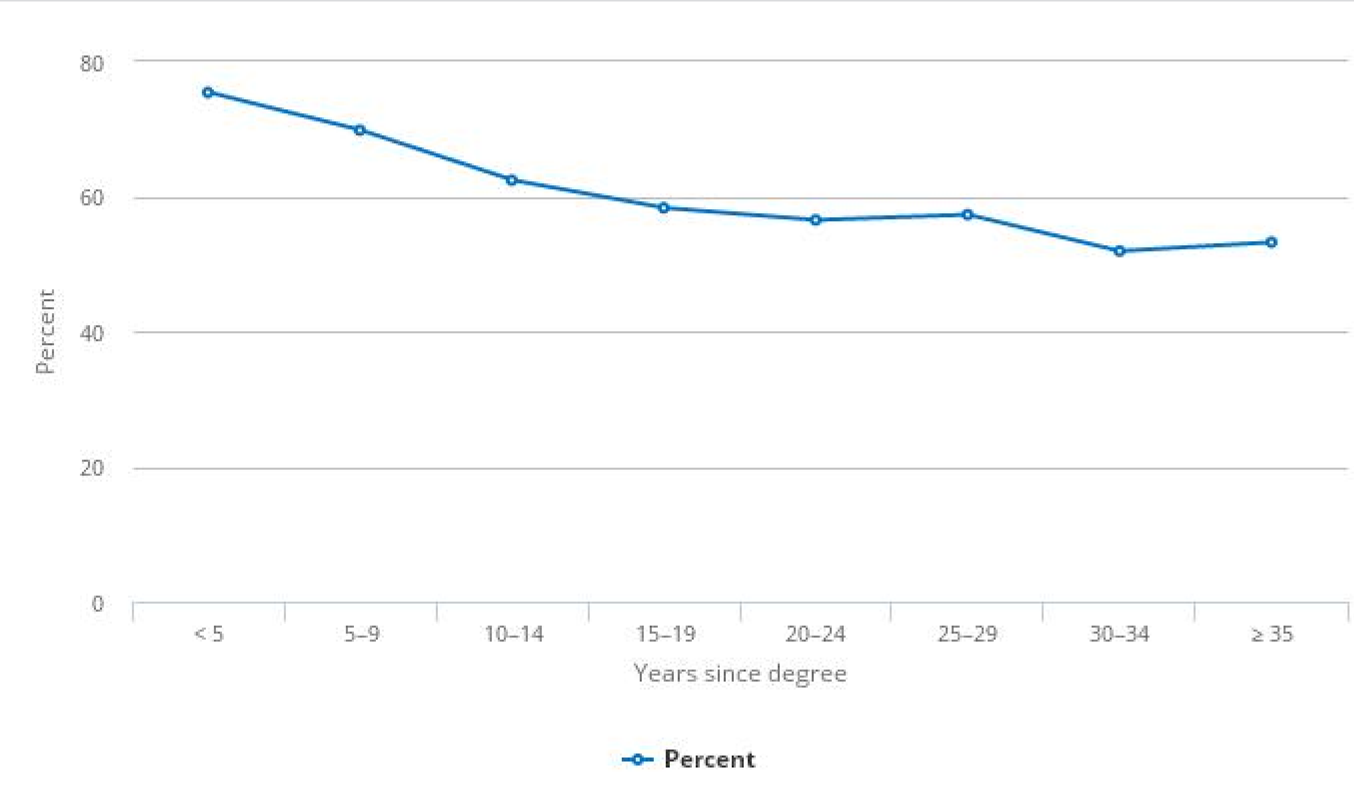
R&D activity tends to decline in later career stages (Figure 3-14). Among S&E doctorate holders who earned their doctorate in 2004 or later, 72% reported R&D activity in 2013. Among those receiving degrees between 1984 and 2003, 59% reported R&D activity in 2013. For those with degrees pre-dating 1984, 53% reported R&D activity in 2013. The decline in R&D activity over the course of individuals' careers may reflect movement into teaching or management, growth of other career interests, or possession of scientific knowledge and skills that are no longer in demand. It may also reflect increased opportunity for more experienced scientists to perform functions involving the interpretation and use of, as opposed to the creation and development of, scientific knowledge.

Figure 3-14

Employed SEH doctorate holders with R&D activity, by years since doctoral degree: 2013



SEH = science, engineering, and health.

NOTE: R&D activity here refers to the share of workers reporting basic research, applied research, design, or development as a primary or secondary work activity in their principal job—activities ranking first or second in work hours.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients (SDR) (2013), http://sestat.nsf.gov.

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Work-Related Training

In addition to formal education, workers receive work-related training. Such training can contribute to innovation and productivity growth by enhancing skills, efficiency, and knowledge. In 2013, 54% of scientists and engineers reported participating in work-related training within the past 12 months of being surveyed (Table 3-11).[iii] Among those who were employed, workers in S&E-related jobs (health-related occupations, S&E managers, S&E precollege teachers, and S&E technicians and technologists) exhibited higher rates of training (73%) than workers in S&E (54%) or non-S&E occupations (59%). Women participated in work-related training at a higher rate than men (56% versus 51%) (Appendix Table 3-6). This difference exists regardless of labor force status.

[iii] Work-related training includes conferences and professional meetings only if the conference or meeting attendance also includes attending a training session; it does not include college coursework while enrolled in a degree program.

Table 3-11 **Scientists and engineers participating in work-related training, by labor force status and occupation: 2013**

Labor force status and occupation	Number	Percent
All scientists and engineers	15,482,000	53.5
Employed	14,705,000	62.4
S&E occupations	3,123,000	54.3
Biological, agricultural, and environmental life scientists	352,000	55.2
Computer and mathematical scientists	1,319,000	49.8
Physical scientists	156,000	48.9
Social scientists	367,000	63.2
Engineers	929,000	59.4
S&E-related occupations	5,452,000	73.3
Non-S&E occupations	6,130,000	59.1
Unemployed	259,000	27.8
S&E occupations	50,000	26.6
Biological, agricultural, and environmental life scientists	8,000	36.4
Computer and mathematical scientists	16,000	18.6
Physical and related scientists	6,000	40.0
Social and related scientists	6,000	30.0
Engineers	14,000	31.1
S&E-related occupations	65,000	39.2
Non-S&E occupations	143,000	26.0
Not in labor force	517,000	11.6

NOTES: Scientists and engineers include those with one or more S&E or S&E-related degrees at the bachelor's level or higher or those who have only a non-S&E degree at the bachelor's level or higher and are employed in an S&E or S&E-related occupation in 2013. Unemployed individuals are those not working but who looked for a job in the preceding 4 weeks. For unemployed, the last job held was used for classification. Detail may not add to total because of rounding.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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Among scientists and engineers who participated in such work-related training, most did so to improve skills or knowledge in their current occupational field (53%) (Appendix Table 3-7).[iv] Others did so for licensure /certification in their current occupational field (23%) or because it was required or expected by their employer (15%). Relative to those who were employed or not in the labor force, those who were unemployed more frequently reported that they engaged in work-related training to facilitate a change to a different occupational field. Those who were not in the labor force more frequently reported that they engaged in this activity for leisure or personal interest than those who were in the labor force.

[iv] Although SESTAT respondents were allowed to provide more than one reason for participating in work-related training, the data presented in this section are on the most important reason for participating in such training.

S&E Labor Market Conditions

This section assesses the overall health of the labor market for scientists and engineers. Indicators of labor market participation (such as rates of unemployment and working involuntarily out of one's degree field) and earnings provide meaningful information on economic rewards and the overall attractiveness of careers in S&E fields. Many labor market indicators are lagging indicators, which change some time after other indicators show that the economy has begun to follow a particular trend. For example, although the most recent recession officially began in December 2007 and ended in June 2009, unemployment rates continued to rise after the recession had officially ended.[i] Rates of unemployment, rates of working involuntarily out of one's field of highest degree, and earnings should all be considered in this context.

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[i] The Business Cycle Dating Committee of the National Bureau of Economic Research is generally the source for determining the beginning and end of recessions or expansions in the U.S. economy. See http://www.nber.org /cycles/recessions.html for additional information.

Unemployment

Unemployment among scientists and engineers compares favorably with the rates for the labor force as a whole and for the college-educated labor force. In February 2013, an estimated 3.8% of the broad SESTAT population were unemployed (Appendix Table 3-8); the comparable unemployment rate for the entire U.S. labor force was more than twice as high, 8.1%.[i] The unemployment rate for the entire college-educated labor force in the same period was 4.3%. Although the unemployment rate among scientists and engineers in February 2013 was lower than in October 2010 (4.3%), it continued to exceed the recession-era October 2008 figure (3.1%) and the October 2006 (2.5%) prerecession rate. This underlines that the nation's S&E population, although somewhat sheltered, is not immune from fluctuations in broader economic conditions.

In 2013, unemployment rates varied across occupational categories. Among those in S&E occupations, unemployment rates ranged from 2.8% (among engineers) to 4.5% (among physical scientists); among those in S&E-related and non-S&E occupations, the rate was 2.2% and 5.0%, respectively (Appendix Table 3-8). Additionally, advanced degree holders were generally less vulnerable to unemployment than those with only bachelor's degrees (Appendix Table 3-8).

The extent of unemployment also varies by career stages. S&E highest degree holders within 5 to 30 years after obtaining their highest degree were less likely to be unemployed than those at earlier points in their careers (Figure 3-15). As workers strengthen their skills by acquiring labor market experience and adding on-the-job knowledge to their formal training, their work situations become more secure. However, in the very late career stages (30 or more years after obtaining their highest degree), the unemployment rates turn higher than for those within 5 to 30 years after obtaining their highest degree. Growing selectivity about desirable work, skill obsolescence, and other factors may contribute to this phenomenon. The trends of lower unemployment during early-to-mid career stages compared with very early or very late stages hold across degree levels (Figure 3-15).

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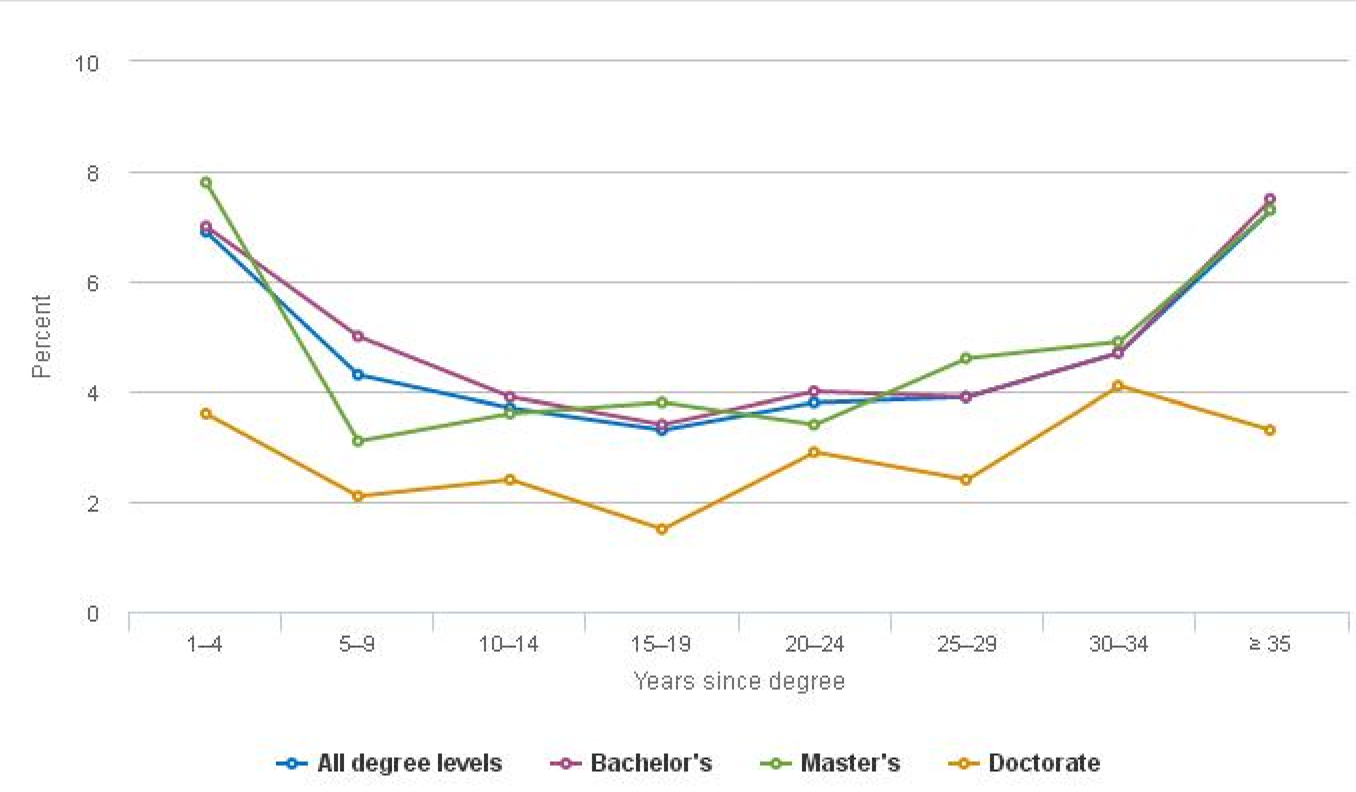
[i] The Bureau of Labor Statistics civilian unemployment rate for persons 16 years and over, not seasonally adjusted, is available at http://data.bls.gov/timeseries/LNU04000000. Accessed 21 November 2014.

Figure 3-15

Unemployment rates of S&E highest degree holders, by level of and years since highest degree: 2013



NOTE: All degree levels includes professional degrees not shown separately.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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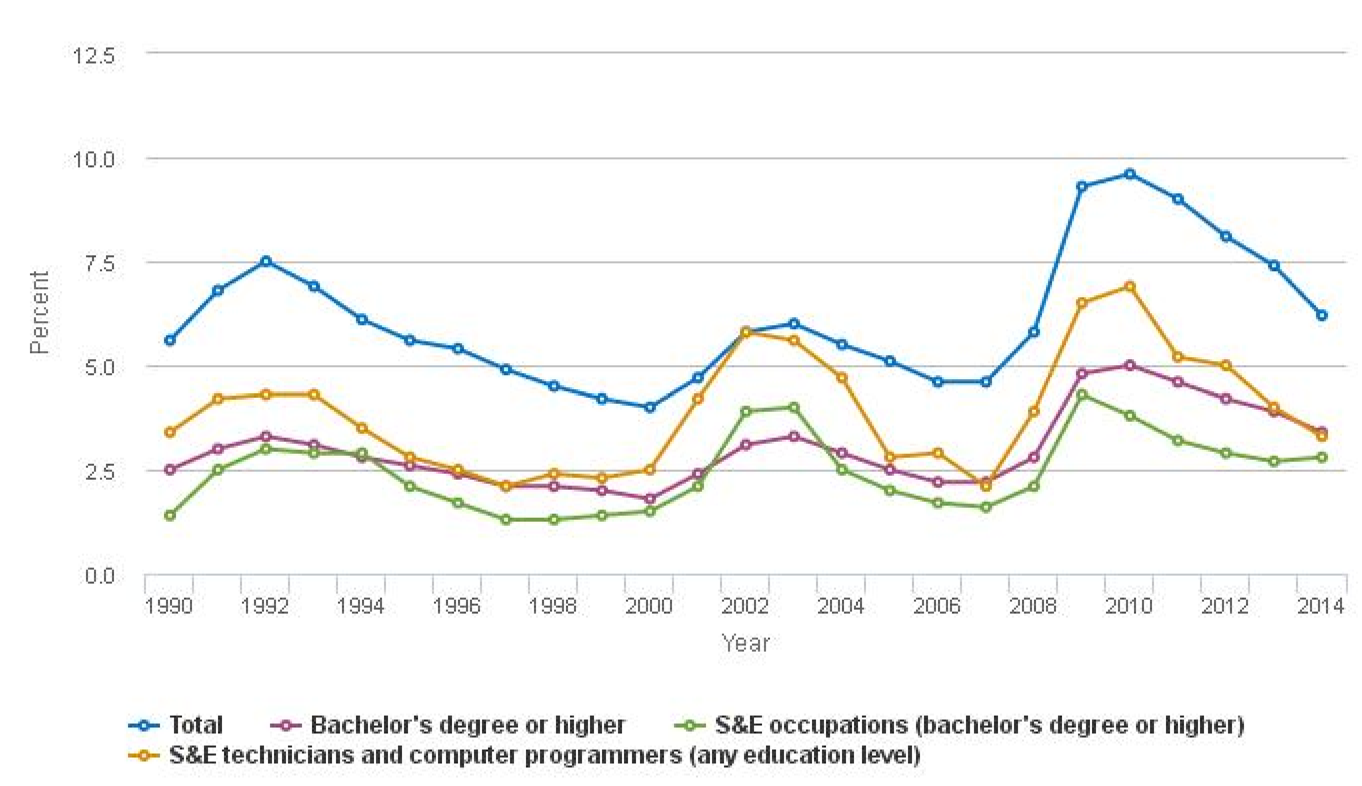
CPS unemployment rates over the past two decades[ii] indicate that workers in S&E occupations have historically experienced lower unemployment rates than the overall labor force (Figure 3-16). Additionally, during the economic downturn that began in late 2007, unemployment rates among S&E workers generally followed this historic pattern (Figure 3-17). Unemployment peaked at 5.7% in S&E jobs and 6.1% in the broader STEM occupations, which include computer programmers, S&E technicians, and S&E managers. In comparison, peak unemployment in all occupations was considerably higher (10.5%). In addition to lower rates, unemployment in S&E occupations began declining earlier than in all occupations.

[ii] The CPS is the source of the official unemployment rate.

Figure 3-16

Unemployment rate, by selected groups: 1990–2014



SOURCES: National Bureau of Economic Research, Merged Outgoing Rotation Group files (1990–2014), Bureau of Labor Statistics, Current Population Survey.

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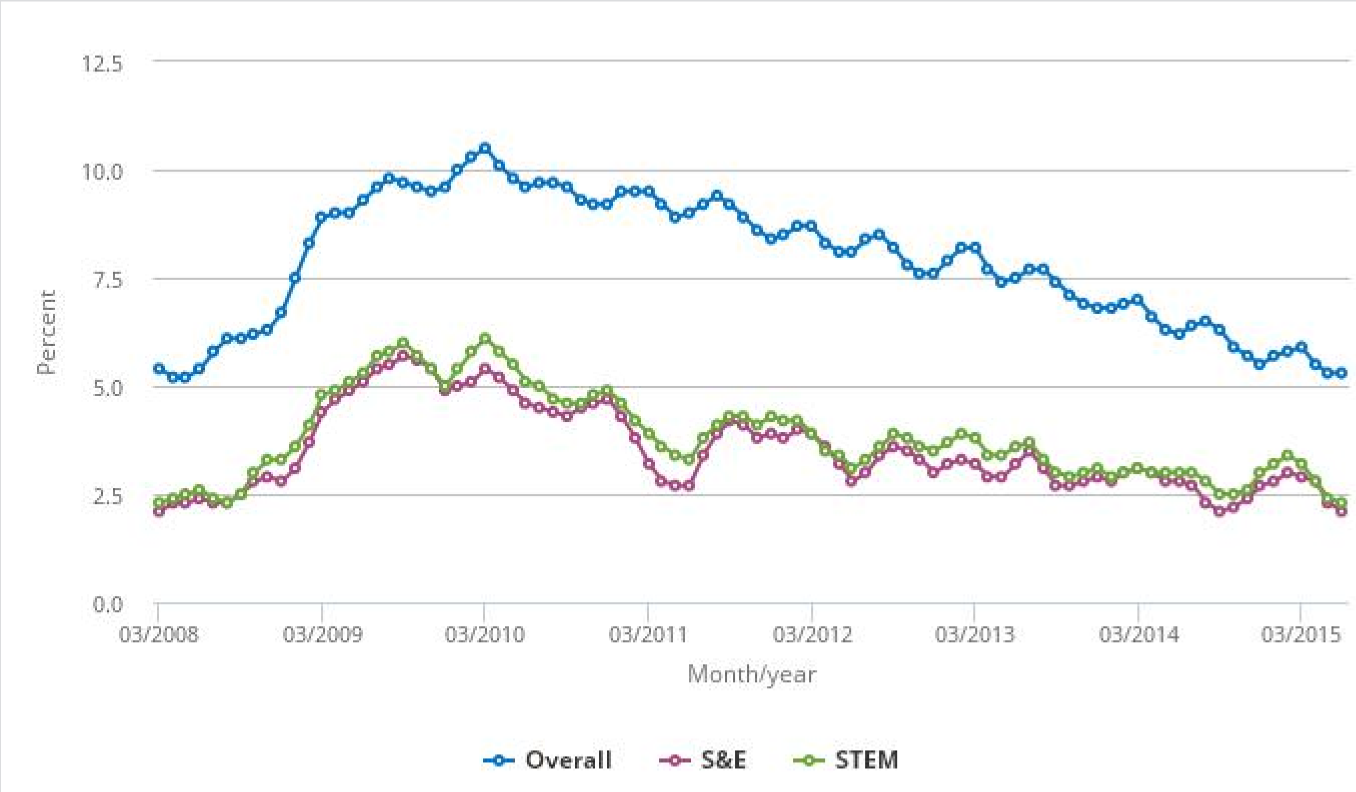
Figure 3-17

Unemployment rates for S&E, STEM, and the overall labor force: March 2008–June 2015



STEM = science, technology, engineering, and mathematics.

NOTES: Data for S&E, STEM, and the total labor force include people at all education levels. Estimates are not seasonally adjusted. Estimates are made by combining 3 months of microrecords of the Current Population Survey (CPS) in order to reduce the problem of small sample sizes and therefore will not match official CPS estimates based on a single month.

SOURCE: Bureau of Labor Statistics, CPS, Public Use Microdata Sample (PUMS), January 2008–June 2015.

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Working Involuntarily Out of One's Field of Highest Degree

Individuals invest time and financial resources in developing their knowledge and skills. Working outside of one’s chosen field of education for involuntary reasons may create skills mismatches and economic inefficiencies that can be viewed as one indicator of labor market stress. Individuals work outside their highest degree field for a variety of reasons. Those reporting that they do so because suitable work was not available in their degree field are referred to here as involuntarily out of field (IOF) workers, and their number relative to all employed individuals is the IOF rate.

Of the nearly 24 million employed scientists and engineers in 2013, almost 1.6 million reported working out of their field of highest degree because of a lack of suitable jobs in their degree field, yielding an IOF rate of 6.7%. For the more than 12 million whose highest degree was in an S&E field, the IOF rate was 8.3% (Table 3-12). SESTAT respondents were allowed to provide more than one reason for working out of field. Other reasons cited by S&E degree holders included pay and promotion opportunities (reported by 1.7 million individuals), change in career or professional interests (1.2 million), working conditions (1.5 million), family-related reasons (776,000), job location

(1.4 million), and other reasons (263,000). This suggests that, in addition to lack of a suitable job, various job-related and personal attributes such as compensation, location, and professional interest may result in out-of-field employment.

Table 3-12 **Scientists and engineers who are working involuntarily out of field, by S&E degree field: 2003–13**

(Percent)

S&E degree field	2003	2006	2008	2010	2013
All scientists and engineers	5.9	6.2	5.3	6.4	6.7
Highest degree in S&E field	7.8	8.1	7.1	8.4	8.3
Biological, agricultural, and environmental life sciences	10.1	9.7	10.1	10.1	9.4
Computer and mathematical sciences	4.9	5.7	4.5	5.1	4.1
Physical sciences	8.8	8.6	7.1	8.2	8.3
Social sciences	10.1	10.6	9.2	11.3	11.8
Engineering	4.2	4.5	3.6	4.9	4.6

NOTES: Scientists and engineers include those with one or more S&E or S&E-related degrees at the bachelor's level or higher or those who have only a non-S&E degree at the bachelor's level or higher and are employed in an S&E or S&E-related occupation. The involuntarily out-of-field rate is the proportion of all employed individuals who report that their job is not related to their field of highest degree because a job in their highest degree field was not available.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2003–13), http://sestat.nsf.gov.

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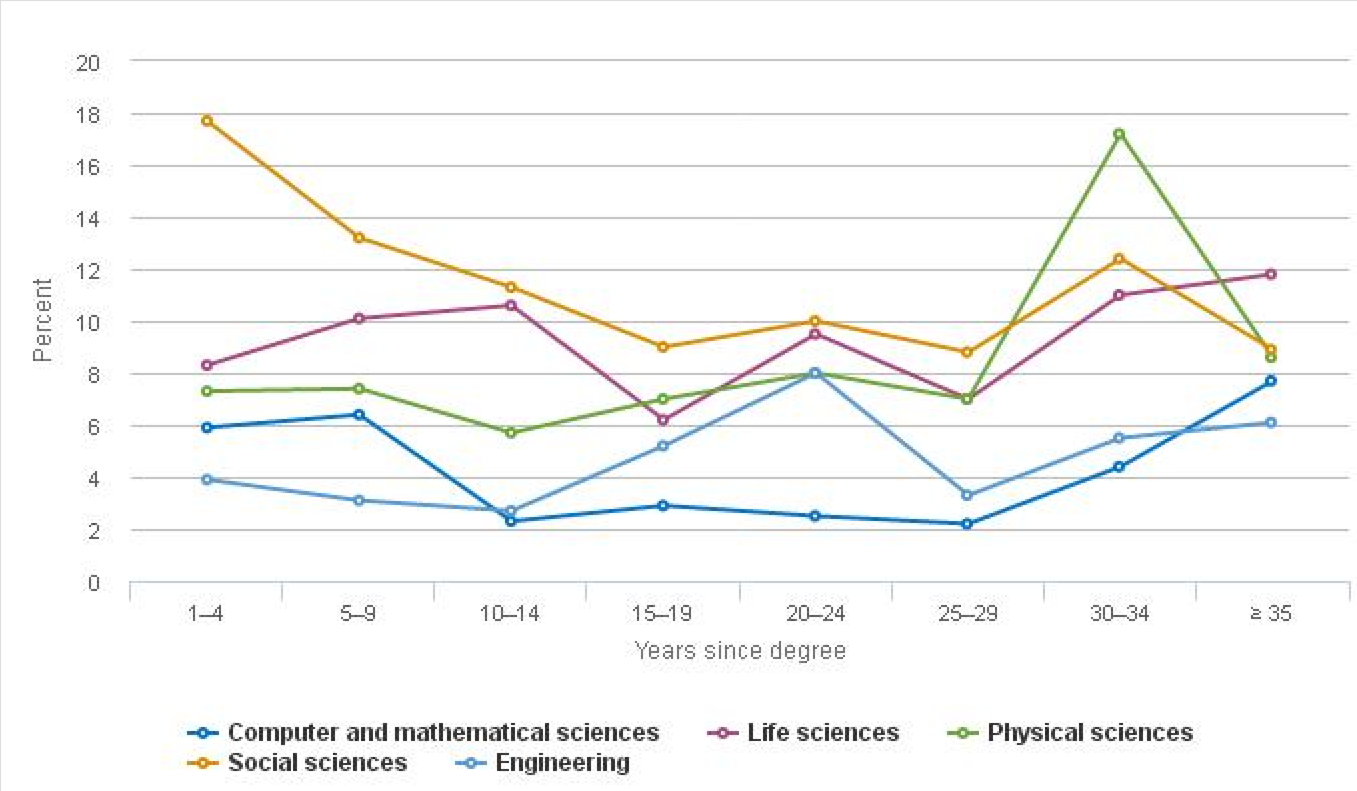
IOF rates vary by S&E degree fields and levels. Those with a highest degree in engineering or computer and mathematical sciences display lower IOF rates than those with a highest degree in physical, life, or social sciences (Table 3-12). The high IOF rates among social sciences degree holders, particularly in comparison with engineering and computer and mathematical sciences degree holders, are evident across most of the career cycle (Figure 3-18). Additionally, advanced degree holders are less likely to work involuntarily out of field than those with bachelor’s degrees only: in 2013, the IOF rate was 3.0% among S&E doctorate holders, 4.9% among those with S&E master’s degrees, and 9.8% among those with S&E bachelor’s degrees.

Figure 3-18

S&E highest degree holders who are working involuntarily out of field, by field of and years since highest degree: 2013



NOTE: Involuntarily out-of-field rate is the proportion of all employed individuals who reported working in a job not related to their field of highest degree because a job in that field was not available.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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Earnings

Based on the OES survey, individuals in S&E occupations earn considerably more than the overall workforce. Median annual salaries in 2014 in S&E occupations (regardless of education level or field) was $80,920, which is more than double the median for all U.S. workers ($35,540) (Table 3-13). This reflects a high level of formal education and technical skills associated with S&E occupations. Median S&E salaries in 2011–14 rose somewhat faster (1.7%) than for all U.S. workers (1.0%). In 2014, salaries for workers in S&E occupations ranged from $68,910 for social scientists to $89,090 for engineers. Salaries for workers in S&E-related occupations displayed similar patterns of higher earnings levels relative to the overall workforce. Health-related occupations, the largest segment of S&E-related occupations, cover a wide variety of workers ranging from physicians, surgeons, and practitioners to nurses, therapists, pharmacists, and health technicians; as a result, these occupations display a large variation in salary levels (Table 3-13).

Table 3-13	Annual salaries in science, technology, and related occupations: May 2011–May 2014

	Mean			Median		
Occupation	Annual salaries in 2011 ($)	Annual salaries in 2014 ($)	Average annual growth rate 2011–14 (%)	Annual salaries in 2011 ($)	Annual salaries in 2014 ($)	Average annual growth rate 2011–14 (%)
All U.S. employment	45,230	47,230	1.5	34,460	35,540	1.0
STEM occupations	80,360	85,530	2.1	74,450	78,730	1.9
S&E occupations	81,390	85,980	1.8	76,900	80,920	1.7
Computer and mathematical scientists	78,810	83,750	2.0	75,150	79,230	1.8
Life scientists	78,570	81,300	1.1	69,240	71,950	1.3
Physical scientists	81,890	85,140	1.3	73,820	76,390	1.1
Social scientists	72,400	75,320	1.3	66,370	68,910	1.3
Engineers	89,500	94,250	1.7	84,940	89,090	1.6
Technology occupations	76,600	82,300	2.4	63,760	67,650	2.0
S&E-related occupations (not listed above)	73,980	77,650	1.6	60,840	63,210	1.3
Health-related occupations	73,880	77,570	1.6	60,630	62,980	1.3
Registered nurses	69,110	69,790	0.3	65,950	66,640	0.3
Dentists, general	161,750	166,810	1.0	142,740	149,540	1.6
Family and general practitioners	177,330	186,320	1.7	167,000	180,180	2.6
Other S&E-related occupations	79,660	82,400	1.1	72,490	74,500	0.9
Non-STEM occupations	40,730	42,380	1.3	31,360	32,390	1.1
Chief executives	176,550	180,700	0.8	166,910	173,320	1.3
General and operations manager	114,490	117,200	0.8	95,150	97,270	0.7
Education administrators, postsecondary	97,170	101,910	1.6	84,280	88,390	1.6

	Mean			Median		
Occupation	Annual salaries in 2011 ($)	Annual salaries in 2014 ($)	Average annual growth rate 2011–14 (%)	Annual salaries in 2011 ($)	Annual salaries in 2014 ($)	Average annual growth rate 2011–14 (%)
Management analysts	87,980	90,860	1.1	78,490	80,880	1.0
Financial analysts	87,740	92,250	1.7	75,650	78,620	1.3
Lawyers	130,490	133,470	0.8	113,310	114,970	0.5
Technical writers	67,280	71,950	2.3	64,610	69,030	2.2

STEM = science, technology, engineering, and mathematics.

NOTES: See table 3-2 for definitions of S&E, S&E-related, and STEM occupations. Occupational Employment Statistics (OES) Survey employment data do not cover employment in some sectors of the agriculture, forestry, fishing, and hunting industry; in private households; or among self-employed individuals. As a result, the data do not represent total U.S. employment.

SOURCE: Bureau of Labor Statistics, OES Survey (May 2011, May 2014).

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The rest of this section presents earnings data for college-educated workers from NSF's NSCG and SESTAT. The NSCG, which covers the entire college-educated population of the United States (regardless of their S&E background), provides earnings data for individuals trained or employed in S&E fields and non-S&E fields. SESTAT, which covers the college-educated scientists and engineers population, is helpful for a deeper analysis of trends among various subgroups of individuals trained or employed in S&E.

Overall, college-educated individuals with an S&E or S&E-related degree enjoy an earnings premium compared to those with a non-S&E degree; for the most part, this earnings premium is present across career stages. Figure 3-19 presents data on median salaries for groups with S&E, S&E-related, or non-S&E highest degrees at comparable numbers of years since receiving their highest degrees. Although median salaries are similar in the beginning for S&E and non-S&E degree holders, both of which are lower than that for S&E-related degree holders, the rise in earnings associated with career progression is much steeper among individuals with S&E degrees. Among S&E highest degree holders, those with engineering or computer and mathematical sciences degrees earn more than degree holders in other broad S&E fields during early-to-mid career stages; engineering degree holders continue to enjoy an earnings premium through later career stages compared with their counterparts with degrees in most other broad S&E fields (Figure 3-20).

Figure 3-19

Median salaries for employed college-educated individuals, by broad field of highest degree and years since highest degree: 2013

NOTE: See table 3-2 for classification of S&E, S&E-related, and non-S&E degree fields.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, National Survey of College Graduates (2013).

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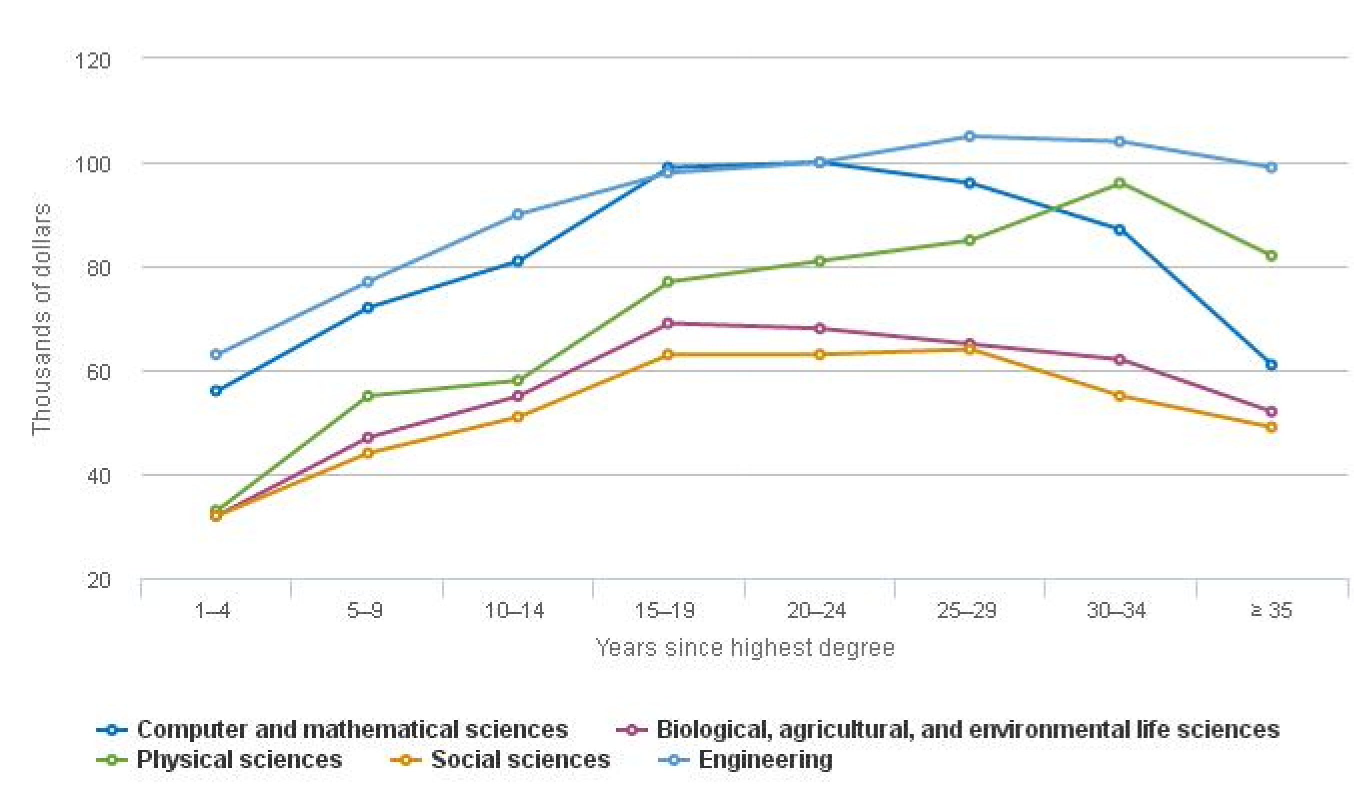
Figure 3-20

Median salaries for S&E highest degree holders, by broad field of and years since highest degree: 2013



SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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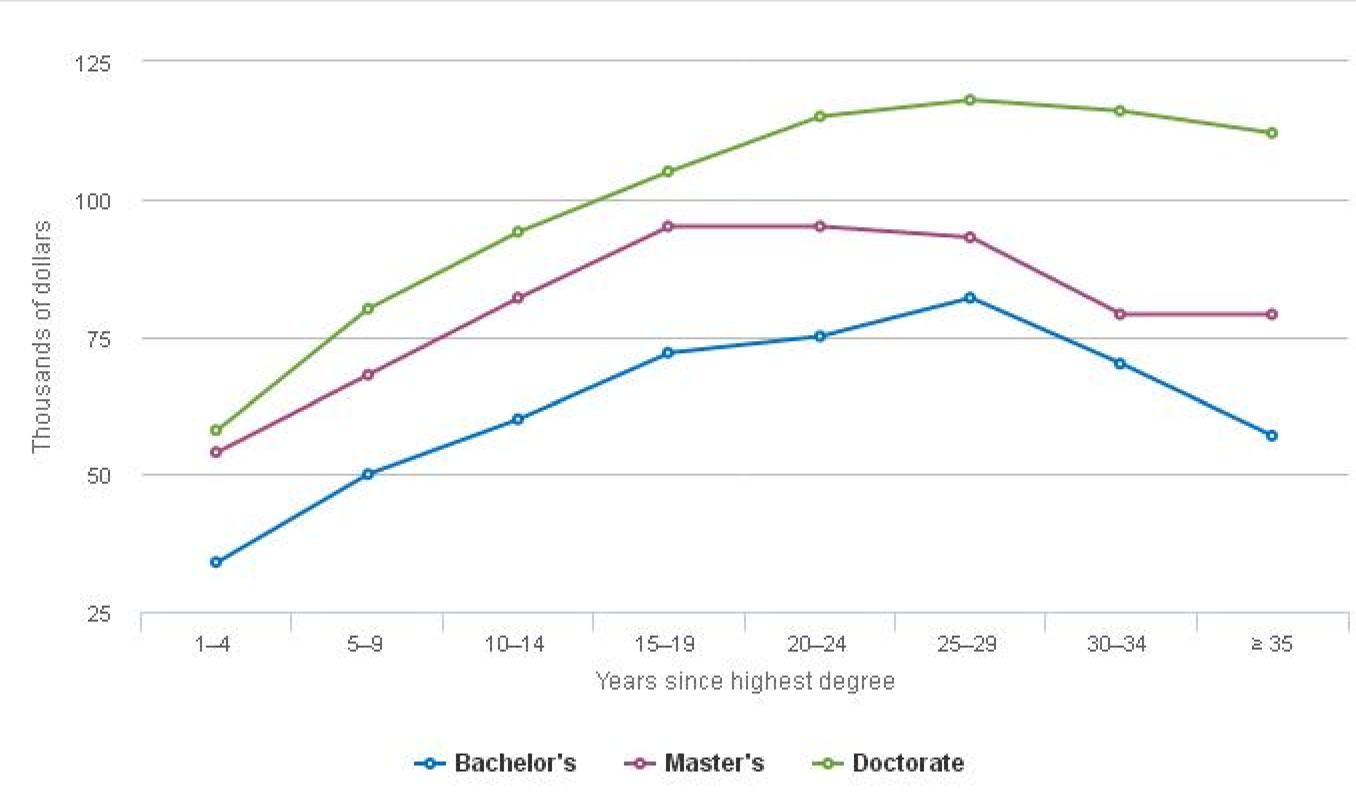
Earnings also vary by degree levels. For those with an S&E highest degree, annual median salaries rise with a master's or doctoral degree (Appendix Table 3-9), and this pattern holds across career stages (Figure 3-21). Among those with an S&E-related or non-S&E highest degree, professional degree holders earn the most (Appendix Table 3-9). The relatively high salaries among S&E-related or non-S&E professional degree holders are driven primarily by medical practitioners and lawyers, respectively. A majority of college graduate workers whose highest degree is a professional degree in an S&E-related field (70%) work as a diagnosing or treating practitioner (with a median salary of $140,000); a majority of those whose highest degree is a professional degree in a non-S&E field (76%) work as a lawyer or judge (with a median salary of $107,000).

Figure 3-21

Median salaries for S&E highest degree holders, by level of and years since highest degree: 2013



SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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Among employed individuals without a bachelor's degree, S&E occupations provide stable jobs with competitive salaries relative to those in non-S&E occupations. (See sidebar, S&E Workers Without a Bachelor's Degree.)

Recent S&E Graduates

In today's knowledge-based and globally integrated economy marked by rapid information flow and development of new knowledge, products, and processes, demand for certain skills and abilities may change fast. The employment outcomes of recent graduates are an important indicator of current changes in labor market conditions. Compared with experienced S&E workers, recent S&E graduates more often bring new ideas and newly acquired skills to the labor market. This section examines the employment outcomes of recent recipients of S&E bachelor's, master's, and doctoral degrees.

General Labor Market Indicators for Recent Graduates

Table 3-14 summarizes some basic labor market statistics in 2013 for recent recipients of S&E degrees; *recent* here is defined as between 1 and 5 years since receiving the highest degree. Among the nearly 24 million SESTAT respondents in February 2013, 2.1 million were *recent* S&E degree recipients. Overall, the unemployment rate among recent S&E graduates was 5.7%, compared with the 3.8% unemployment rate overall among the SESTAT population of scientists and engineers.

Table 3-14 **Labor market indicators for recent S&E degree recipients up to 5 years after receiving degree, by level and field of highest degree: 2013**

Indicator and highest degree level	All S&E fields	Biological, agricultural, and environmental life sciences	Computer and mathematical sciences	Physical sciences	Social sciences	Engineering
Unemployment rate (%)						
All degree levels	5.7	5.6	4.2	3.7	7.9	2.4
Bachelor's	6.5	6.4	3.3	4.7	9.0	3.1
Master's	4.2	3.8	6.7	S	5.1	0.8
Doctorate	2.3	2.6	S	5.0	3.1	S
Involuntarily out-of-field (IOF) rate (%)						
All degree levels	11.7	9.5	6.1	6.7	18.5	3.7
Bachelor's	14.4	10.8	8.2	9.8	22.2	3.9
Master's	6.0	8.0	S	S	9.1	4.8
Doctorate	1.6	2.7	S	5.3	3.2	S
Median annual salary ($)						
All degree levels	40,000	34,000	57,000	34,000	34,000	65,000
Bachelor's	35,000	30,000	52,000	30,000	31,000	60,000
Master's	57,000	43,000	77,000	33,000	45,000	75,000
Doctorate	62,000	49,000	76,000	60,000	60,000	88,000

S = suppressed for reasons of confidentiality and/or reliability.

NOTES: Median annual salaries are rounded to the nearest $1,000. All degree levels includes professional degrees not broken out separately. Data include degrees earned from February 2008 to February 2012. The IOF rate is the proportion of all employed individuals who report that their job is not related to their field of highest degree because a job in their highest degree field was not available.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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Among recent bachelor's degree holders, the unemployment rate averaged 6.5%, ranging from about 3% for those with engineering (3.1%) and computer and mathematical sciences (3.3%) degrees to 9.0% for those with social sciences degrees. Overall, unemployment was generally lower for those with recent doctorates than for those with recent bachelor's or master's level degrees. Early in their careers, as individuals gather labor market experience and on-the-job skills, they tend to have a higher incidence of job change and unemployment, which may partially explain some of the higher unemployment rates seen among those with a bachelor's degree as their highest degree.

A useful but more subjective indicator of labor market conditions for recent graduates is the proportion who report that their job is unrelated to their highest degree field because a job in their degree field was not available (i.e., the IOF rate). Of the nearly 2.1 million employed scientists and engineers who received their highest degree in an S&E field in the previous 5 years, an estimated 11.7% indicated working involuntarily out of field in 2013 (Table 3-14). As such, the IOF rate among recent S&E degree recipients in 2013 was higher than the IOF rate among the overall SESTAT population with an S&E highest degree (8.3%). SESTAT respondents were allowed to report more than one reason for working out of field as well as the most important reason for working out of field. When asked about the most important reason for working out of field, the reasons most frequently cited by recent S&E degree recipients were lack of a suitable job in their degree field (cited by 38% of those working out of field), followed by pay and promotion opportunities (20%) and change in career or professional interests (13%). The responses provided by all S&E highest degree holders working out of field (regardless of graduation year) were similar, but the factors were ranked differently: the most frequently cited reasons were pay and promotion opportunities (cited by 25% of all S&E highest degree holders working out of field), followed by change in career or professional interests (20%) and lack of a suitable job in their degree field (19%).

IOF rates vary across S&E degree levels and fields. Overall, IOF rates are lower among advanced degree holders compared with those with only bachelor's level degrees, but there exists significant variation across degree fields. Among recent bachelor's degree holders, the IOF rate ranged from 3.9% among recent engineering graduates to 22.2% among recent graduates in social sciences (Table 3-14). Among recent bachelor's degree holders in social sciences, IOF rates were high in all major fields, including economics, political sciences, psychology, and sociology and anthropology. However, within social sciences, recent master's degree and doctorate recipients experienced significantly lower IOF rates than recent bachelor's degree holders. On the contrary, among recent recipients of engineering degrees, IOF rates were similar across degree levels.

The median salary for recent S&E bachelor's degree recipients in 2013 was $35,000, ranging from $30,000 in life sciences and physical sciences to $60,000 in engineering (Table 3-14). Recent master's degree recipients had a median salary of $57,000, and recent doctorate recipients had a median salary of $62,000.

Recent Doctorate Recipients

The career rewards of highly skilled individuals in general, and doctorate holders in particular, often extend beyond salary and employment to the more personal rewards of doing the kind of work for which they have trained. No single standard measure satisfactorily reflects the state of the doctoral S&E labor market. This section discusses a range of relevant labor market indicators, including unemployment rates, IOF employment, employment in academia compared with other sectors, employment in postdoctoral positions, and salaries. Although a doctorate can expand career and salary opportunities, these opportunities may come at the price of many years of lost labor market earnings due to the number of years required to earn the degree.

Unemployment. In February 2013, the unemployment rate for science, engineering, and health (SEH) doctorate recipients up to 3 years after receiving their doctorates was 2.7% (Table 3-15), compared to an unemployment rate of 2.1% for all SEH doctorates. The unemployment rate for recent SEH doctorate recipients was also lower than the unemployment rate for the entire SESTAT population regardless of level or year of award of highest degree (3.8%).

Table 3-15 Employment characteristics of recent SEH doctorate recipients up to 3 years after receiving doctorate, by field of degree: 2001–13

	Recent doctorates (*n*)						Unemployment rate (%)						Involuntarily out-of-field rate (%)					
Field of doctorate	2001	2003	2006	2008	2010	2013	2001	2003	2006	2008	2010	2013	2001	2003	2006	2008	2010	2013
All recent SEH doctorates	48,700	43,700	49,500	52,600	52,700	45,500	1.3	2.5	1.2	1.5	2.3	2.7	2.8	2.1	1.4	1.3	1.8	2.3
Biological, agricultural, and environmental life sciences	12,300	11,200	12,600	13,400	14,100	12,200	1.4	2.4	0.9	1.7	1.5	3.4	2.6	1.0	0.3	1.0	1.5	2.6
Computer and information sciences	1,600	1,400	1,500	2,400	2,500	2,000	0.3	4.1	1.9	S	S	S	S	S	2.6	1.4	S	S
Mathematics and statistics	2,200	1,600	2,000	2,400	2,400	2,200	0.2	3.4	S	S	S	S	1.4	3.4	2.2	1.1	S	S
Physical sciences	7,700	6,500	7,400	7,500	7,700	6,400	1.5	1.3	1.1	3.0	2.6	4.8	5.4	4.2	2.6	2.3	1.4	1.7
Psychology	7,200	6,300	7,000	5,800	5,400	4,700	1.5	2.7	1.2	0.8	3.8	S	3.0	1.5	1.4	0.8	2.0	S
Social sciences	5,800	6,000	6,200	5,900	6,000	5,400	1.6	3.1	1.4	2.1	3.4	3.8	3.3	3.0	2.3	3.4	3.5	5.9
Engineering	9,400	8,000	9,500	12,000	11,300	9,600	1.5	3.0	1.8	1.2	2.7	2.1	2.0	3.0	1.6	0.7	1.9	2.2
Health	2,400	2,700	3,200	3,300	3,400	3,000	0.4	0.7	0.9	1.2	S	S	S	1.1	S	S	S	S

NOTES: S = suppressed for reasons of confidentiality and/or reliability.

SEH = science, engineering, and health.

Involuntarily out-of-field rate is the proportion of all employed individuals who report working in a job not related to their field of doctorate because a job in that field was not available. Data for 2001 and 2006 include graduates from 12 months to 36 months prior to the survey reference date; data for 2003, 2008, and 2010 include graduates from 15 months to 36 months prior to the survey reference date; data for 2013 include graduates from 19 months to 36 months prior to the survey reference date. Detail may not add to total because of rounding.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients (SDR) (2001–13), http://sestat.nsf.gov.

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Working involuntarily out of field. About 2.3% of employed recent SEH doctorate recipients reported that they took a job that was not related to the field of their doctorate because a suitable job in their field was not available (Table 3-15). This compared favorably with the IOF rate for the entire SESTAT population with an S&E highest degree (8.3%).

Tenure-track positions. Although many science doctorate recipients aspire to tenure-track academic appointments (Sauermann and Roach 2012), most end up working in other types of positions and sectors. In 2013, about 12% of those who earned their SEH doctorate within the previous 3 years had a tenure or tenure-track faculty appointment (Table 3-16).[i] Across the broad SEH fields, this proportion varied significantly, from less than 10% among recent doctorates in life sciences, physical sciences, and engineering to 38% among those in social sciences.

[i] In this chapter, someone who is on tenure track but not yet tenured is referred to as "tenure-track" faculty.

Table 3-16 **Employed SEH doctorate recipients holding tenure and tenure-track appointments at academic institutions, by field of and years since degree: 1993–2013**

(Percent)

Years since doctorate and field	1993	1995	1997	1999	2001	2003	2006	2008	2010	2013
< 3 years										
All SEH fields	18.1	16.3	15.8	13.5	16.5	18.6	17.7	16.2	14.7	12.4
Biological, agricultural, and environmental life sciences	9.0	8.5	9.3	7.7	8.6	7.8	7.2	6.5	7.6	5.3
Computer and information sciences	31.5	36.5	23.4	18.2	20.7	32.5	31.2	22.0	20.8	21.1
Mathematics and statistics	40.9	39.8	26.9	18.9	25.2	38.4	31.6	31.3	26.1	25.0
Physical sciences	8.8	6.9	8.5	7.8	10.0	13.3	9.8	8.8	6.8	6.9
Psychology	12.8	13.6	14.7	16.0	15.6	14.6	17.0	18.1	16.0	11.1
Social sciences	43.5	35.9	37.4	35.4	38.5	44.8	39.3	45.4	41.1	38.0
Engineering	15.0	11.5	9.4	6.4	11.3	10.8	12.4	9.3	7.5	6.6
Health	33.9	34.2	30.1	28.1	32.1	30.3	36.2	27.7	24.2	20.7
3–5 years										
All SEH fields	27.0	24.6	24.2	21.0	18.5	23.8	25.9	22.9	19.7	19.4
Biological, agricultural, and environmental life sciences	17.3	17.0	18.1	16.4	14.3	15.5	13.7	14.3	10.6	10.6
Computer and information sciences	55.7	37.4	40.7	25.9	17.3	32.2	45.7	37.8	22.2	13.8
Mathematics and statistics	54.9	45.5	48.1	41.0	28.9	45.5	50.6	40.7	41.7	29.6

Years since doctorate and field	1993	1995	1997	1999	2001	2003	2006	2008	2010	2013
Physical sciences	18.8	15.5	14.5	11.9	15.8	18.3	19.7	16.5	14.7	14.3
Psychology	17.0	20.7	16.8	17.6	17.5	19.9	23.8	18.3	19.1	17.6
Social sciences	54.3	52.4	50.4	46.5	38.8	46.0	50.4	48.9	46.7	48.5
Engineering	22.7	19.3	19.4	12.6	10.8	15.9	16.3	15.5	13.0	14.6
Health	47.4	40.2	41.1	39.5	25.1	40.8	43.1	34.4	33.3	32.4

NOTES: SEH = science, engineering, and health.
Proportions are calculated on the basis of all doctorates working in all sectors of the economy. Data for 1993–99, 2001, and 2006 include graduates from 12 months to 60 months prior to the survey reference date; data for 2003, 2008, and 2010 include graduates from 15 months to 60 months prior to the survey reference date; data for 2013 include graduates from 19 months to 60 months prior to the survey reference date.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients (1993–2013), http://sestat.nsf.gov.

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The proportion of SEH doctorates who hold a tenure or tenure-track faculty appointment increases with years of experience. In 2013, 19% of SEH doctorates in the labor market for 3 to 5 years had tenure or a tenure-track appointment, compared with 12% of their colleagues who were within 3 years of doctorate receipt (Table 3-16). The extent of the increase varies across the broad areas of training. In social sciences, for example, a relatively large percentage of individuals obtain a tenure or tenure-track position within 3 years of earning their doctorate, and the increase associated with 3 to 5 years of labor market exposure is more modest than in some other fields, such as physical sciences or engineering. (See chapter 5 for an in-depth discussion of various types of academic positions held by S&E doctorate holders.)

The availability of tenure-track positions may be counterbalanced by the availability of desirable nonacademic employment opportunities. Among recent doctorates in most S&E fields, median salaries are significantly higher in the business sector than in tenured or tenure-track academic positions (Table 3-17). The proportion of recent graduates who obtain tenure or tenure-track employment has declined since 1993 in a number of broad areas of SEH training (Table 3-16). One of the steepest declines occurred in computer sciences, particularly among individuals within 3 to 5 years of receiving their doctorates, despite the high demand for computer sciences faculty.

Table 3-17 **Median salaries for recent SEH doctorate recipients up to 5 years after receiving degree, by field of degree and employment sector: 2013**

(Dollars)

		Education					
		4-year institutions					
Field of doctorate	All sectors	All positions	Tenured or tenure-track position	Postdoc	2-year or precollege institutions	Government	Business/ industry
All SEH fields	70,000	54,000	71,000	44,000	53,000	79,000	91,000

		Education					
		4-year institutions					
Field of doctorate	All sectors	All positions	Tenured or tenure-track position	Postdoc	2-year or precollege institutions	Government	Business/ industry
Biological, agricultural, and environmental life sciences	51,000	46,000	68,000	43,000	46,000	68,000	71,000
Computer and information sciences	105,000	78,000	88,000	S	S	101,000	120,000
Mathematics and statistics	72,000	60,000	62,000	63,000	S	89,000	96,000
Physical sciences	63,000	50,000	60,000	46,000	51,000	73,000	90,000
Psychology	62,000	54,000	60,000	42,000	53,000	83,000	66,000
Social sciences	66,000	62,000	68,000	48,000	58,000	89,000	86,000
Engineering	90,000	70,000	82,000	45,000	S	88,000	99,000
Health	78,000	70,000	71,000	42,000	S	79,000	99,000

S = suppressed for reasons of confidentiality and/or reliability.

SEH = science, engineering, and health.

NOTES: Salaries are rounded to the nearest $1,000. Data include graduates from 19 months to 60 months prior to the survey reference date. The 2-year or precollege institutions include 2-year colleges and community colleges or technical institutes and also preschool, elementary, middle, or secondary schools. The 4-year institutions include 4-year colleges or universities, medical schools, and university-affiliated research institutes.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients (2013), http://sestat.nsf.gov.

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Salaries for recent SEH doctorate recipients. For all SEH degree fields in 2013, the median annual salary for recent doctorate recipients within 5 years after receiving their degrees was $70,000 (Table 3-17). Across various SEH degree fields, median annual salaries ranged from a low of $51,000 in biological sciences to a high of $105,000 in computer and information sciences. Between 2010 and 2013, median salaries increased overall among recent recipients of SEH doctoral degrees (the median salary for recent SEH doctorate recipients in 2010 was $66,000).

By type of employment, salaries for recent doctorate recipients ranged from $44,000 for postdoctoral positions in 4-year institutions to $91,000 for those employed in the business sector (Table 3-17). Each sector, however, exhibited substantial internal variation by SEH fields of training.

Postdoctoral Positions

A significant number of new S&E doctorate recipients take a postdoctoral appointment (generally known as a postdoc) as their first position after receiving their doctorate. Postdoc positions are defined as temporary, short-term positions, primarily for acquiring additional training in an academic, government, industry, or nonprofit setting.[ii] In many S&E disciplines, a postdoc position is necessary to be competitive for obtaining a faculty position.

Individuals in postdoc positions often perform cutting-edge research and receive valuable training. These positions, however, generally offer lower salaries than permanent positions. A factor that has received much attention in science policy is the growth seen over the last three decades in the number of postdocs in both traditional (e.g., life sciences and physical sciences) and nontraditional (e.g., social sciences and engineering) academic disciplines and in an environment where the availability of research-intensive academic positions—the type of jobs for which postdocs are typically trained—have not risen at a similar pace (e.g., American Chemical Society 2013; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 2000 and 2014; National Institutes of Health 2012;). Neither the reasons for this growth nor its effects on the state of scientific research are well understood. However, possible contributing factors include increases in competition for tenure-track academic research jobs, the need for collaborative research in large teams, the influx of graduate students in SEH areas with strong postdoc traditions, and the need for additional specialized training. (See sidebar, Employment Patterns among Biomedical Sciences Doctorates.)

[ii] Although the formal job title is often *postdoc fellowship* or *research associate*, titles vary among organizations. This chapter generally uses the shorter, more commonly used, and best understood name, *postdoc*. A postdoc is generally considered a temporary position that individuals take primarily for additional training—a period of advanced professional apprenticeship—after completion of a doctorate.

Employment Patterns among Biomedical Sciences Doctorates

Employment patterns in the areas of biomedical sciences have changed in the past two decades. The growth in the number of doctorates trained in the field has far surpassed the growth in tenure-track academic positions, intensifying the competition for academic jobs (NIH 2012). This sidebar uses data from NSF's Survey of Doctorate Recipients (SDR) to examine the changes over time in employment patterns among U.S.-trained biomedical sciences doctorates. Foreign-trained doctorates are not covered by the SDR and are therefore not included in the analysis presented in this sidebar.

Between 1993 and 2013, the number of biomedical sciences doctorate holders rose substantially, about 83%, from about 105,000 to nearly 192,000.* Over this same time, the proportion employed in 4-year academic institutions declined (from 55% to 49%) as did the proportion employed in tenure or tenure-track positions (from 35% to 25%) despite the fact that both increased in absolute number. In contrast, the proportion of biomedical sciences doctorates employed in the business sector rose (from 31% to 38%). The comparable changes among doctorate holders in other SEH areas of training were smaller: between 1993 and 2013, the total size of this population rose 58%, the proportion employed in the 4-year academic institutions declined (from 43% to 40%), and the proportion employed in the business sector rose (from 45% to 47%).

Between 1993 and 2013, the proportion of biomedical sciences doctorates reporting research (basic or applied) as their primary or secondary work activity declined in both 4-year academic institutions (from 78% to 70%) and businesses (from 55% to 47%). The majority of the increase in the number of biomedical sciences doctorates employed in the business sector was driven by those whose jobs did not involve research as their primary or secondary work activity. For-profit businesses accounted for two-thirds of the increase in the overall business sector biomedical workforce, with nonprofit organizations and unincorporated businesses accounting for the remainder of the increase. The for-profit business sector also has a smaller share of its biomedical doctorates performing research as a primary or secondary work activity compared to nonprofit organizations.

The field of biomedical sciences has a strong tradition of postdoctoral training. In 2013, among those who received their doctorates within the past 10 years of being surveyed, 26% of biomedical sciences doctorates reported being in a postdoctoral position, compared to only 7% of those with a doctorate in another SEH field. When asked about the primary reason for accepting these positions, "postdoc generally expected in field" was reported by 43% of postdocs with a biomedical sciences doctorate, compared to about 31% of postdocs with a doctorate in another SEH field. However, between 1993 and 2013, the proportion of doctorates employed in postdoc appointments declined both among biomedical sciences doctorates (from 30% to 26%) and among doctorates in other SEH fields (from 9% to 7%).

Despite the changes in employment patterns, overall employment indicators for biomedical sciences doctorates are generally favorable. In 2013, the unemployment rate for this group was 2.3%, and the rate of working involuntarily out of field (IOF) was 2.9%. These rates are both similar to those for doctorates in other SEH areas of training: an unemployment rate of 2.0% and an IOF rate of 3.0%. The median salary for biomedical sciences doctorates was $91,000 (compared to $99,000 for doctorates in other SEH areas of training). Median salaries in 4-year academic institutions and for-profit businesses, the two sectors that together employed three-fourths of biomedical sciences doctorates, were $78,000 and $120,000, respectively.

Foreign-trained doctorates in the field have grown significantly over time (NIH 2012), but the data on this segment of the workforce are limited. The SDR data, which cover U.S.-trained doctorate holders, show that the number of foreign-born individuals in the field has increased rapidly over the past two decades: between 1993 and 2013, the number of non-U.S. citizens with U.S. biomedical sciences doctorates rose by 260%; the comparable increase among other SEH doctorates as a whole, although substantial, was smaller (143%).

* See NIH (2012) for a discussion on the fields of science considered to be biomedical sciences. Based on the report, the following degree categories from the SDR are included in the data presented in this sidebar: biochemistry and biophysics, bioengineering and biomedical engineering, cell and molecular biology, microbiological sciences and immunology, zoology, biology (general), botany, ecology, genetics (animal and plant), nutritional science, pharmacology (human and animal), physiology and pathology (human and animal), and other biological sciences. Agricultural and food sciences, and environmental life sciences are not included in the analysis.

Number of postdocs. The estimated number of postdocs varies depending on the data source used. No single data source measures the entire population of postdocs. Two NSF surveys, the Survey of Doctorate Recipients (SDR) and the Survey of Graduate Students and Postdoctorates in Science and Engineering, include data related to the number of postdocs in the United States. The SDR estimated that 27,100 U.S. SEH doctorate recipients in 2013 were employed in postdoc positions, compared with 30,800 in 2010 and 19,800 a decade earlier in 2003. The vast majority of these postdoc positions were in 4-year academic institutions (75% in 2013), with the remainder in the business sector (14% in 2013) and government sector (11% in 2013). Within the business sector, nonprofit organizations accounted for the vast majority of postdoc positions.

The estimated totals from NSF's Survey of Graduate Students and Postdoctorates in Science and Engineering, which cover academic postdocs, are significantly higher: 61,900 in 2013, compared with 63,400 in 2010 and 46,700 in 2003 (NSF/NCSES, 2015a and 2015b). The two surveys cover different segments of the postdoc population. The Survey of Graduate Students and Postdoctorates in Science and Engineering gathers information on postdocs employed in U.S. academic graduate departments, regardless of where these individuals earned their doctorates. It does not cover individuals in nonacademic employment, at non-degree-granting graduate departments, or at some university research centers. In contrast, the SDR covers U.S. residents who earned research doctorates in SEH fields from U.S. universities, but not those with doctorates from non-U.S. universities. Additionally, the SDR does not cover some recent doctorates.[iii] As a result, the SDR omits a large number of postdocs who are foreign trained or who had completed a 1-year postdoc immediately after graduation from a U.S. institution. The two survey estimates overlap in some populations (U.S.-trained doctorates and those working in academia), but differ in others (the Survey of Graduate Students and Postdoctorates in Science and Engineering covers foreign-trained doctorates but not those in the industry or government sectors). In addition, the titles of postdoc researchers vary across organizations and often change as individuals advance through their postdoc appointments; both of these factors further complicate the data collection process (NIH 2012).[iv]

Postdocs by academic discipline. Although postdocs are increasingly common in SEH fields, the extent to which a postdoc appointment is part of an individual's career path varies greatly across SEH fields. Postdocs have historically been more common in life sciences and physical sciences than in other fields such as social sciences and engineering. Among new doctorate recipients in 2013, nearly 64% in life sciences (including agricultural sciences /natural resources, biological/biomedical sciences, and health sciences) and 54% in physical sciences indicated they would take a postdoc appointment, compared to 36% in social sciences and 35% in engineering (Appendix Table 3-10).[v] However, in life sciences and physical sciences, the proportion of new doctorate recipients indicating that they would take a postdoc position rose significantly between the early 1970s and the early 1990s and has fluctuated within a relatively narrow range since then. In social sciences, the comparable proportion has continued to rise gradually since the early 1970s. In engineering, the comparable proportion has risen overall between 1973 and 2013 despite periodic fluctuations within this 40-year period.

Another indicator of the variation in the postdoc tradition across S&E disciplines is the proportion of recent graduates who are employed as a postdoc (as opposed to those who plan to take a postdoc position after graduation). In 2013, about half of those who received their doctorates in the previous 3 years in biological, agricultural, and environmental life sciences (54%) or physical sciences (45%) were employed in postdoc positions, compared to only 6% of those who received doctorates in social sciences (Figure 3-22).

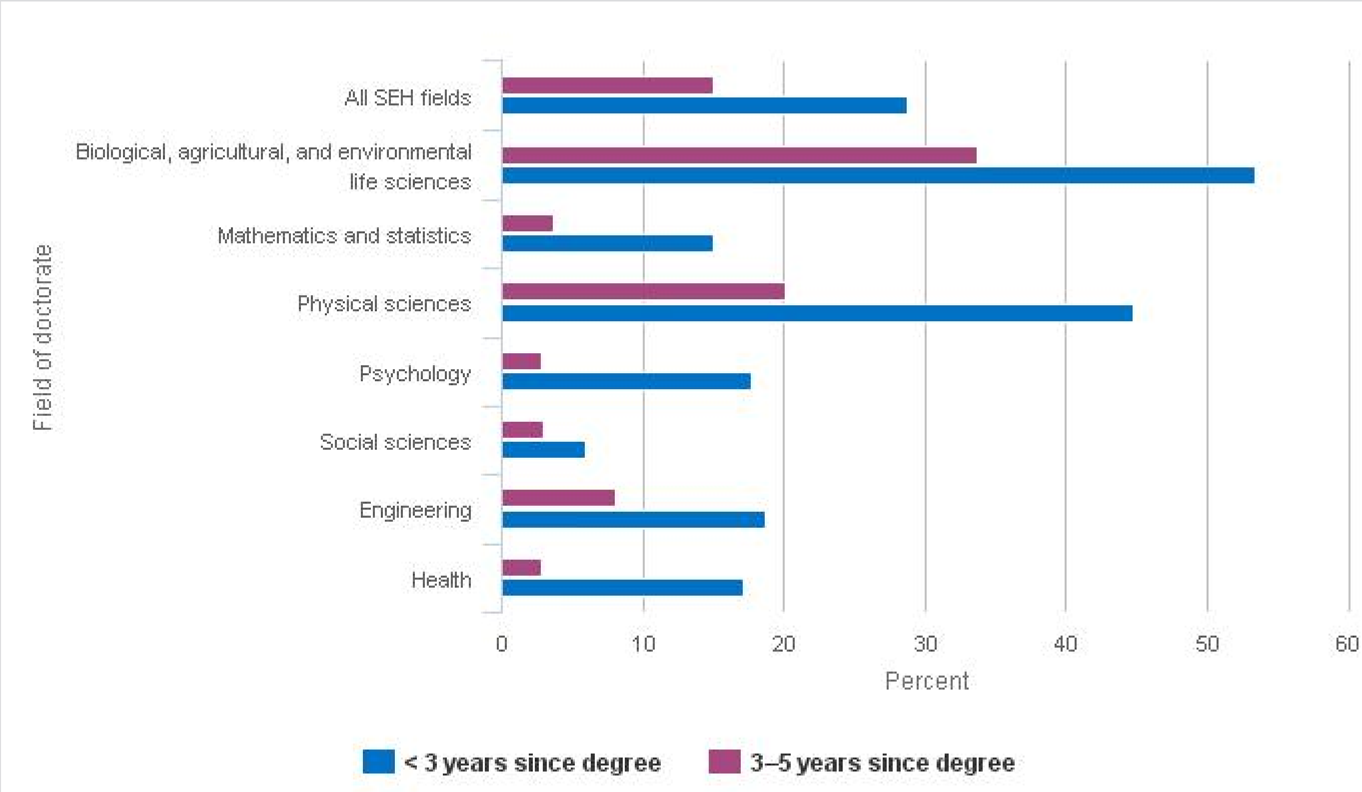
[iii] Data from the 2013 SDR were collected from doctoral graduates who received SEH research degrees from a U.S. academic institution before 1 July 2011 and as such underestimate the number of 1-year postdoctoral appointments completed prior to the reference date of February 2013.

[iv] NSF is currently developing a data collection strategy as part of its Early Career Doctorates Project (ECDP) to gather in-depth information about postdoc researchers and other early career doctorates. The ECDP will collect information related to educational achievement, professional activities, employer demographics, professional and personal life balance, mentoring, training and research opportunities, and career paths and plans for individuals who earned their doctorate in the past 10 years and are employed in an academic institution or a research facility.

[v] These data are from the Survey of Earned Doctorates (SED), which is administered to individuals receiving research doctoral degrees from all accredited U.S. institutions.

Figure 3-22

Recent U.S. SEH doctorate recipients in postdoc positions, by field of and years since doctorate: 2013



SEH = science, engineering, and health.

NOTES: Proportions are calculated on the basis of all doctorates working in all sectors of the economy. Data include graduates from 19 months to 60 months prior to the survey reference date (February 2013). Data for computer and information sciences doctorates are suppressed for reasons of confidentiality and/or reliability.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients (2013), http://sestat.nsf.gov.

Science and Engineering Indicators 2016

Postdoc compensation. Low compensation for postdocs is frequently raised as a concern by those who are worried about the effect of the increasing number of postdoc positions on the attractiveness of science careers. In 2013, among individuals who had received their doctorate within the past 5 years, the median salary for postdocs ($46,000) was just over half the median salary for individuals who were in other employment (e.g., non-postdoc positions) ($80,000) (Table 3-18). The postdoc salary differential ranged from about half among individuals with doctorates in engineering (52%) and health (55%) to three-quarters or more among those with doctorates in social sciences (75%) and mathematics and statistics (85%).

Table 3-18	Median salaries for recent U.S. SEH doctorate recipients in postdoc and non-postdoc positions up to 5 years after receiving degree: 2013

(Dollars)

Field of doctorate	All positions	Postdocs	Non-postdocs
All SEH	70,000	46,000	80,000
Biological, agricultural, and environmental life sciences	51,000	44,000	66,000
Computer and information sciences	105,000	S	106,000
Mathematics and statistics	72,000	64,000	75,000
Physical sciences	63,000	48,000	77,000
Psychology	62,000	42,000	65,000
Social sciences	66,000	50,000	67,000
Engineering	90,000	47,000	91,000
Health	78,000	45,000	82,000

NOTES: S = suppressed for reasons of confidentiality and/or reliability.
SEH = science, engineering, and health.
Salaries are rounded to the nearest $1,000. Data include graduates from 19 months to 60 months prior to the survey reference date.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients (2013), http://sestat.nsf.gov.

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Among recent graduates, somewhat larger proportions of postdocs than non-postdocs have access to certain employer-provided benefits, such as health insurance (96% of postdocs and 91% of non-postdocs) and paid vacation, sick, or personal days (90% of postdocs and 84% of non-postdocs). However, a much smaller proportion of recent graduates in postdoc positions have access to employer-provided pensions or retirement plans (54% of postdocs and 82% of non-postdocs) or profit-sharing plans (6% of postdocs and 23% of non-postdocs). Information on the quality of these benefits—for example, the coverage and premium of health insurance plans, number of personal days offered by employers, and type of retirement benefits and profit sharing plans—is not available.

Reasons for taking postdoc positions. The 2013 SDR asked individuals in postdoc positions to report their primary reason for accepting these appointments. Most responses were consistent with the traditional objective of a postdoc position as a type of advanced apprenticeship for career progression, such as “postdoc generally expected in field” (37%), “additional training in PhD field” (18%), “training in an area outside of PhD field” (15%), or “work with a specific person or place” (14%). A smaller proportion (12%) of those in postdoc appointments reported lack of other suitable employment as the primary reason for accepting these positions. However, in life sciences and physical sciences, the two broad fields with relatively high levels of postdoc appointments, the proportions of those reporting lack of other employment as the primary reason for accepting a postdoc position were low (11% and 15%, respectively) compared with the proportion of those in social sciences (40%), an area where postdocs are typically not as common.

Characteristics of postdocs. According to the Survey of Graduate Students and Postdoctorates in Science and Engineering, women held 39% of the nearly 62,000 academic postdoc positions in 2013 in SEH fields.[vi] Temporary visa holders accounted for 52% of the academic postdocs, and U.S. citizens and permanent residents accounted for the remaining 48%. Among postdocs in engineering, however, the proportion of women was lower (22%) and the proportion of temporary visa holders was higher (62%) compared to the overall SEH shares. Between 1979 and

2013, the number of academic postdocs increased threefold, driven primarily by temporary visa holders who accounted for nearly two-thirds (60%) of the total increase. The majority of academic postdocs (64%) in 2013 were supported by research grants; the rest were supported by fellowships, traineeships, or other mechanisms.

[vi] The data tables for the 2013 Survey of Graduate Students and Postdoctorates in Science and Engineering are available at http://ncsesdata.nsf.gov/gradpostdoc/2013/ (accessed on 19 August 2015).

Age and Retirement of the S&E Workforce

The U.S. S&E workforce, reflecting overall population trends, is aging. This section focuses on indicators of the aging of the S&E workforce, including retirement patterns of S&E workers and workforce participation levels among older individuals. The age distribution and retirement patterns of S&E workers have important implications for the supply of S&E expertise in the economy, but the overall effect is uncertain. Over time, members of the S&E labor force may gain skills, experience, and judgment that translate into rising output and productivity. Consequently, the retirement of large numbers of experienced workers could mean the loss of valuable S&E expertise and knowledge. However, the retirement of older workers also makes room for newly trained S&E workers who may bring updated skills and new approaches to solving problems.[i]

The aging of the S&E labor force is reflected in the median age, which has risen from 41 years in 1993 to 43 years in 2013. For proper context, the median age nationally for the U.S. population was 34 years in 1993 and 38 years in 2013.[ii] Another indicator, the percentage of individuals in the S&E labor force between 51 and 75 years of age, has risen from about 20% in 1993 to 34% in 2013 (Figure 3-23). Over that period, this proportion rose for both men and women, but the women in the labor force continue to be younger relative to their male counterparts (Figure 3-23). In 1993, the median ages were 38 years for women and 42 years for men, whereas in 2013 the median ages were 42 years for women and 45 years for men.

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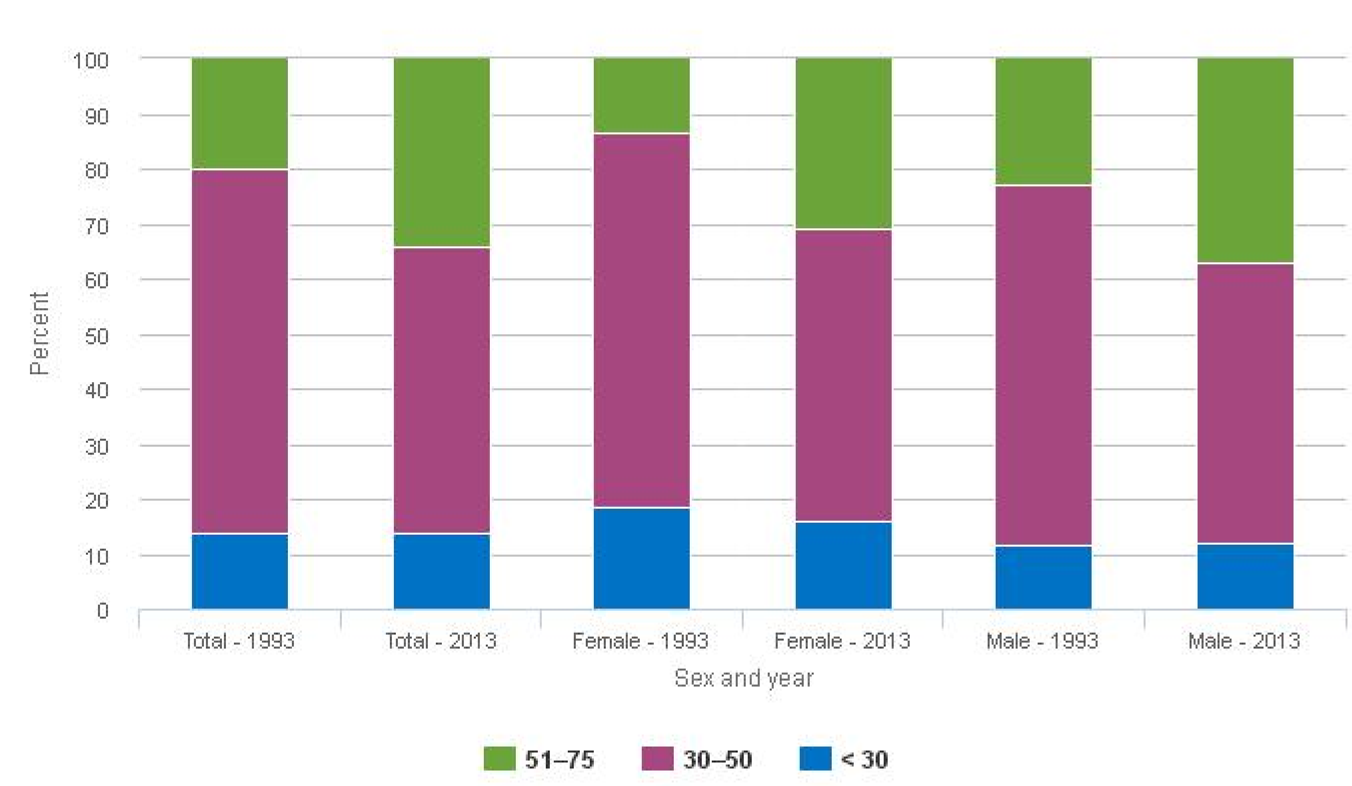
[i] See Stephan and Levin (1992) and Jones, Reedy, and Weinberg (2014) for in-depth discussions on age and scientific productivity.

[ii] The 1993 and 2013 data on median age for the U.S. population are from the U.S. Census Bureau's Population Estimates Program, available at http://www.census.gov/popest/data/historical/index.html. The 2013 data are available at http://www.census.gov/popest/data/national/asrh/2013/index.html and the 1993 data are available at http://www.census.gov/popest/data/national/totals/1990s/tables/nat-agesex.txt (accessed on 2 February 2015).

Figure 3-23

Age distribution of scientists and engineers in the labor force, by sex: 1993 and 2013



NOTES: For 1993 data, scientists and engineers include those with one or more S&E degrees at the bachelor's level or higher or those who have only a non-S&E degree at the bachelor's level or higher and are employed in an S&E occupation. For 2013 data, scientists and engineers include those with one or more S&E or S&E-related degrees at the bachelor's level or higher or those who have only a non-S&E degree at the bachelor's level or higher and are employed in an S&E or S&E-related occupation. The Scientists and Engineers Statistical Data System (SESTAT) does not cover scientists and engineers over age 75.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, SESTAT (1993, 2013), http://sestat.nsf.gov.

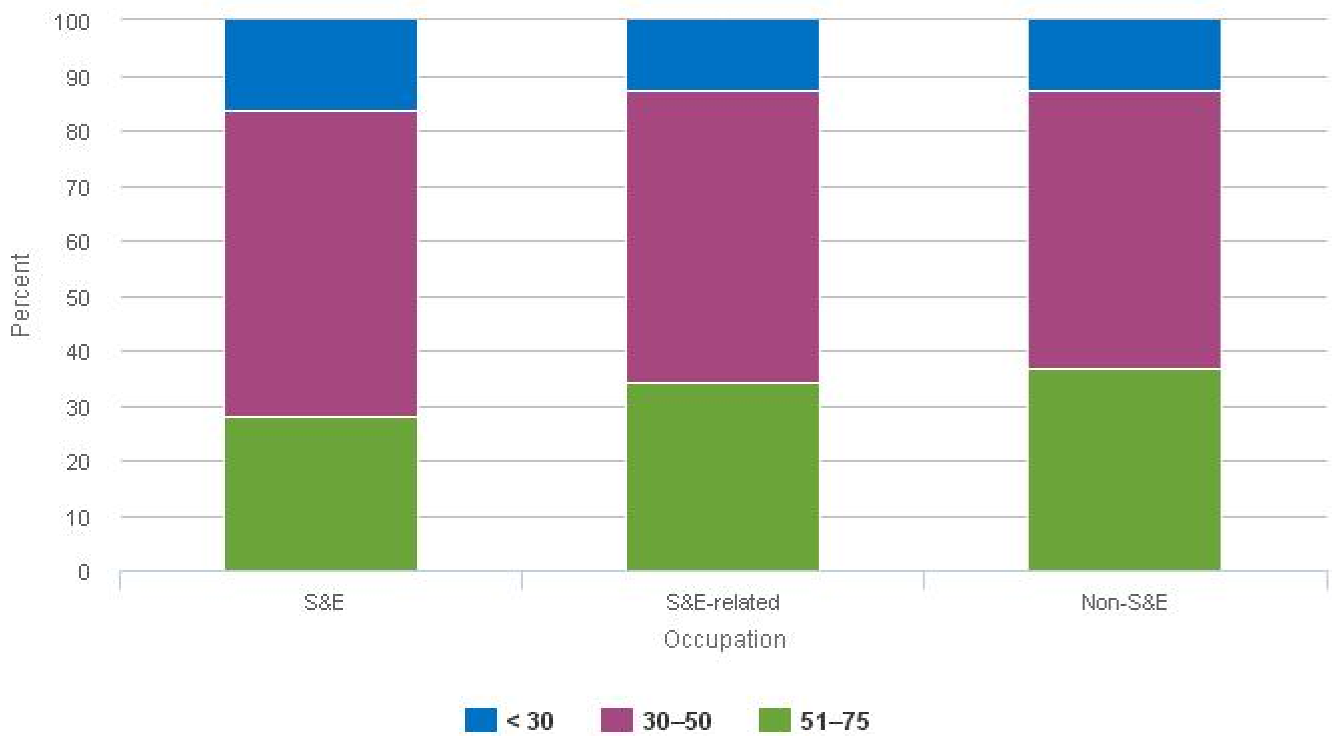
Science and Engineering Indicators 2016

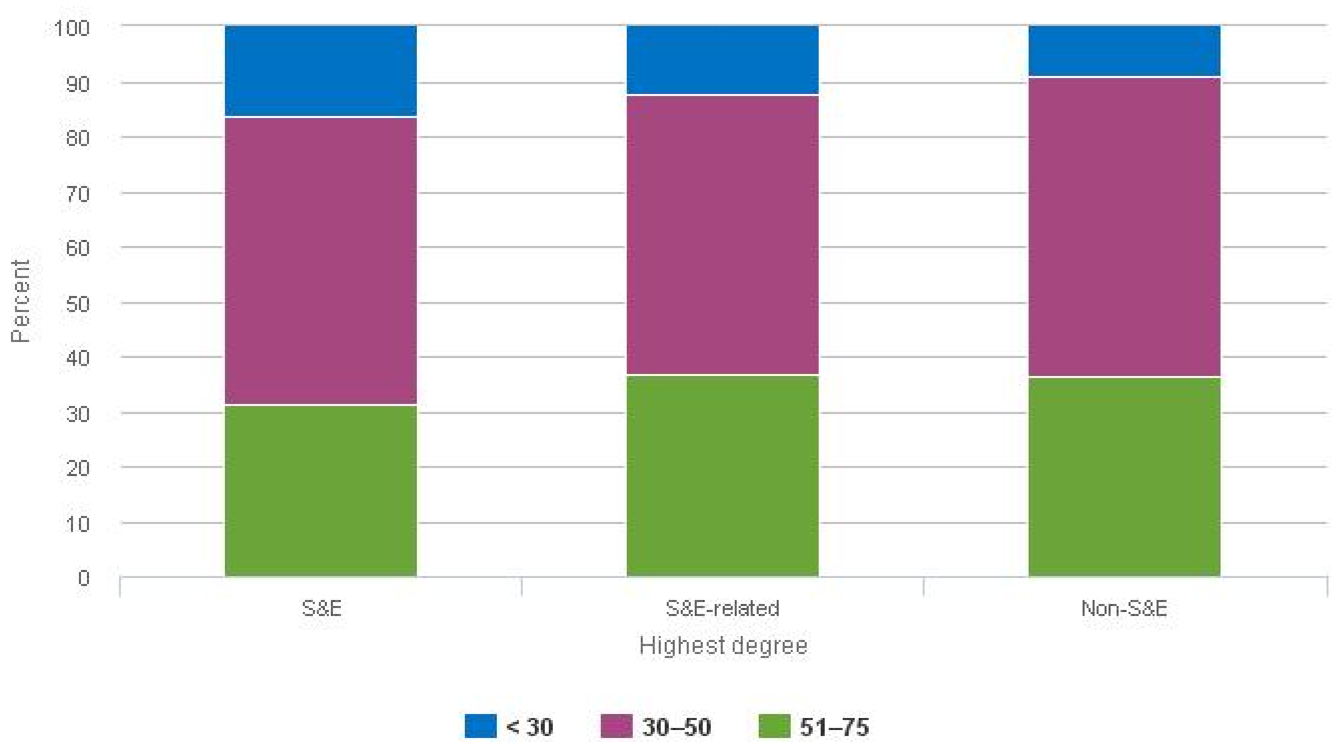
Age Differences among Occupations

SESTAT respondents working in S&E occupations are younger than those in S&E-related or non-S&E occupations (Figure 3-24). In 2013, 28% of those in S&E occupations were between 51 and 75 years of age compared with 34% of those in S&E-related occupations and 37% of those in non-S&E occupations. The median age of the SESTAT population employed in S&E occupations was 41 years, compared to 44 years among those employed in S&E-related or non-S&E occupations. This may suggest, among other things, that as S&E workers age, they transition from S&E occupations to S&E-related or non-S&E occupations.

Figure 3-24

Age distribution of employed scientists and engineers, by broad occupational category and broad field of highest degree: 2013





NOTES: Scientists and engineers include those with one or more S&E or S&E-related degrees at the bachelor's level or higher or those who have only a non-S&E degree at the bachelor's level or higher and are employed in an S&E or S&E-related occupation. The Scientists and Engineers Statistical Data System (SESTAT) does not cover scientists and engineers over age 75.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, SESTAT (2013), http://sestat.nsf.gov.

Science and Engineering Indicators 2016

Age Differences among Degree Fields

Similar to the trend seen across broad occupational categories, S&E highest degree holders are generally younger than those holding highest degrees in S&E-related or non-S&E fields (Figure 3-24). In 2013, a smaller proportion of S&E highest degree holders (31%) than S&E-related (37%) or non-S&E (36%) highest degree holders were between 51 and 75 years of age. In addition, degree holders in different S&E fields varied in their ages. S&E highest degree holders in physical sciences, particularly the men in this group, were older than those in other broad S&E fields (Appendix Table 3-11). S&E highest degree holders in computer and information sciences, a relatively new field with rapid growth, were relatively young: only about 1 out of 5 were between 51 and 75 years of age.

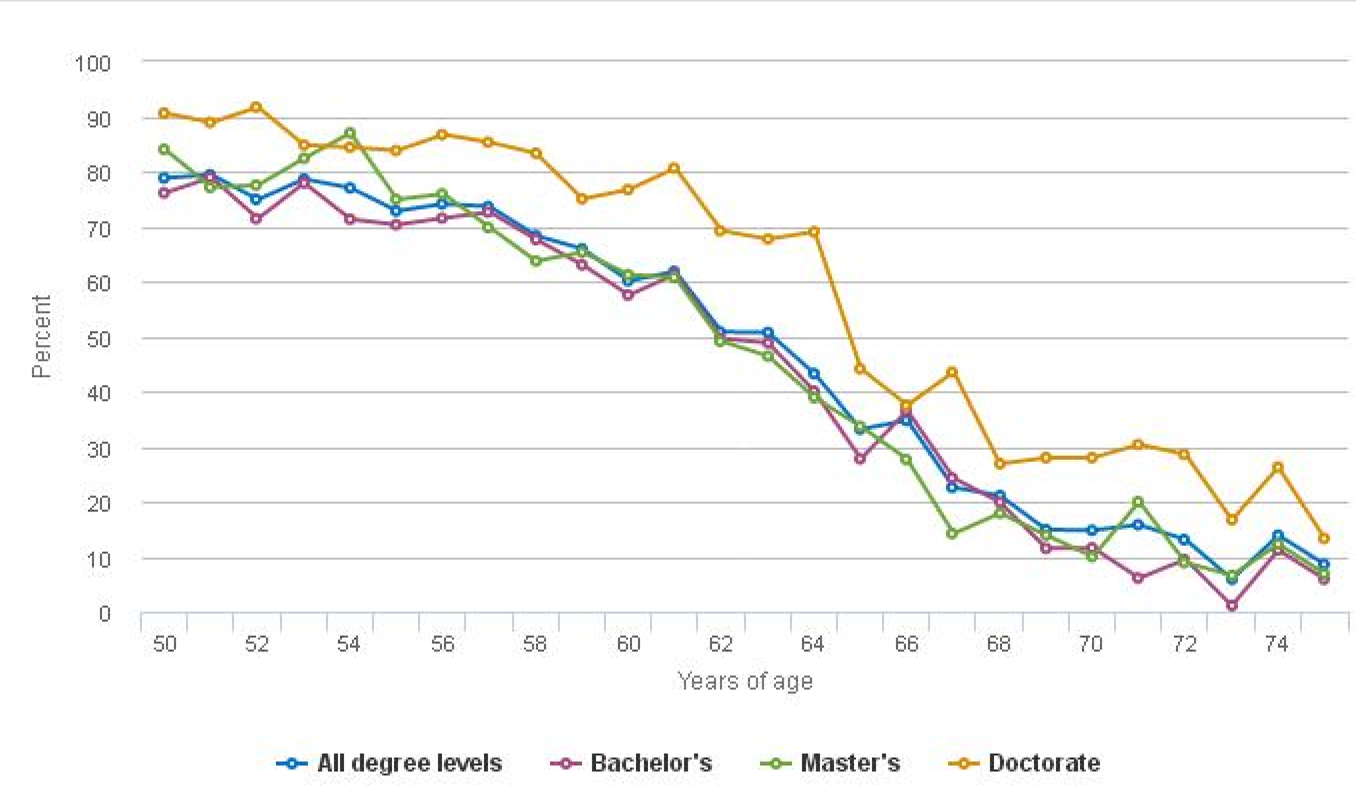
Within broad degree areas, the age profile of different degree fields varies (Appendix Table 3-11). For example, within life sciences degree fields, between 30% and 31% of highest degree holders in biological sciences and environmental life sciences were between 51 and 75 years of age compared with 47% of highest degree holders in agricultural and food sciences. In all broad S&E fields of highest degree except computer and mathematical sciences, women were younger than their male counterparts (Appendix Table 3-11).

Retirement

Trends in labor force participation among older individuals provide useful information about retirement patterns and how these patterns may have changed over time. Recent patterns of leaving the labor force and shifting to part-time work among older members of the workforce suggest that the labor force participation rate among scientists and engineers begins to decline sometime between the ages of 55 and 60 and is markedly reduced by the time workers reach their late 60s. One indication of the relationship between age and the level of labor force participation is illustrated by Figure 3-25, which shows the proportions of older scientists and engineers working full time. In 2013, at age 50, 79% of scientists and engineers worked full time (35 hours or more per week) in their principal job. Among individuals in their late-50s, this proportion dropped steeply. Among those in their mid-60s, for example, only about one-third worked full time. The overall pattern of declining full-time participation starting in individuals' mid- to late-50s held at all degree levels, although doctorate holders generally worked full time at higher rates than bachelor's degree holders.

Figure 3-25

Older scientists and engineers who work full time, by age and highest degree level: 2013



NOTES: All degree levels includes professional degrees not reported separately. Scientists and engineers include those with one or more S&E or S&E-related degrees at the bachelor's level or higher or those who have only a non-S&E degree at the bachelor's level or higher and are employed in an S&E or S&E-related occupation.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

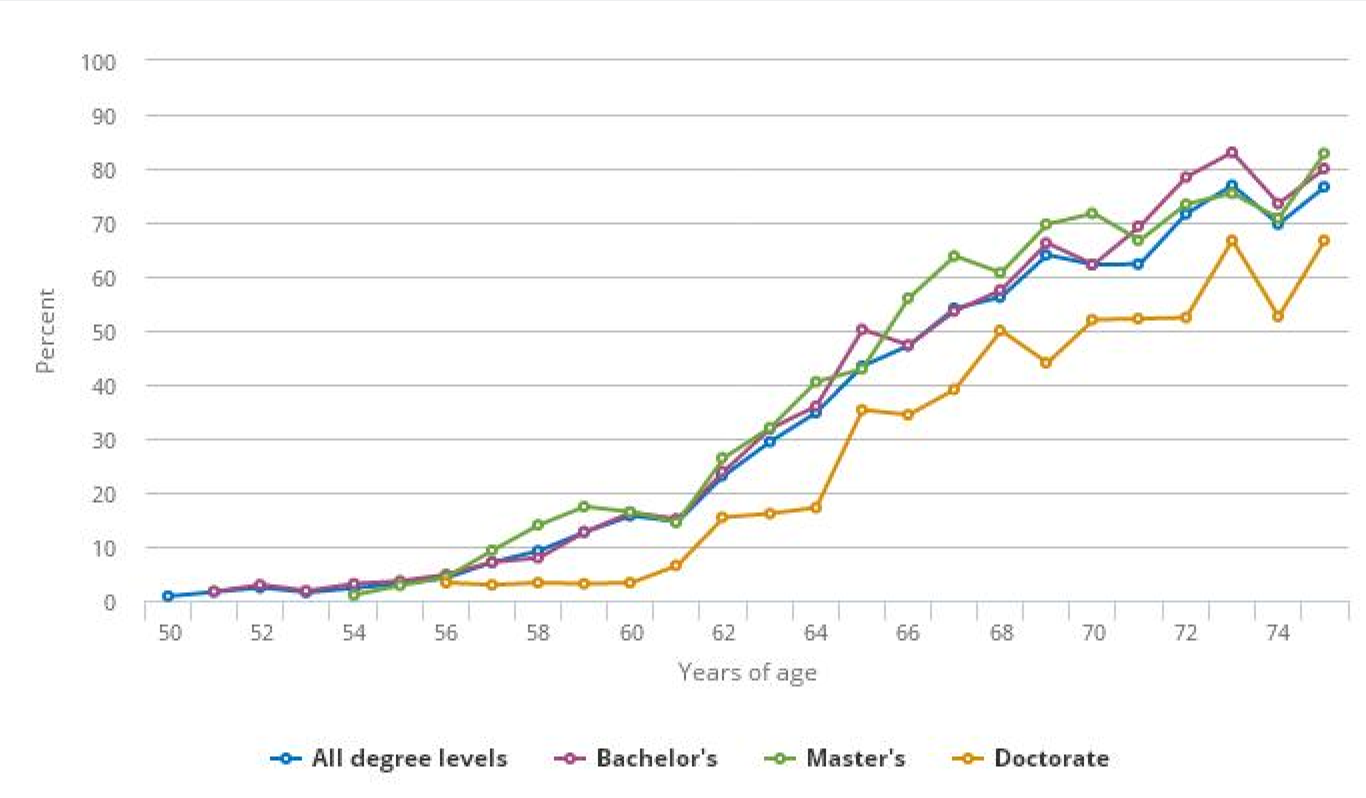
Science and Engineering Indicators 2016

Between 1993 and 2013, increasing proportions of scientists and engineers in their 60s reported still being in the labor force. Whereas 69% of those aged 60 to 64 were in the labor force in 1993, by 2013 this had risen to 74%. For those between the ages of 65 and 69, the proportion rose from 39% in 1993 to 48% in 2013.

Reasons provided for labor force nonparticipation or part-time work status also shed light on the relationship between age and retirement (Figure 3-26 illustrates the relationship between age and labor force nonparticipation because of retirement). In 2013, about 2.9 million scientists and engineers reported that they were out of the labor force because of retirement. The vast majority (90%) of retired individuals were 60–75 years of age. Individuals with doctorates typically reported lower rates of retirement than those without doctorates.

Figure 3-26

Older scientists and engineers who report not working because of retirement, by age and highest degree level: 2013



S = suppressed for reasons of confidentiality and/or reliability.

NOTES: All degree levels includes professional degrees not reported separately. Scientists and engineers include those with one or more S&E or S&E-related degrees at the bachelor's level or higher or those who have only a non-S&E degree at the bachelor's level or higher and are employed in an S&E or S&E-related occupation.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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Retirement does not always mean that workers permanently leave the labor force. After nominally retiring from their jobs, some workers continue to work part time, work in a different capacity, or decide to return to the labor market at a later time. About 1.7 million employed scientists and engineers in 2013 reported that they had previously retired from a job. A total of 757,000 scientists and engineers working part time in 2013 reported their reason for working part time as having “previously retired or semi-retired.” Individuals who chose to stay in or return to the labor market following an occurrence of retirement were younger (median age 61) than those who were out of the labor force following retirement (median age 66).

Women and Minorities in the S&E Workforce

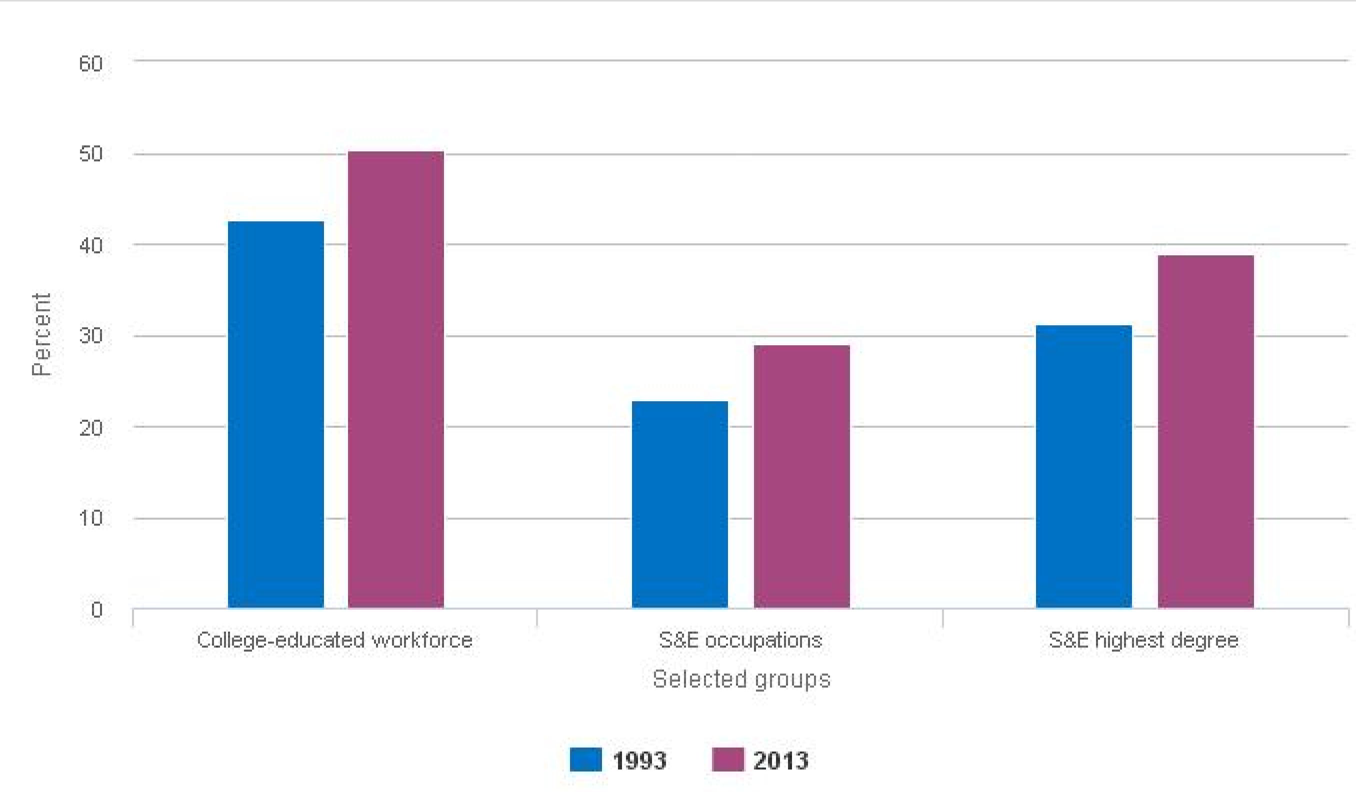
As researchers and policymakers increasingly emphasize the need for expanding S&E capabilities in the United States, many view demographic groups with lower rates of S&E participation as an underutilized source of human capital for S&E work. Historically, in the United States, S&E fields have had particularly low representation of women and members of several racial and ethnic minority groups (i.e., blacks, Hispanics, American Indians or Alaska Natives), both relative to the concentrations of these groups in other occupational or degree areas and relative to their overall representation in the general population. More recently, however, women and racial and ethnic minorities increasingly have been choosing a wider range of degrees and occupations. This section presents data on S&E participation among women and among racial and ethnic minorities. It also presents data on earnings differentials by sex and by race and ethnicity.

Women in the S&E Workforce

Historically, men have outnumbered women by wide margins with regards to both S&E employment and S&E training. Although the number of women in S&E occupations or with S&E degrees doubled over the past two decades, the disparity has narrowed only modestly. This imbalance is still particularly pronounced in S&E occupations. In 2013, women constituted only 29% of workers in these occupations, although they accounted for half of the college-educated workforce overall. Among S&E degree holders, the disparity was smaller but nonetheless significant with women representing 39% of employed individuals with a highest degree in S&E (Figure 3-27).

Figure 3-27

Women in the workforce and in S&E: 1993 and 2013



SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) and National Survey of College Graduates (NSCG) (1993, 2013), http://sestat.nsf.gov.

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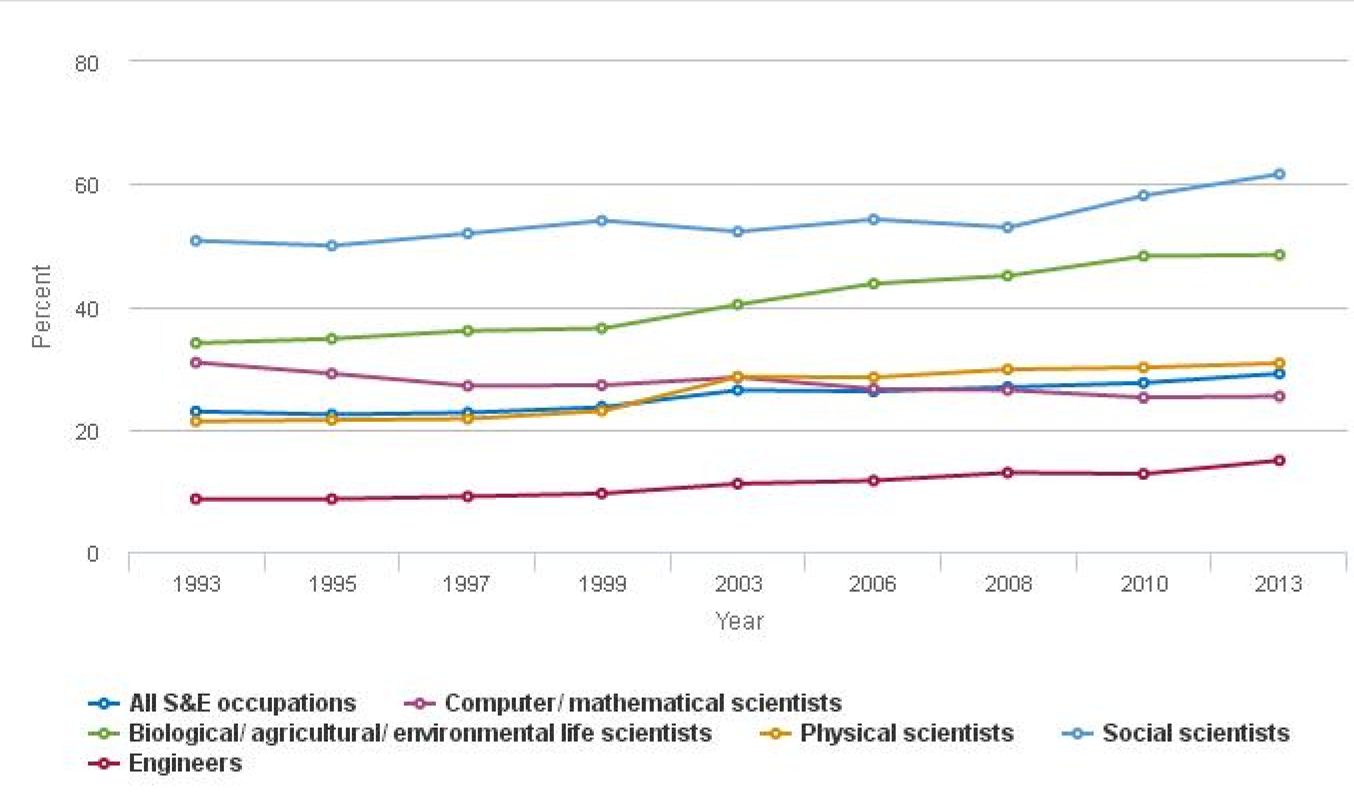
Women in S&E Occupations

Although women represented only 29% of individuals in S&E occupations in 2013, women's presence varies widely across S&E occupational fields (Appendix Table 3-12 and Figure 3-28). The percentage of female S&E workers continues to be lowest in engineering, where women constituted 15% of the workforce in 2013. Among engineering occupations with large numbers of workers, women accounted for only 8% of the workforce of mechanical engineers and about 11% to 12% of the workforce of electrical and computer hardware engineers and of aerospace, aeronautical, and astronautical engineers (Appendix Table 3-12).

Figure 3-28

Women in S&E occupations: 1993–2013



NOTE: National estimates were not available from the Scientists and Engineers Statistical Data System (SESTAT) in 2001.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, SESTAT (1993–2013), http://sestat.nsf.gov.

Science and Engineering Indicators 2016

Other disproportionately male S&E occupations include physical scientists (31% women) and computer and mathematical scientists (25% women). Within physical sciences occupations, physicists and astronomers have the largest imbalance (11% women). Within computer and mathematical sciences occupations, the largest component, computer and information scientists, has a smaller proportion of women (24%), compared with the mathematical scientists component, which is closer to parity (42% women).

In 2013, sex parity in S&E occupations was close among life scientists (48% women). The largest component of life sciences, biological and medical scientists, had reached gender parity (52% women). The field of social sciences was majority female (62%). Occupations within social sciences, however, varied widely: women accounted for 49% of economists but for 74% of psychologists. Psychologists, estimated at about 208,000 total workers in SESTAT (Appendix Table 3-12), represent an example of a large S&E occupation with substantially more women than men.

In contrast to jobs in S&E occupations, a majority of jobs in S&E-related occupations (56%) are held by women (Appendix Table 3-12). The largest component, health-related occupations, has a large share of women (69%) whose jobs are primarily as nurse practitioners, pharmacists, registered nurses, dietitians, therapists, physician assistants, and health technologists and technicians; women represented the vast majority of workers in these particular health occupations. In contrast, among health occupations such as diagnosing and treating practitioners, women accounted for a much smaller proportion (37%).

Since the early 1990s, the number of women working in each broad S&E occupational category has risen significantly (Figure 3-28). The rate of growth has been strong among life scientists, computer and mathematical scientists, and social scientists. These three broad S&E fields together employed 80% of women in S&E occupations in 2013, compared with 62% of men in S&E occupations. Between 1993 and 2013, the number of women nearly tripled among life scientists (an increase of 181%) and more than doubled among social scientists (an increase of 122%). The number of men also grew, but the rate of growth for women was greater than that for men, resulting in an increase in the proportion of female life scientists and female social scientists.

During the same period, the number of women in computer and mathematical sciences occupations also doubled (an increase of 120%). However, this new, rapidly growing and changing field attracted relatively more men than women (male participation grew 188%). The result has been an overall decline in the proportion of women from 31% to 25%. These trends make the gender disparity among computer and mathematical scientists second only to the gender disparity among engineers. However, the declining proportion of women in computer and mathematical sciences occupations does not extend to doctorate-level workers: Among those with a doctorate, the proportion of women increased, from 16% in 1993 to 21% in 2013.

During the past two decades, the proportion of women also increased among workers in engineering (from 9% to 15%) and in physical sciences (from 21% to 31%). In these two occupational categories, this increase was led by an expansion of women's numbers in the workforce (by 94% in engineering and 63% in physical sciences) while men's numbers barely changed between 1993 and 2013. (See sidebar Women in Leading Roles and Positions for a discussion on the presence of women in leading roles.)

Women in Leading Roles and Positions

This sidebar reports data from NSF's Scientists and Engineers Statistical Data System (SESTAT) on the presence of women in various types of leading roles, including management occupations, supervisory positions, and academic positions. Overall, the data indicate that men outnumber women in a wide range of leading roles despite the increasing presence of women in many of these positions.

Data from SESTAT indicate that women accounted for 31% of scientists and engineers employed in S&E management occupations in 2013 (Appendix Table 3-12). The gender imbalance was particularly pronounced among engineering managers (11% women), computer and information systems managers (24% women), and natural sciences managers (32% women). In contrast, a majority of medical and health services managers were women (55%). Among scientists and engineers employed as non-S&E managers, 27% were women, although the proportion of women in these jobs ranged from 25% among top-level managers, executives, and administrators (e.g., chief executive officer/chief operating officer/chief financial officer, president, district/general manager/provost) to 42% among education administrators (i.e., registrar, dean, principal).

Data from SESTAT also provide information on work activities in one's principal job. In 2013, women accounted for 37% of the 9 million scientists and engineers who reported supervising the work of others as part of their principal job, which reflects an increase since 1993 when the comparable proportion was 25%.

Data from the Survey of Doctorate Recipients (SDR) show a similar pattern among academically employed S&E doctorate holders. In 2013, women accounted for 29% of the tenured faculty positions held by U.S.-educated S&E doctorate holders. Women were closer to parity among tenure-track (but not yet tenured) faculty (42% women). The number of women in tenured or tenure-track positions has risen significantly in the past two decades. Between 1993 and 2013, the number of female science, engineering, and health (SEH) doctorate holders in such positions more than doubled (from about 27,000 to 62,000). The number of men in these positions also grew (by 5%), although not as fast as the number of women, resulting in an increase in the overall share of women among tenured positions (from 14% to 29%) and tenure-track positions (from 30% to 42%). However, the presence of women significantly varies across SEH fields. Life sciences, social sciences, psychology, and health fields generally have higher concentrations of female faculty than engineering, computer sciences, physical sciences, and mathematics. (See chapter 5 for additional details on academic employment of SEH doctorates.)

Additionally, data from the SDR show that in 2013 women accounted for 28% of SEH doctorate holders employed as an academic dean, department head, or department chair and for 34% of those employed as an academic president, provost, or chancellor.

Women among S&E Highest Degree Holders

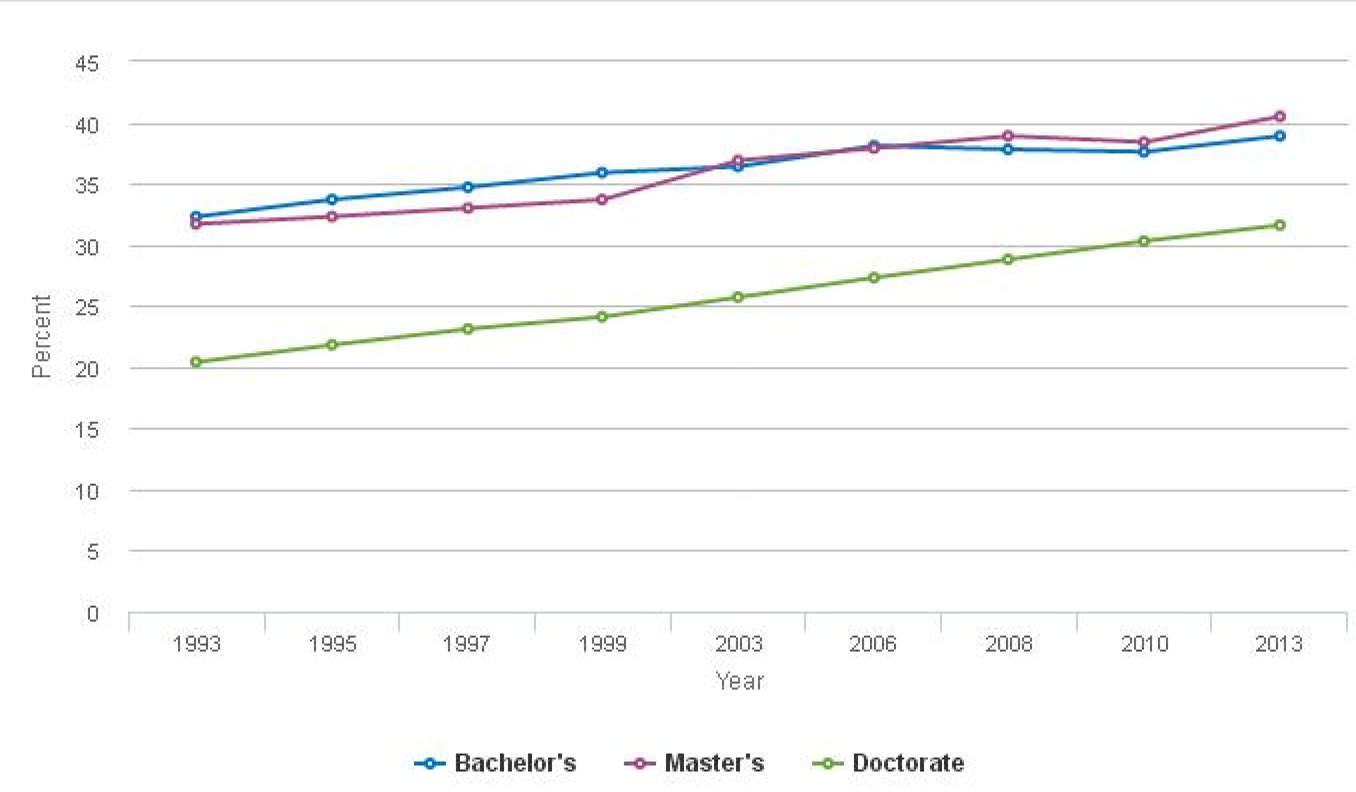
The sex disparity among employed S&E highest degree holders is less than the disparity among those in S&E occupations. In 2013, among individuals with a highest degree in an S&E field, women constituted 39% of those who were employed, up from 31% in 1993 (Figure 3-27). The pattern of variation in the proportion of men and women among degree fields echoes the pattern of variation among occupations associated with those fields (Appendix Table 3-13). In 2013, 55% of S&E highest degree holders in social sciences fields were women, as were 48% of those with a highest degree in the biological and related sciences. Men outnumbered women among computer sciences and mathematics highest degree holders (30% women) and among physical sciences highest degree holders (30% women). Disparities, however, were greatest among those with a highest degree in engineering (15% women).

In all broad fields except computer and mathematical sciences, the proportion of women in the workforce with associated highest degrees has been increasing since 1993. In computer and mathematical sciences, this proportion has declined as the number of women with a highest degree in the field has risen, but less rapidly than that of men in this new and rapidly growing field.

Sex differences are not limited to the field of degree, but also extend to the level of S&E degree. Overall, men outnumber women among S&E highest degree holders at the bachelor's, master's, and doctoral levels. The sex disparity is more severe among S&E doctorate holders than among S&E bachelor's or master's degree holders. For example, in 2013 women accounted for 39% and 41% of those whose highest degree in S&E was at the bachelor's and master's level, respectively, but 32% of those whose highest degree in S&E was at the doctoral level (Figure 3-29). Engineering was an exception: in this field, women represented a similar proportion (14%) of highest degree holders at the bachelor's and doctorate levels. However, for S&E fields overall at all three degree levels, the proportion of women has risen in the past two decades (Figure 3-29).

Figure 3-29

Employed women with highest degree in S&E, by degree level: 1993–2013



NOTE: National estimates were not available from the Scientists and Engineers Statistical Data System (SESTAT) in 2001.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, SESTAT (1993–2013), http://sestat.nsf.gov.

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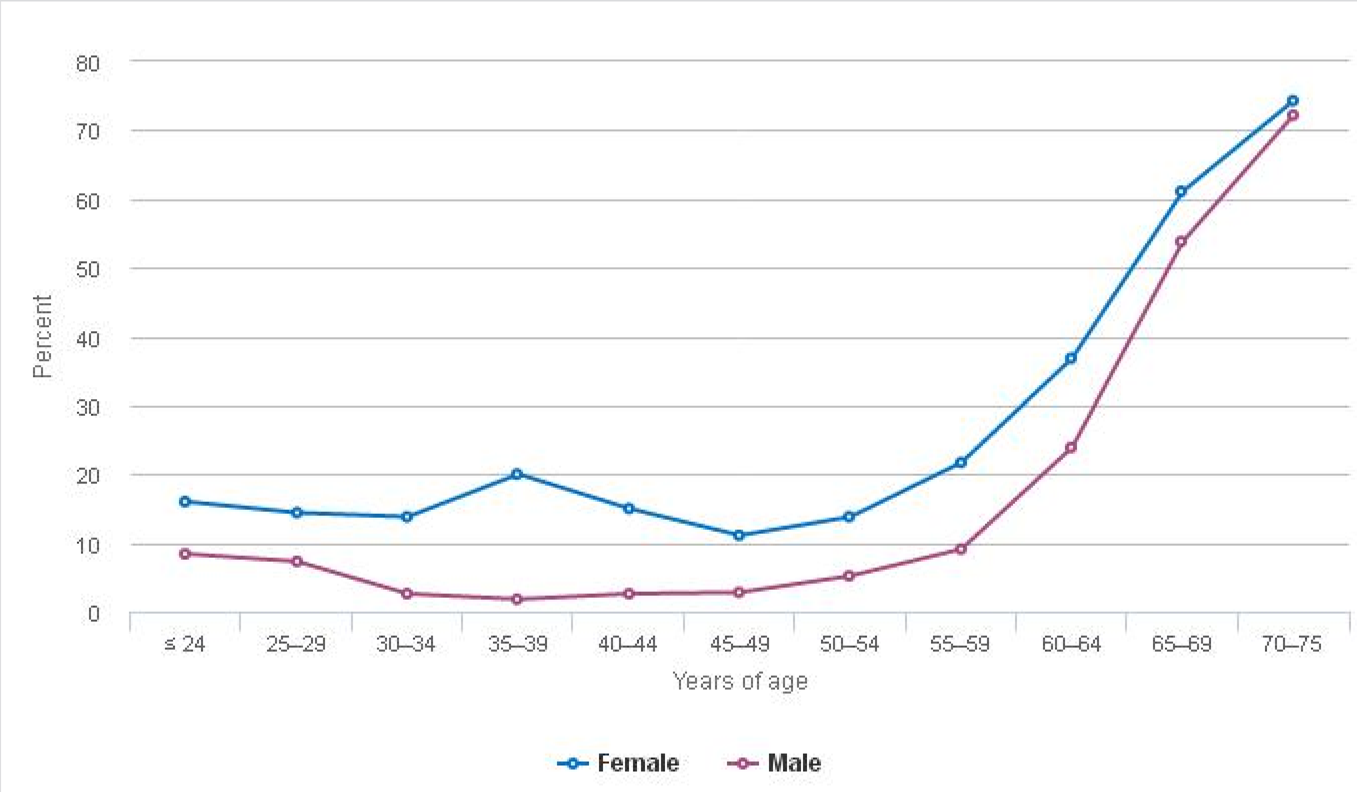
Working men and women with S&E highest degrees also differ in the extent to which they are employed in the same field as their S&E highest degree. This disparity is largely the result of women having a high concentration in the two degree areas—social sciences and life sciences—where degree holders most often work in an occupation outside of S&E. In 2013, these two broad fields accounted for nearly three-fourths (73%) of all employed women with S&E highest degrees, compared with 41% of all employed men with S&E highest degrees (Appendix Table 3-13).

Across all S&E degree areas, 19% of women with an S&E highest degree are employed in the S&E field in which they earned their highest degree compared with 31% of men (Appendix Table 3-14). However, the pattern varies by degree fields. Among life sciences and engineering degree holders, similar proportions of men and women are employed in the broad S&E field in which they earned their degree. Computer and mathematical sciences fields represent an exception in which a larger proportion of men (56%) than women (39%) work in an occupation that matches their broad degree field and a larger proportion of women (42%) than men (26%) work in non-S&E occupations. Among those with life sciences degrees, although a similar proportion of men (23%) and women (23%) work in their degree field, a larger proportion of women (32%) than men (18%) are employed in S&E-related occupations. The vast majority of social sciences degree holders work in non-S&E occupations, and this pattern is observed among both male (80%) and female (79%) degree holders.

Men and women with a highest degree in an S&E field also differ in their labor force nonparticipation rates. Compared with men, women were more likely to be out of the labor force (22% versus 14% for men). The difference in nonparticipation was particularly pronounced between the ages of 30 and 65 (Figure 3-30). In 2013, 19% of the women in this age group with an S&E highest degree were out of the labor force compared with 8% of the men. Many women in this group identified family reasons as an important factor: 39% of women reported that family was a factor for their labor force nonparticipation compared with 9% of men. Within this age range, women were also much more likely than men to report that they did not need to work or did not want to work (29% of women versus 16% of men). Men, on the other hand, were much more likely than women to cite retirement as a reason for not working (26% of women versus 48% of men).

Figure 3-30

Highest degree holders in S&E not in the labor force, by sex and age: 2013



NOTE: Not in the labor force includes those neither working nor looking for work in the 4 weeks prior to February 2013.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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Minorities in the S&E Workforce

The participation of underrepresented racial and ethnic minorities in the S&E workforce has been a concern of policymakers who are interested in the development and employment of diverse human capital to maintain the United States' global competitiveness in S&E. This section addresses the level of diversity in S&E by race and Hispanic ethnicity.[i] Like the preceding section, this section draws on data from NSF's SESTAT surveys to report on levels of S&E participation: first across occupations and then across the overall workforce with S&E degrees.

Whether defined by occupation, S&E degree, or a combination of the two, the majority of scientists and engineers in the United States are non-Hispanic whites. The next largest group of scientists and engineers are Asians. Several racial and ethnic minority groups, including blacks, Hispanics, and American Indians or Alaska Natives, have low levels of participation in S&E fields both compared with other groups and compared with their proportion in the population (Table 3-19).

[i] In this chapter, American Indian or Alaska Native, Asian, black, Native Hawaiian or Other Pacific Islander, white, and more than one race refer to individuals who are not of Hispanic origin. Hispanics may be any race.

Table 3-19 **Racial and ethnic distribution of U.S. residents, and of employed individuals in S&E occupations, with S&E degrees, and with college degrees: 2013**

(Percent)

Race and ethnicity	S&E occupations	S&E highest degree holders	College degree holders	U.S. residential population[a]
Total (*n*)	5,749,000	12,446,000	43,839,000	229,000,000
American Indian or Alaska Native	0.2	0.3	0.3	0.6
Asian	17.4	13.5	8.4	5.2
Black	4.8	5.8	7.2	11.7
Hispanic	6.1	7.9	7.7	14.6
Native Hawaiian or Other Pacific Islander	0.2	0.3	0.3	0.1
White	69.9	70.5	74.6	66.2
More than one race	1.5	1.6	1.5	1.6

NOTES: [a] Age 21 and older.
Hispanic may be any race. American Indian or Alaska Native, Asian, black or African American, Native Hawaiian or Other Pacific Islander, white, and more than one race refer to individuals who are not of Hispanic origin.

SOURCES: Census Bureau, American Community Survey (ACS) (2013); National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT), and National Survey of College Graduates (NSCG) (2013), http://sestat.nsf.gov.

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Race and Ethnicity Trends in S&E Occupations

In 2013, among the 5.7 million workers employed in S&E occupations, 70% were white, which is close to the proportion (66%) in the U.S. population age 21 and older (Table 3-19). However, S&E participation by whites varied across the broad S&E occupational categories, from 65% of computer and mathematical scientists to 78% of social scientists (Appendix Table 3-15). The concentration of whites in some occupations was more pronounced: they accounted for at least 90% of workers among forestry and conservation scientists, geologists and earth scientists, and political scientists.

Asians, with about 1 million workers in S&E occupations, accounted for 17% of S&E employment, much higher than their share of the U.S. population age 21 and older (5%). Asians had a large presence in computer and engineering fields, constituting 39% of computer software engineers, 25% of software developers, 29% of computer hardware engineers, 29% of bioengineers or biomedical engineers, and 26% of postsecondary teachers in engineering (Appendix Table 3-15). On the contrary, the proportion of Asians in social sciences occupations was much lower both compared with their participation in other S&E fields and compared with whites. For example, Asians accounted for just 7% of workers in social sciences occupations.

Overall, Hispanics accounted for 6% of employment in S&E occupations, which is lower than their share of the U.S. population age 21 and older (15%) (Table 3-19). Hispanics had a particularly large presence among psychologists (11%); mathematical scientists (11%); medical scientists (excluding practitioners) (8%); and industrial engineers (10%). Blacks accounted for 5% of S&E employment, which is lower than their share of the U.S. population age 21 and older (12%) (Table 3-19). Blacks had relatively high participation rates among computer systems analysts (11%), database administrators (13%), information security analysts (16%), and sociologists (10%).

Over the past two decades, the U.S. workforce in S&E occupations has become more diverse with increasing proportions of Asians, blacks, and Hispanics and a decreasing proportion of whites (Table 3-20). In 1993, 84% of workers in S&E occupations reported their race as white. By 2013, this proportion declined to 70%. Most of the decline in the proportion of whites during this period was offset by an increase in the proportion of Asians and, to a lesser degree, by increases in the proportion of other groups, particularly Hispanics.

Table 3-20 **Distribution of workers in S&E occupations, by race and ethnicity: 1993–2013**

(Percent)

Race and ethnicity	1993	1995	1997	1999	2003	2006	2008	2010	2013
American Indian or Alaska Native	0.2	0.3	0.3	0.3	0.3	0.4	0.3	0.2	0.2
Asian	9.1	9.6	10.4	11.0	14.2	16.1	16.9	18.5	17.4
Black	3.6	3.4	3.4	3.4	4.3	3.9	3.9	4.6	4.8
Hispanic	2.9	2.8	3.1	3.4	4.4	4.6	4.9	5.2	6.1
Native Hawaiian or Other Pacific Islander	NA	NA	NA	NA	0.3	0.5	0.4	0.2	0.2
White	84.1	83.9	82.9	81.8	75.2	73.2	71.8	69.9	69.9
More than one race	NA	NA	NA	NA	1.4	1.4	1.7	1.4	1.5

NA = not available.

NOTES: Hispanic may be any race. American Indian or Alaska Native, Asian, black or African American, Native Hawaiian or Other Pacific Islander, white, and more than one race refer to individuals who are not of Hispanic origin. Before 2003, respondents could not classify themselves in more than one racial and ethnic category, and Asian included Native Hawaiian and Other Pacific Islander.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (1993–2013), http://sestat.nsf.gov.

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Some of the changes by race over time may reflect changes to the way NSF and other federal government surveys collect information on this topic. After 2000, respondents to NSF surveys were able to report more than one race. Some of those who self-reported as white in the 1990s may have instead reported a multiracial identity after 2000 once they were given this option, which would decrease the estimated numbers of whites. However, because less than 2% of S&E workers reported a multiracial identity in years when that option was available, it is unlikely that this change contributed much to the decline in the proportion of whites between 1993 and 2013.

Racial and Ethnic Differences among S&E Degree Holders

Among those in the workforce whose highest degree is in S&E, the shares of racial and ethnic groups vary similarly across degree fields as they do in occupations (Table 3-21; Appendix Table 3-16). Compared to other broad S&E

fields, Asians have higher participation rates among those with degrees in engineering and in computer and mathematical sciences; blacks have higher participation rates among those with degrees in computer and mathematical sciences and in social sciences; Hispanics have slightly lower participation rates among those with degrees in computer and mathematical sciences and in physical sciences. Whites represent relatively smaller segments of degree holders in engineering and computer and mathematical sciences than in life, physical, and social sciences.

Table 3-21 **Racial and ethnic distribution of employed individuals with S&E highest degree, by field of highest degree: 2013**

(Percent)

Race and ethnicity	All S&E fields	Biological, agricultural, and environmental life sciences	Computer and mathematical sciences	Physical sciences	Social sciences	Engineering
Employed with highest degree in S&E (*n*)	12,446,000	1,896,000	2,197,000	731,000	4,764,000	2,859,000
American Indian or Alaska Native	0.3	0.3	0.1	0.7	0.3	0.2
Asian	13.5	12.0	20.9	16.1	6.2	20.3
Black	5.8	4.6	7.4	2.3	7.5	3.6
Hispanic	7.9	7.4	5.9	5.2	9.2	8.3
Native Hawaiian or Other Pacific Islander	0.3	S	0.1	0.1	0.5	0.2
White	70.5	73.7	64.2	74.1	74.3	66.1
More than one race	1.6	1.5	1.3	1.4	2.0	1.3

NOTES: S = suppressed for reasons of confidentiality and/or reliability.
Hispanic may be any race. American Indian or Alaska Native, Asian, black or African American, Native Hawaiian or Other Pacific Islander, white, and more than one race refer to individuals who are not of Hispanic origin.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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The demographic groups also differ in the level of their highest degree (Table 3-22), with Asians accounting for larger proportions of those whose highest degree is at the master's or doctoral level, relative to their counterparts with a highest degree at the bachelor's level. Conversely, blacks, Hispanics, and whites all represent larger proportions of those whose highest degree is at the bachelor's degree level, relative to those with a doctorate as their highest degree.

Table 3-22 **Racial and ethnic distribution of employed individuals with S&E highest degree, by level of highest degree: 2013**

(Percent)

Race and ethnicity	Bachelor's	Master's	Doctorate
Employed with highest degree in S&E (*n*)	8,932,000	2,596,000	873,000
American Indian or Alaska Native	0.3	0.1	0.2
Asian	10.5	20.6	23.7
Black	6.1	5.8	3.0
Hispanic	8.6	6.7	3.8
Native Hawaiian or Other Pacific Islander	0.4	0.2	0.1
White	72.3	65.1	68.3
More than one race	1.7	1.5	1.0

NOTES: Hispanic may be any race. American Indian or Alaska Native, Asian, black or African American, Native Hawaiian or Other Pacific Islander, white, and more than one race refer to individuals who are not of Hispanic origin.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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Asian S&E highest degree holders are more likely than those in other racial and ethnic groups to work in S&E occupations and to work in the area in which they earned their degree. Among black, Hispanic, and white S&E degree holders, between 21% and 26% work in their same broad field, compared to 36% among Asian S&E degree holders (Appendix Table 3-14).

Women in S&E by Race and Ethnicity

The rise in female participation in S&E over the past two decades was the result of increasing participation by members of all race and ethnic groups, although the growth among Asian and Hispanic women was particularly strong. Among workers in S&E occupations, the number of women who identified themselves as Asian or Hispanic increased at least fourfold between 1993 and 2013. As a result, both the Asian share and the Hispanic share of female workers in S&E occupations rose during this period (Table 3-23). The number of women employed in S&E occupations who reported themselves as black more than doubled (rising by 158%) between 1993 and 2013. In comparison, although the number of female workers who identified themselves as non-Hispanic white rose substantially (82%), their participation did not grow as steeply as members of other race and ethnic groups, resulting in an overall decline in the white share of female S&E workers over time (Table 3-23). A broadly similar pattern is observed among female S&E highest degree holders.

Table 3-23 **Racial and ethnic distribution of employed women in S&E occupations and with S&E highest degrees: 1993 and 2013**

(Percent)

	Women in S&E occupations		Women with S&E highest degrees	
Race and ethnicity	1993	2013	1993	2013
Total (*n*)	755,000	1,670,000	2,205,000	4,839,000
American Indian or Alaska Native	0.3	0.2	0.3	0.3

	Women in S&E occupations		Women with S&E highest degrees	
Race and ethnicity	1993	2013	1993	2013
Asian	9.3	17.7	7.3	12.2
Black	5.7	6.6	8.1	7.6
Hispanic	3.2	6.9	3.6	9.4
Native Hawaiian or Other Pacific Islander	NA	0.1	NA	0.3
White	81.5	66.9	80.6	68.3
More than one race	NA	1.4	NA	1.9

NA = not available.

NOTES: Hispanic may be any race. American Indian or Alaska Native, Asian, black or African American, Native Hawaiian or Other Pacific Islander, white, and more than one race refer to individuals who are not of Hispanic origin. In 1993, respondents could not classify themselves in more than one racial and ethnic category, and Asian included Native Hawaiian and Other Pacific Islander.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (1993, 2013), http://sestat.nsf.gov.

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Salary Differences for Women and Racial and Ethnic Minorities

Women and racial and ethnic minority groups generally receive less pay than their male and white counterparts (Table 3-24). However, salary differences between men and women were somewhat larger than salary differences among racial and ethnic groups (Table 3-24; Appendix Table 3-17 and Appendix Table 3-18). Overall, salary differences between men and women and among racial and ethnic groups remained largely unchanged between 1995 and 2013 (Table 3-24).

Table 3-24 **Median annual salary among S&E highest degree holders working full time, by sex, race, and ethnicity: 1995, 2003, and 2013**

(Dollars)

Characteristic	1995	2003	2013
All	44,000	60,000	72,000
Sex			
Female	34,000	45,000	55,000
Male	49,000	68,000	80,000
Race and ethnicity			
American Indian or Alaska Native	S	48,000	68,000
Asian	45,000	64,000	80,000
Black	35,000	48,000	58,000
Hispanic	38,000	50,000	59,000
Native Hawaiian or Other Pacific Islander	NA	56,000	78,000

Characteristic	1995	2003	2013
White	45,000	60,000	74,000
More than one race	NA	50,000	64,000

NA = not available; S = suppressed for reasons of confidentiality and/or reliability.

NOTES: Salaries are rounded to the nearest $1,000. Data for 1995 include some individuals with multiple races in each category. Hispanic may be any race. American Indian or Alaska Native, Asian, black or African American, Native Hawaiian or Other Pacific Islander, white, and more than one race refer to individuals who are not of Hispanic origin.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (1995, 2003, 2013), http://sestat.nsf.gov.

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Differences in average age, work experience, academic training, sector and occupation of employment, and other characteristics can make direct comparison of salary statistics misleading. Statistical models can estimate the size of the salary difference between men and women, or the salary differences between racial and ethnic groups, when various salary-related factors are taken into account. Estimates of these differences vary somewhat depending on the assumptions that underlie the statistical model used. The analyses presented in this section show that statistical models to control for effects of education, experience, and other factors on salaries tend to reduce, but not fully eliminate, the disparities. The remainder of this section presents estimated salary differences between men and women among individuals who are otherwise similar in age, work experience, field of highest degree, type of academic institution awarding highest degree (by Carnegie 2010 classification and private/public status), occupational field and sector, and other relevant characteristics that are likely to influence salaries. Data related to salary differences between minorities (American Indians or Alaska Natives, blacks, Hispanics, Native Hawaiians or Other Pacific Islanders, and those reporting more than one race) and Asians and whites are also included.

Accounting only for level of degree, women working full time whose highest S&E degree is at the bachelor's level earned 30% less than men (Figure 3-31).[i] The salary difference is smaller but substantial at both the master's level (28%) and the doctoral level (21%). The salary differences for non-Asian minorities relative to whites and Asians are narrower (Figure 3-32). On average, minority salary levels are 19% lower than those of whites and Asians at the bachelor's level, 20% lower at the master's level, and 16% lower at the doctoral level.

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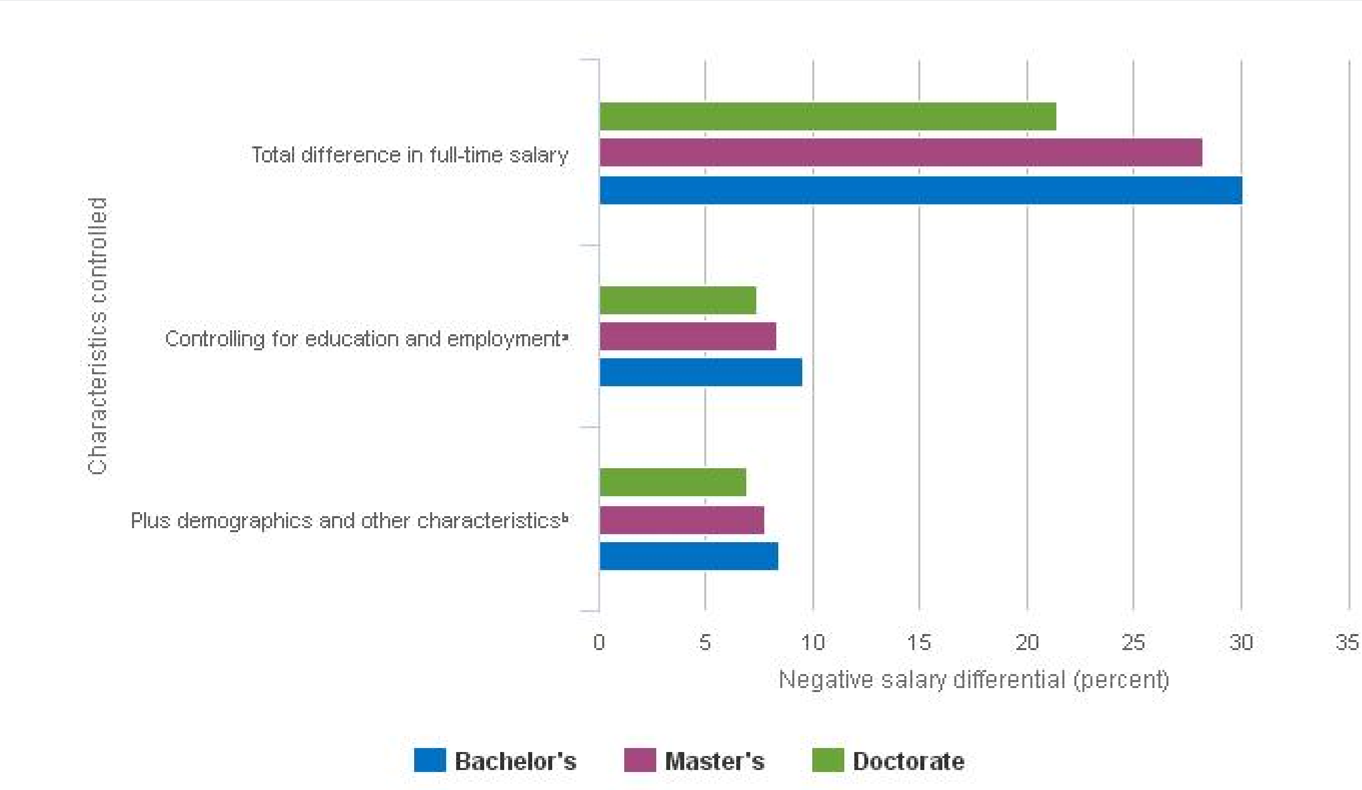
[i] Salary differences represent estimated percentage differences in women's reported full-time annual salary relative to men's reported full-time annual salary as of February 2013. Coefficients are estimated in an ordinary least squares regression model using natural log of full-time annual salary as the dependent variable. This estimated percentage difference in earnings differs slightly from the observed difference in median earnings by sex because the former addresses differences in mean earnings rather than median.

Figure 3-31

Estimated salary differences between women and men with highest degree in S&E employed full time, controlling for selected characteristics, by degree level: 2013



[a] Included are 20 Scientists and Engineers Statistical Data System (SESTAT) field-of-degree categories (out of 21 S&E fields), 38 SESTAT occupational categories (out of 39 categories), 6 SESTAT employment sector categories (out of 7 categories), years since highest degree, years since highest degree squared, Carnegie classification of school awarding highest degree, and private or public status of postsecondary institution awarding highest degree.

[b] In addition to the above education- and employment-related variables, the following indicators are included: nativity and citizenship, race and ethnic minority, marital status, disability, number of children living in the household, geographic region (classified into 9 U.S. Census divisions), and whether either parent holds a bachelor's or higher-level degree.

NOTES: Salary differences represent the estimated percentage difference in women’s average full-time salary relative to men’s average full-time salary. Coefficients are estimated in an ordinary least squares regression model using the natural log of full-time annual salary as the dependent variable and then transformed into percentage difference.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, SESTAT (2013), http://sestat.nsf.gov.

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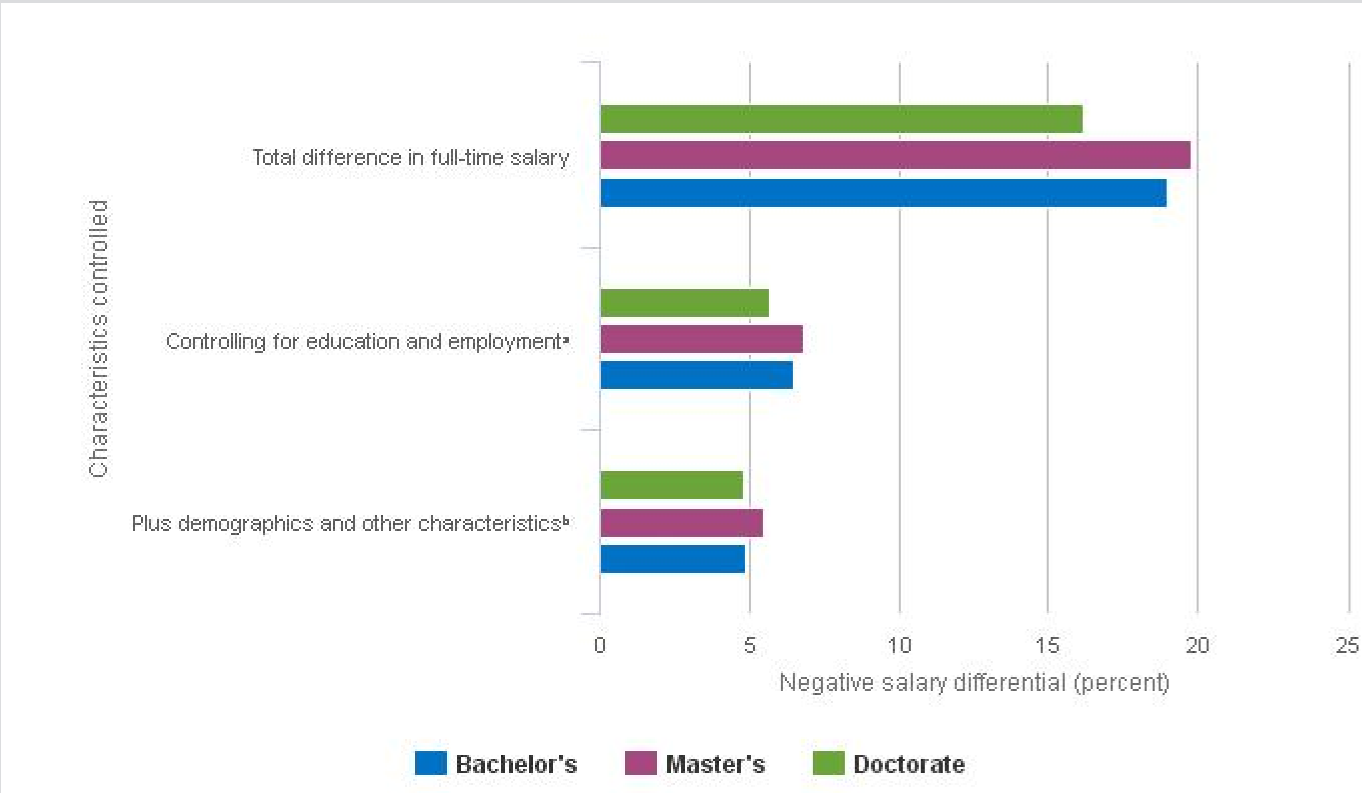
Figure 3-32

Estimated salary differences between minorities and whites and Asians with highest degree in S&E employed full time, controlling for selected characteristics, by degree level: 2013



[a] Included are 20 Scientists and Engineers Statistical Data System (SESTAT) field-of-degree categories (out of 21 S&E fields), 38 SESTAT occupational categories (out of 39 categories), 6 SESTAT employment sector categories (out of 7 categories), years since highest degree, years since highest degree squared, Carnegie classification of school awarding highest degree, and private or public status of postsecondary institution awarding highest degree.

[b] In addition to the above education- and employment-related variables, the following indicators are included: nativity and citizenship, sex, marital status, disability, number of children living in the household, geographic region (classified into 9 U.S. Census divisions), and whether either parent holds a bachelor's or higher-level degree.

NOTES: Salary differences represent the estimated percentage difference in the average full-time salary of minorities relative to the average full-time salary of whites and Asians. Coefficients are estimated in an ordinary least squares regression model using the natural log of full-time annual salary as the dependent variable and then transformed into percentage difference. Minorities include American Indian or Alaska Natives, blacks, Hispanics (of any race), Native Hawaiian or Other Pacific Islanders, and those reporting more than one race.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, SESTAT (2013), http://sestat.nsf.gov.

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Effects of Education, Employment, and Experience on Salary Differences

Salaries differ across degree field, occupational field and sector, and experience. Such differences in degree and occupational fields account for a portion of the salary differences by sex and by race and ethnicity. Median salaries in 2013 were generally higher among full-time workers with a highest degree in engineering ($91,000), physical sciences ($75,000), or computer and mathematical sciences ($84,000) than for those with a highest degree in life sciences ($57,000) or social sciences ($56,000). Degree areas with lower salaries generally have higher concentrations of women and of racial and ethnic minorities. Disproportionately larger shares of degree holders in life sciences, and particularly in social sciences, compared to other S&E degree fields, work in occupations not categorized as S&E, and the salaries for these occupations are generally lower than for S&E occupations (Appendix Table 3-17).

Salaries also differ across employment sectors. Academic and nonprofit employers typically pay less for similar skills than employers in the private sector, and government compensation generally falls somewhere between these two groups. These differences are salient for understanding salary variations by sex and by race and ethnicity because men, Asians, and whites are more highly concentrated in the private for-profit sector.

Salaries also vary by indicators of experience, such as age and years since completing one's degree. Because of the rapid increase in female participation in S&E fields in recent years, women with S&E degrees who are employed full time generally have fewer years of labor market experience than their male counterparts: the median number of years since highest degree is 13 for women versus 17 for men; the median age is 40 years for women versus 43 for men. Whites with S&E degrees who are employed full time also generally have more years of labor market experience than other racial and ethnic groups: the median number of years since highest degree is 18 years for whites, 14 years for Asians, 11 years for Hispanics, 12 years for blacks, 17 years for American Indians or Alaska Natives, and 16 years for Native Hawaiians or Other Pacific Islanders.

Eliminating the effects of differences in field of highest degree, degree-granting institution, field of occupation, employment sector, and experience,[ii] the estimated salary difference between men and women narrows by more than half (Figure 3-31). However, women still earn 10% less than men among individuals whose highest degree is at the bachelor's level, and 7%–8% less than men among individuals whose highest degree is at the master's or doctoral level. The pattern is similar among racial and ethnic groups: compared with whites and Asians, S&E highest degree holders in other racial and ethnic groups working full time earn 6%–7% less at each degree level (Figure 3-32).

Effects of Demographic and Other Factors on Salary Differences

Salaries vary by factors beyond education, occupation, and experience. For example, marital status, the presence of children, parental education, and other personal characteristics are often associated with salary differences. These differences reflect a wide range of issues, including, but not limited to, factors affecting individual career- and education-related decisions, differences in how individuals balance family obligations and career aspirations, productivity and human capital differences among workers that surveys do not measure, and possible effects of employer prejudice or discrimination. Salaries also differ across regions, partly reflecting differences in the cost of living across geographic areas.

However, adding such measures of personal and family characteristics[iii] to education, occupation, and experience results in only marginal changes in the estimated salary differences between men and women, and among racial and ethnic groups, compared with estimates that account for education, occupation, and experience alone. Women's adjusted salary differentials are 7% among S&E doctorates and 8% among S&E bachelor's degree and master's degree holders (Figure 3-31). Adjusted salary differences among racial and ethnic groups are 5% among bachelor's and doctoral degree holders and 6% among those with master's degrees (Figure 3-32).

The analysis of salary differences suggests that attributes related to human capital (fields of education and occupation, employment sector, and experience) are much more important than socioeconomic and demographic attributes in explaining the salary differences observed among S&E highest degree holders by sex and across racial and ethnic groups. Nonetheless, the analysis also shows that measurable differences in human capital do not entirely explain income differences between demographic groups.[iv]

Salary Differences among Recent Graduates

Salary differences among recent S&E graduates, particularly across racial and ethnic groups, are substantially narrower than in the population of S&E degree holders as a whole. Such employment metrics of recent graduates warrant particular attention as important indicators of current conditions in the labor market, particularly for young people considering S&E careers.

Substantially narrower salary differences among recent versus all S&E graduates, particularly across racial and ethnic groups, suggest that recent cohorts of S&E degree holders are getting closer to earnings parity than their older counterparts. For example, in 2013, among recent graduates who attained their highest degree in or after 2008, minorities working full time earned between 4% (at the bachelor's level) and 9% (at the doctorate level) less than Asians and whites. These salary differences are higher, ranging from 16% to 20%, among all S&E highest degree holders (regardless of graduation year) (Figure 3-32).

After accounting for differences in education, occupation, and experience, the salary differences for recently graduated minorities relative to whites and Asians are reduced among master's and doctoral degree holders (although a 3%–4% salary gap remains) and nearly attenuated among bachelor's degree holders. In contrast, when all S&E highest degree holders (regardless of graduation cohort) are included in the analysis, a 6%–7% salary gap at each degree level remains unexplained by these human capital attributes (Figure 3-32).

After controlling for differences in education, employment, demographic, and socioeconomic attributes, the gender salary gap among recent graduates ranges from 2% to 6% among master's and doctoral degree holders, and almost disappears among bachelor's degree holders. In comparison, a 7%–8% salary gap remains at each degree level among all S&E highest degree holders (regardless of graduation cohort).

[ii] Included are 20 SESTAT field of degree categories (out of 21 S&E fields), 38 SESTAT occupational categories (out of 39 categories), 6 SESTAT employment sector categories (out of 7), years since highest degree, years since highest degree squared, Carnegie classification of school awarding highest degree, and private/public status of postsecondary institution awarding highest degree.

[iii] In addition to the education- and employment-related variables, the following indicators are included: nativity and citizenship, marital status, disability, number of children living in the household, geographic region (classified into nine U.S. Census divisions), and whether either parent holds a bachelor's or higher level degree. The sex regression controls for racial and ethnic minority status, and the race and ethnicity regression controls for sex.

[iv] The regression analysis addresses major factors that affect differences in earnings but does not attempt to cover all possible sources of difference. For a more detailed discussion on the topic, see Blau and Kahn (2007), Mincer (1974), Polachek (2008), and Xie and Shauman (2003).

Immigration and the S&E Workforce

The industrialized nations of the world have long benefitted from the inflow of foreign-born scientists and engineers and the S&E skills and knowledge they bring. S&E skills are more easily transferrable across international borders than many other skills, and many countries have made it a national priority to attract international talent in S&E (NSB 2008). A large proportion of workers employed in S&E fields in the United States are foreign born. This section presents data on foreign-born scientists and engineers in the U.S. economy, including recent indicators of migration to the United States and the rate at which foreign-born recipients of U.S. doctoral degrees remain in the United States after earning their degree. Data from various sources, including NSF (SESTAT and Survey of Earned Doctorates [SED]), the Census Bureau, and the U.S. Citizenship and Immigration Services (USCIS) are discussed to study the immigrant S&E workforce in the United States.[i]

Foreign-born is a broad category, ranging from long-term U.S. residents with strong roots in the United States to recent immigrants who compete in global job markets and whose main social, educational, and economic ties are in their countries of origin. When interpreting data on foreign-born workers, the range of individuals in this category should be kept in mind.

Nationally representative survey data, such as SESTAT and ACS, although collected in different ways, yield broadly consistent estimates of the number of foreign-born scientists and engineers in the United States. In 2013, foreign-born individuals accounted for 27% of college-educated workers employed in S&E occupations in the United States (Table 3-25), which is higher than their representation in both the overall population (13%) and among all college graduates (15%). Both the number and proportion of foreign-born workers employed in S&E occupations in the United States have risen over time (Table 3-25).

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[i] For information on high-skill migration worldwide, see Defoort (2008), Docquier and Rapoport (2012), Docquier, Lowell, and Marfouk (2009), and Docquier and Marfouk (2006).

Table 3-25 **Foreign-born workers in S&E occupations, by education level: 1993, 2003, and 2013**

(Percent)

	1993	2003		2013	
Education	SESTAT	SESTAT	ACS	SESTAT	ACS
All college educated	15.8	22.6	25.2	26.5	26.9
Bachelor's	11.4	16.4	18.7	18.9	19.2
Master's	20.7	29.4	32.0	34.3	36.7
Doctorate	26.8	36.4	38.7	42.1	42.2

NOTES: ACS = American Community Survey; SESTAT = Scientists and Engineers Statistical Data System.
All college educated includes professional degree holders not broken out separately. The data from the ACS include all S&E occupations except postsecondary teachers of S&E because these occupations are not separately identifiable in the ACS data files.

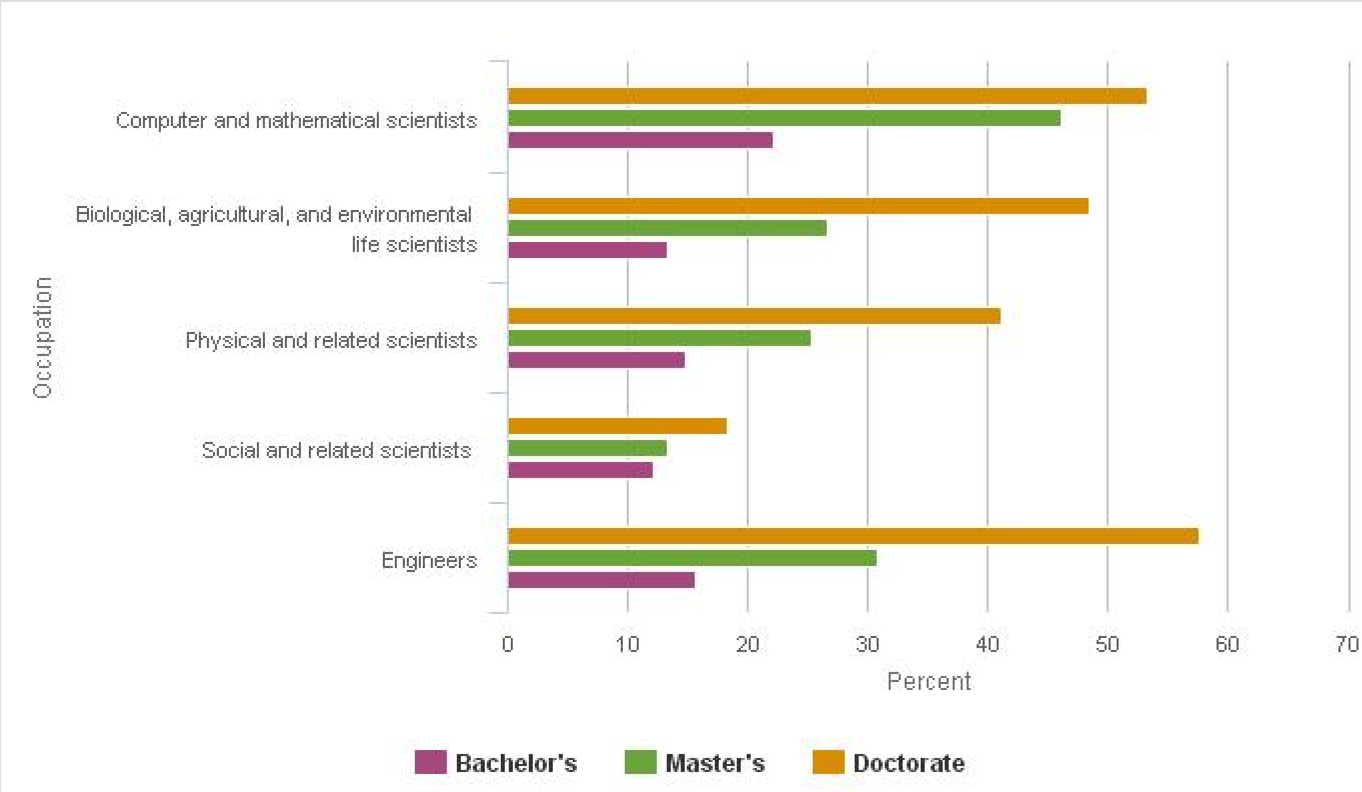
SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, SESTAT (1993, 2003, 2013), http://sestat.nsf.gov; Census Bureau, ACS Public Use Microdata Sample (PUMS) (2003, 2013).

Characteristics of Foreign-Born Scientists and Engineers

Foreign-born workers employed in S&E occupations tend to have higher levels of education than their U.S. native-born counterparts. Among individuals employed in S&E occupations, 20% of foreign-born workers have a doctorate, compared to 10% of U.S. native-born individuals in these occupations. In most S&E occupations, the higher the degree level, the greater the proportion of the workforce who are foreign born (Figure 3-33). This relationship is weakest among social scientists and strongest among computer and mathematical scientists and engineers. In 2013, at the bachelor's degree level, the proportion of foreign-born individuals in S&E occupations ranged from 12% (social scientists) to 22% (computer and mathematical scientists). However, at the doctoral level, over 40% were foreign born in each S&E occupation except social sciences.

Figure 3-33

Foreign-born scientists and engineers employed in S&E occupations, by highest degree level and broad S&E occupational category: 2013



SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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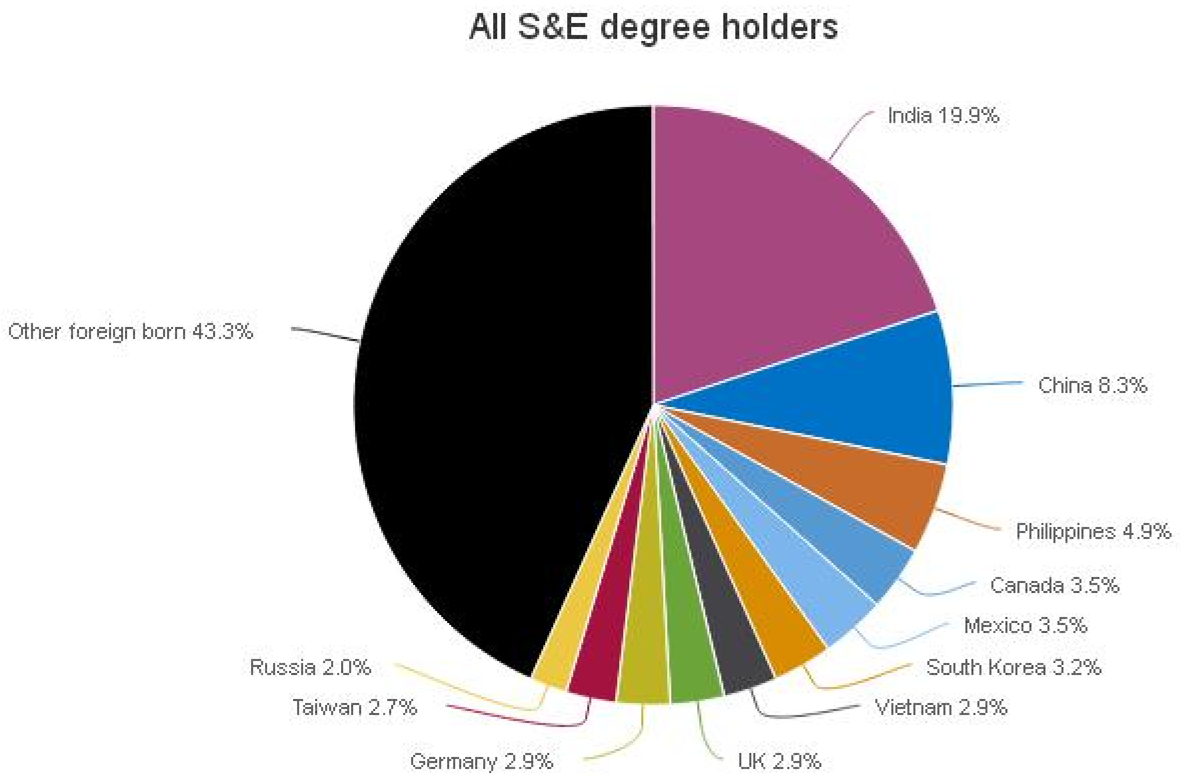
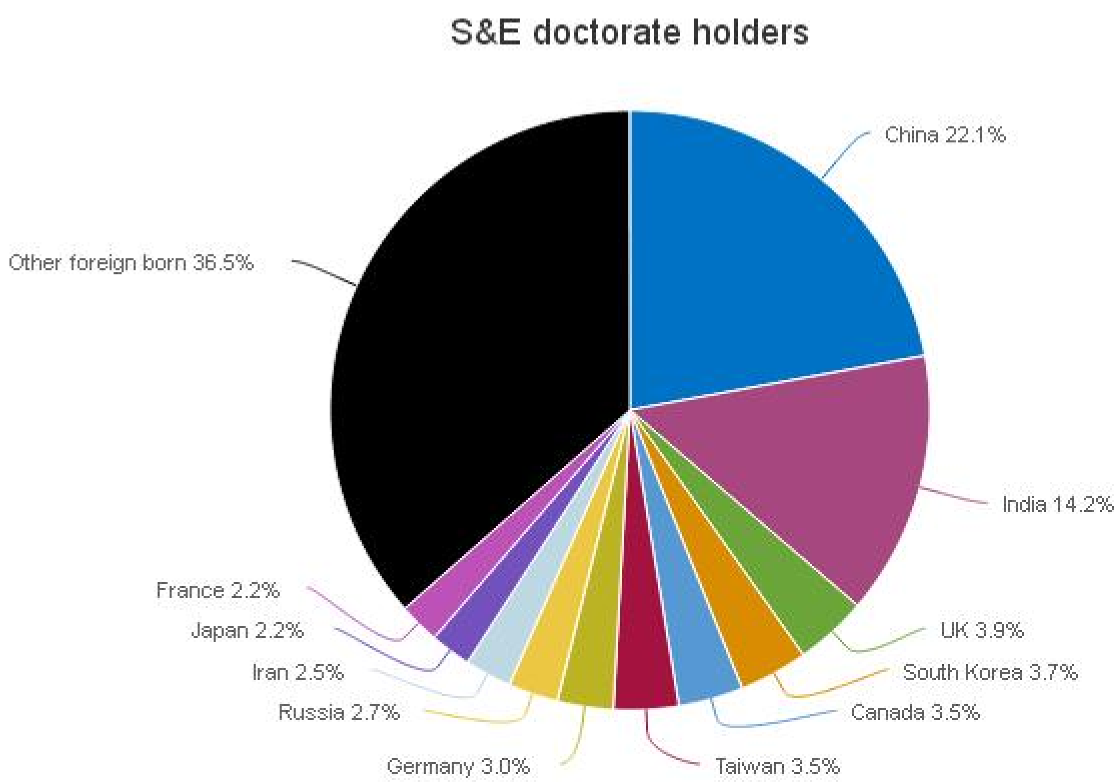
In 2013, among SESTAT respondents employed in S&E occupations, foreign-born workers (median age 39 years) were younger than their native-born counterparts (median age 42). The distribution by sex was largely similar across foreign-born (28% female) and native-born (29% female) workers in S&E occupations. Asians accounted for 59% of foreign-born workers in S&E occupations but for only 3% of U.S. native-born workers in these occupations (Appendix Table 3-19). In comparison, whites represented 27% of foreign-born workers in S&E occupations but 86% of native-born workers in these occupations. Nearly 90% of all Asians employed in S&E occupations were foreign born.

In 2013, 57% of foreign-born individuals in the United States with an S&E highest degree were from Asia; another 20% were from Europe. North and Central America, the Caribbean, South America, and Africa each supplied 4% to 6% of the foreign-born S&E highest degree holders in the United States. In 2013, the leading country of origin among these immigrants was India, which accounted for 20% of the foreign-born S&E degree holders in the United States (Figure 3-34). With less than half the total for India, China was the second leading country with 8%. Source countries for the 402,000 foreign-born holders of S&E doctorates were somewhat more concentrated, with China providing a higher proportion (22%) than India (14%). These patterns by source region and country for foreign-born S&E highest degree holders in the United States have been stable since at least 2003.

Figure 3-34

Foreign-born individuals with highest degree in S&E living in the United States, by place of birth: 2013





UK = United Kingdom.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013), http://sestat.nsf.gov.

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The SESTAT surveys ask respondents to provide information on where they received their postsecondary degrees and their motivation for coming to the United States. This information sheds light on the educational and career paths of foreign-born scientists and engineers in the United States and possible factors that influence these paths. The majority of foreign-born scientists and engineers in the United States received their initial university training abroad. In 2013, there were about 4.6 million college-educated, foreign-born scientists and engineers employed in the United States; of these, 2.2 million received their first bachelor's degree abroad. Many of these individuals came to the United States for job or economic opportunities (32%), family-related reasons (27%), or educational opportunities (21%). In contrast, only 6% of foreign-born scientists and engineers with a U.S. bachelor's degree cited job or economic opportunities, and many more cited family-related reasons (42%) or educational opportunities (23%) as their primary reasons for coming to the United States.

A substantial number of foreign-born scientists and engineers in the United States appear to come here for further higher education after receiving their initial university training abroad. Nearly two-thirds (63%) of the 1.1 million employed foreign-born scientists and engineers who received their initial university training abroad and who hold a master's degree, doctorate, or professional degree completed their highest degree in the United States. Among these individuals, the most frequently cited reason for coming to the United States was educational opportunities (43%). Family-related reasons (12%) and job/economic opportunities (12%) were cited by much smaller proportions. Among the foreign-born doctorate holders employed in the United States, 65% received this degree from a U.S. institution.

New Foreign-Born Workers

During the 2007–09 economic downturn, two indicators—the number of temporary work visas issued by the U.S. government in visa classes for high-skill workers and the stay rates of foreign-born U.S. doctorate recipients—showed evidence that the volume of new foreign-born workers entering the U.S. S&E workforce might be declining. However, recent data indicate that this period of decline was temporary. In addition to these two indicators, this section discusses characteristics of workers with temporary work visas and country profiles of new foreign-born workers.

Temporary Visas

The number of temporary work visas issued for high-skill workers provides an indication of new immigrant workers entering the U.S. labor force.[i] After several years of growth, the largest classes of these temporary visas declined during the recent economic downturn (Figure 3-35). Despite the increases in the issuance of temporary visas since FY 2009, the total numbers of visas issued in some categories have not yet reached the recent highs seen in FY 2007, before the beginning of the economic downturn (Figure 3-35). A decline in the issuance of these visas, particularly H-1B visas, had also occurred around the more mild recession in 2001.

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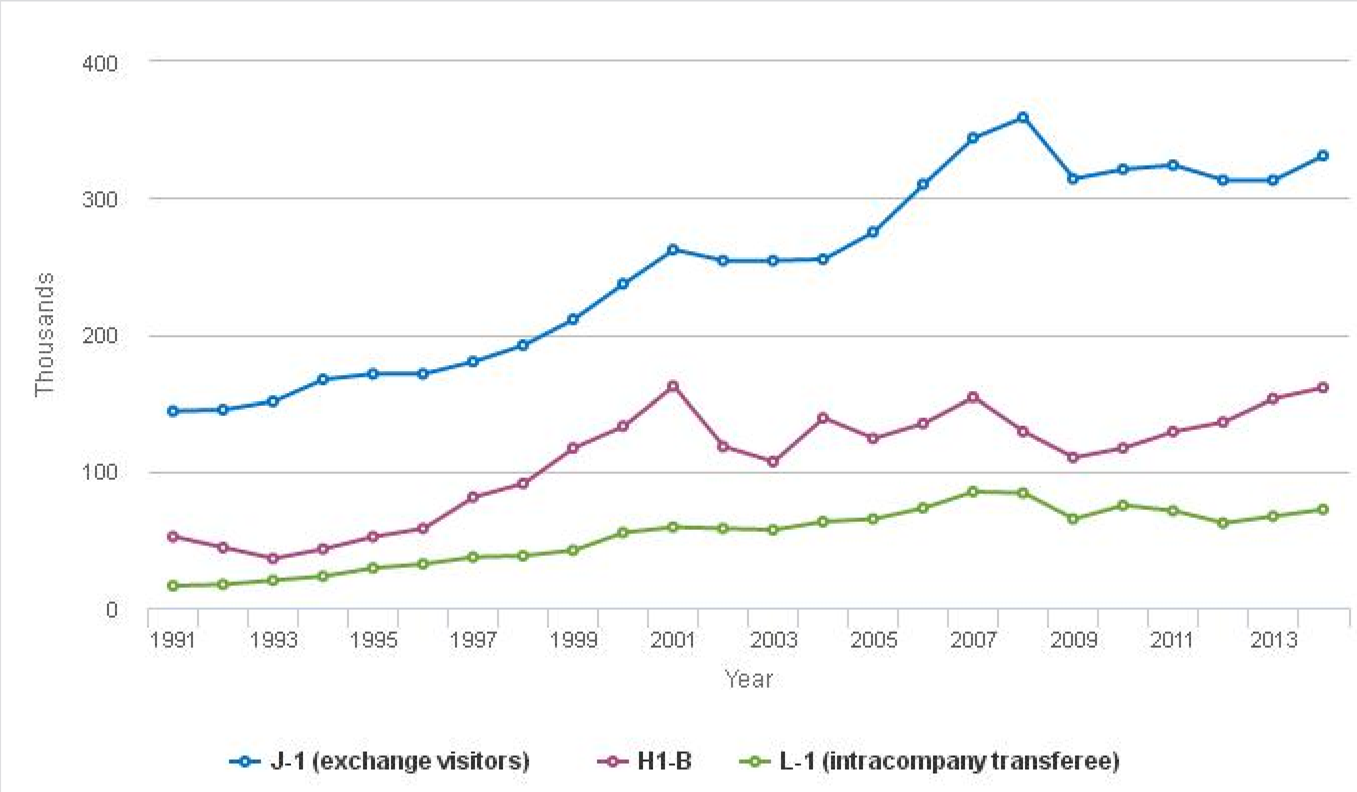
[i] For all types of temporary work visas, the actual number of individuals using them is less than the number issued. For example, some individuals may have job offers from employers in more than one country and may choose not to foreclose any options until a visa is certain.

Figure 3-35

Temporary work visas issued in categories with many high-skilled workers: FYs 1991–2014



NOTE: J-1 exchange visitor visa is used for many different skill levels.

SOURCES: U.S. Department of State, Nonimmigrant Visa Issuances by Visa Class and by Nationality and Nonimmigrant Visas by Individual Class of Admission, http://travel.state.gov/content/visas/english/law-and-policy/statistics.html (accessed 18 August 2015).

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H-1B visas account for a significant proportion of foreign-born high-skill workers employed by U.S. firms on temporary visas. This type of visa is issued to individuals who seek temporary entry into the United States in a specialty occupation that requires professional skills. It is issued for up to 3 years with the possibility of an extension to 6 years. In 2014, the United States issued about 161,000 H-1B visas, up 46% from the recent low in 2009 (110,000) and higher than the recent peak in 2007 (154,000) (Figure 3-35).

Issuance of visas in other temporary work categories that usually contain large numbers of high-skill workers has also risen since 2009; however, the H-1B visa category has shown continued increase since 2009, unlike certain other visa classes such as the J-1 and L-1 categories (Figure 3-35).

Characteristics of H-1B Visa Recipients

The majority of H-1B visa recipients work in S&E or S&E-related occupations. However, precise counts of H-1B visas issued to individuals in these occupations cannot be obtained because USCIS does not classify occupations with the same taxonomy used by NSF. In FY 2014, workers in computer-related occupations as classified by USCIS were the most common recipients of H-1B visas, accounting for 65% of new H-1B visas issued (Appendix Table 3-20). The total number of newly initiated H-1B visas for workers in computer-related fields has increased substantially since 2010, following a steep decline between 2008 and 2009 during the economic downturn (DHS USCIS 2010, 2012, 2013, 2015). The proportion of H-1B recipients who worked in computer sciences was considerably lower in the earlier part of the 2000s. For example, in 2002, only 25% of H-1B visa recipients worked in computer-related fields (NSB 2012).

H-1B visa recipients tend to possess a bachelor's or higher level degree. In FY 2014, nearly half of new H-1B visa recipients (46%) had a bachelor's degree; the rest (54%) had an advanced degree, including 41% with a master's degree, 3% with a professional degree, and 10% with a doctorate (DHS USCIS 2015). In FY 2014, 66% of new H-1B visa recipients were from India, and 11% were from China (DHS USCIS 2015). The preponderance of advanced degrees notwithstanding, H-1B visa recipients were relatively young. In FY 2014, 42% of new H-1B visa recipients were between the ages of 25 and 29, and 31% were between the ages of 30 and 34 (DHS USCIS 2015).

Table 3-26 shows the starting salaries of new recipients of H-1B visas by occupation group. These starting salaries are reported by employers in the final visa application forms sent to USCIS and differ from the H-1B salaries that firms report earlier in the process on their applications to the Department of Labor. The relatively low median salaries for workers in life sciences may reflect the use of H-1B visas to hire individuals for relatively low-paying postdoc positions.

Table 3-26 **Annual salaries for new H-1B visa recipients, by occupation: FY 2014**

(Dollars)

Occupation	Median	Mean
Administrative specializations	57,000	67,000
Architecture, engineering, and surveying	75,000	80,000
Art	52,000	60,000
Computer-related occupations	67,000	74,000
Education	52,000	64,000
Entertainment and recreation	41,000	59,000
Law and jurisprudence	90,000	108,000
Life sciences	50,000	57,000
Managers and officials	90,000	101,000
Mathematics and physical sciences	70,000	75,000
Medicine and health	66,000	112,000
Miscellaneous professional, technical, and managerial	75,000	85,000
Museum, library, and archival sciences	48,000	60,000
Religion and theology	36,000	39,000
Social sciences	65,000	76,000
Writing	44,000	50,000

SOURCE: Department of Homeland Security (DHS), U.S. Citizenship and Immigration Services; *Characteristics of H-1B Specialty Occupation Workers, Fiscal Year 2014 Annual Report to Congress (February 26, 2015)*, http://www.uscis.gov/sites/default/files/USCIS/Resources/Reports%20and%20Studies/H-1B/h-1B-characteristics-report-14.pdf, accessed 7 May 2015.

Short-Term Stay Rates for U.S. S&E Doctorate Recipients

Among doctorate recipients, the period immediately after earning their doctorate is a pivotal point that can substantially affect long-term career trajectories. During this period, foreign-born doctorate recipients who remain in the United States may set themselves on a path to long-term residency.

At the time they receive their doctorates, foreign-born students at U.S. universities report whether they intend to stay in the United States and whether they have a firm offer to work in the United States (either a postdoc or a job) the following year.[i] These responses provide estimates of short-term stay rates.[ii]

Most foreign-born noncitizen recipients of U.S. S&E doctorates (including those on temporary and permanent visas) plan to stay in the United States after graduation (Figure 3-36). According to the most recent estimates, at the time of doctorate receipt, 75% of foreign-born noncitizen recipients of U.S. S&E doctorates planned to stay in the United States, and 44% had either accepted an offer of postdoc study or employment or were continuing employment in the United States. Both of these proportions have risen since the 1980s. In 1993, 65% planned to stay in the United States after graduation, and 33% said they had firm offers in hand. Throughout the 1980s, these proportions were about 50% and 33%, respectively (NSB 2012).

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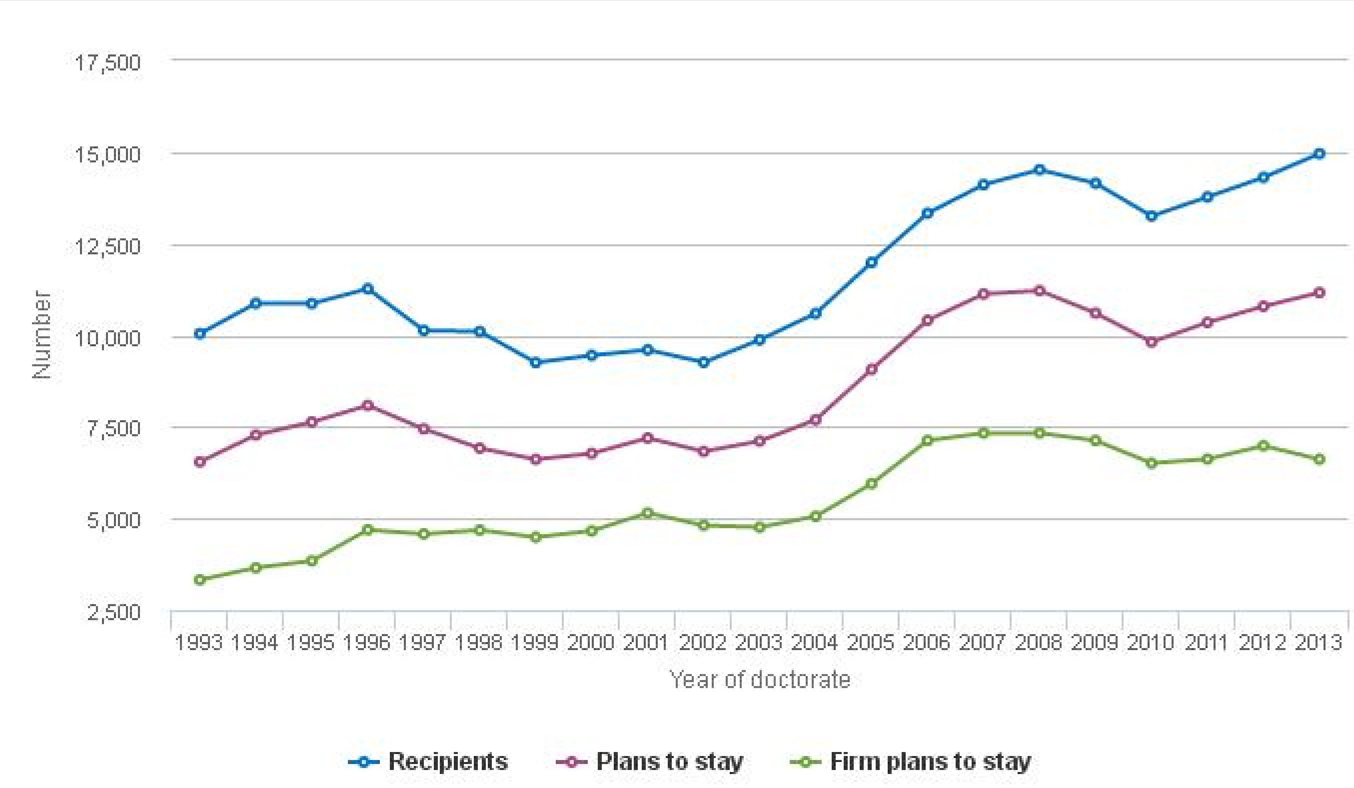
[i] This question is part of the SED, which is administered to individuals receiving research doctoral degrees from all accredited U.S. institutions. For information on the SED, see http://www.nsf.gov/statistics/srvydoctorates/. The information on plans to stay or definite commitments to stay reflects intentions within the year after graduation as reported by the doctorate recipients around their graduation date. As such, any changes in intentions after survey completion are not captured.

[ii] Many foreign recipients of U.S. doctorates who report that they plan to stay in the United States the year after graduation may do so using their student (F-1) visa and never obtain a new visa that would permit a longer stay. Student visas permit an additional 12-month stay in the United States after graduation if a student applies for optional practical training (OPT). OPT refers to paid or unpaid work that is performed at least 20 hours a week and that is related to a student's field of study. Starting in April 2008, those earning a degree in STEM fields could apply for an extension of their OPT to a total of 29 months. Data from the Department of Homeland Security's Student and Exchange Visitor Information System show that 68% of students with F-1 visas completing a doctorate in any field between 1 November 2013 and 31 October 2014 had applied for OPT.

Figure 3-36

Plans at graduation of foreign recipients of U.S. S&E doctoral degrees to stay in the United States, by year of doctorate: 1993–2013



NOTE: Data include foreign doctorate recipients on temporary and permanent visas and also those with unknown visa status.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations of the Survey of Earned Doctorates (SED) (1993–2013).

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Although stay rates have risen over the long haul, they have fluctuated within a relatively narrow range since the beginning of the 2000s (Figure 3-36 and Appendix Table 3-21). Among foreign-born S&E doctorate recipients, both the percentage reporting plans to stay in the United States and the percentage reporting firm offers to stay declined approximately since 2006, a period marked by the onset of the economic downturn and its aftermath. The overall number of foreign-born S&E doctorate recipients also declined in 2009 and 2010, although the numbers have since risen and the 2013 level exceeded the recent peak seen in 2008.

Overall, S&E short-term stay rates reflect the high short-term stay rates in mathematics and computer science, biological sciences, physical and earth sciences, and engineering (Appendix Table 3-21). According to the most recent estimates, the short-term stay rates in these four fields ranged from 77% to 82%, as measured by reports of intentions to stay in the United States. However, the short-term stay rates for foreign-born U.S. S&E doctorate recipients in health fields (70%) were somewhat lower, and those in social sciences (56%) were substantially lower. The proportion of foreign S&E doctorate recipients reporting firm offers to work showed a similar pattern across doctorate fields.

Stay rates vary by place of origin. Between 2010 and 2013, the vast majority of U.S. S&E doctorate recipients from China (84%) and from India (86%) reported plans to stay in the United States, and close to 55% of these individuals reported accepting firm offers for employment or postdoc research in the United States (Appendix Table 3-21). U.S. S&E doctorate recipients from Japan, South Korea, and Taiwan were less likely than those from China and India to stay in the United States. No more than half of U.S. S&E doctorate recipients from Turkey, Germany, and Italy had firm plans to stay in the United States after graduation. In North America, the percentage of U.S. S&E doctorate recipients who had definite plans to stay in the United States was higher for those from Canada than for those from Mexico.

Among U.S. S&E doctorate recipients from the two top countries of origin, China and India, the proportions reporting plans to stay in the United States have declined since the early 2000s (Appendix Table 3-21).

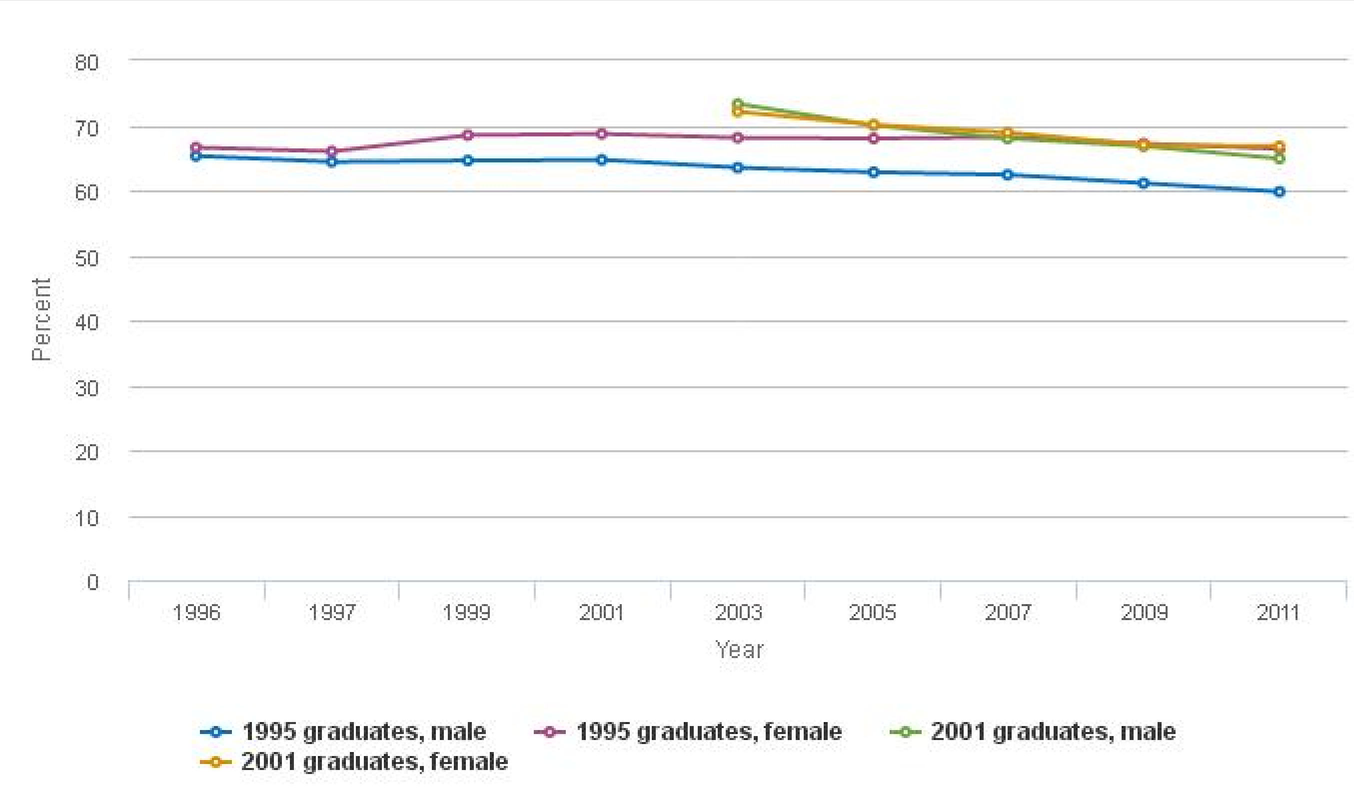
Long-Term Stay Rates for U.S. S&E Doctorate Recipients

Long-term stay rates indicate the degree to which foreign-born recipients of U.S. S&E doctorates enter and remain in the U.S. workforce to pursue their careers. For a particular cohort of foreign-born noncitizen S&E doctorate recipients, the proportion of that cohort who pay federal taxes a given number of years after receiving their degrees is an indicator of the cohort's long-term stay rate. Estimates of short-term stay rates are derived from data on reported intentions to stay in the United States within the year after graduation. The information on reported intentions to stay can be compared with stay rates based on tax data to analyze how stated intentions for the period immediately after graduation compare with actual behavior.

Stay rate data include foreign-born noncitizen recipients of U.S. S&E doctorates who were on either a permanent or a temporary visa at the time they received their doctorates. For the 1995 and the 2001 graduating cohorts, stay rate data are available separately for men and women. For the 1995 cohort, the stay rates for men declined with additional years since award of the doctorate whereas the stay rates for women did not show a similar pattern of decline (Figure 3-37). However, the data for the 2001 cohort show comparable changes in stay rates for both sexes. The men and women in this more recent cohort both start out with stay rates higher than the earlier cohort, but stay rates for women declined in similar fashion to those for men.

Figure 3-37

Stay rates for U.S. S&E doctoral degree recipients with permanent or temporary visas at graduation, by sex: 1996–2011



NA = not available.

NOTE: Data are not available for all categories for all years.

SOURCE: Finn, M. 2014. Stay Rates of Foreign Doctoral Recipients from U.S. Universities: 2011. Oak Ridge, TN: Oak Ridge Institute for Science and Education.

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Long-term stay rates vary greatly by country of citizenship, and the patterns are broadly similar to those observed in short-term stay rate data based on stated intentions. While Figure 3-37 shows the stay rate data annually for fixed cohorts (1995 and 2001 graduating cohorts), Table 3-27 presents data on 5-year stay rates in 2011. The 5-year stay rate data in 2011 reflect the stay rate of the cohort who received their doctorates 5 years earlier in 2006. Among doctorate recipients with temporary visas at graduation, those from China and India had stay rates that were significantly higher than average, and those from South Korea and other Asian countries and economies such as Taiwan, Japan, and Thailand had stay rates that were significantly lower than average (Table 3-27). In the Middle East, those from Iran had above-average stay rates, whereas those from Egypt and Turkey had below-average stay rates.

Table 3-27	Five-year stay rates for U.S. S&E doctorate recipients with temporary visas at graduation, by selected country/economy: 2011

(Percent)

Country/economy	5-year stay rate
All countries	66
China	85
Taiwan	38
Japan	38
South Korea	42
India	82
Thailand	19
Iran	92
Turkey	56
Egypt	48
Greece	47
Germany	53
Italy	57
France	62
Romania	83
Russia	73
Canada	55
Mexico	39
Brazil	37

SOURCE: Note: Data reflect the stay rate for the 2006 graduating cohort.

Finn, M. 2014. Stay Rates of Foreign Doctoral Recipients from U.S. Universities: 2011. Oak Ridge, TN: Oak Ridge Institute for Science and Education.

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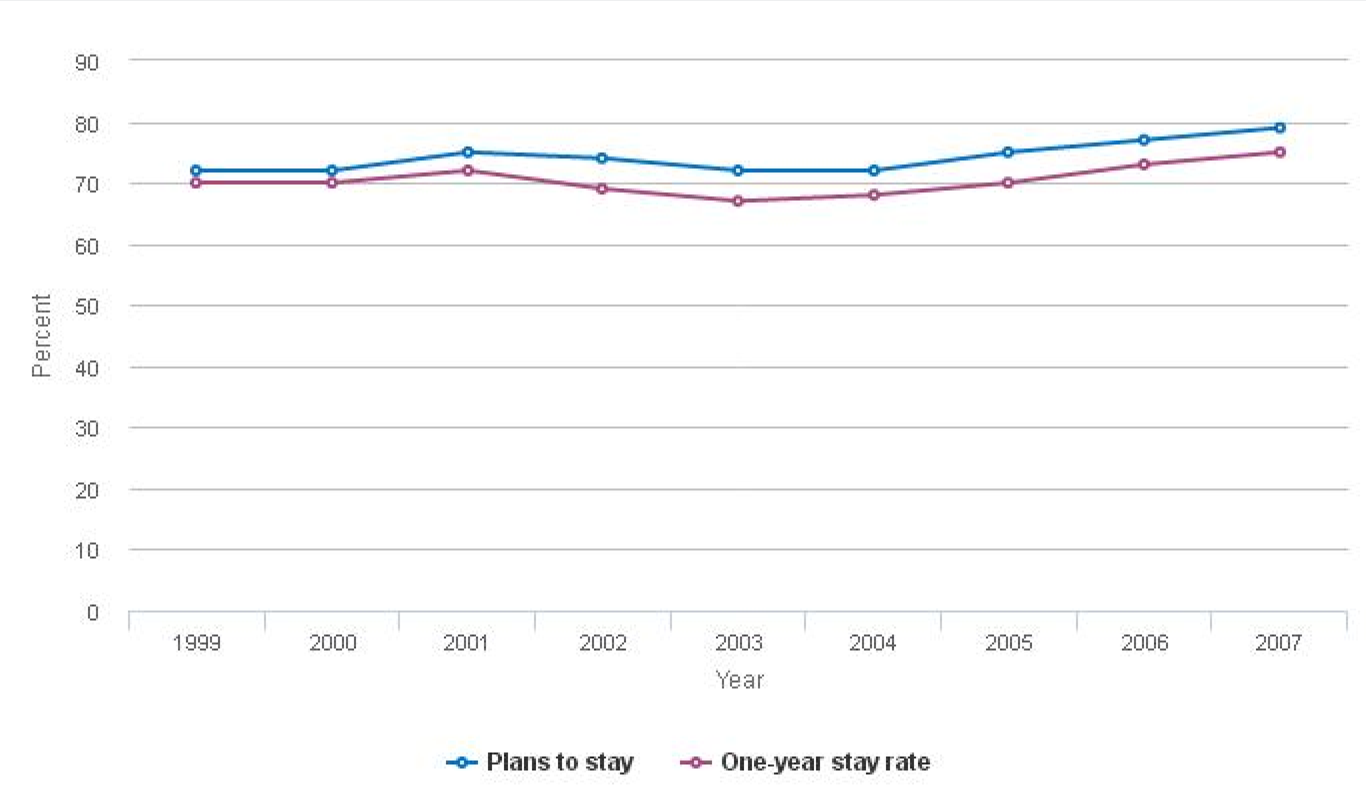
In recent years, the average 5-year stay rates have fluctuated within a fairly narrow range (between 64% and 67% from 2003 to 2011), neither increasing nor decreasing consistently (Finn 2014). From 2003 to 2011, stay rates among doctorate recipients with temporary visas from China and India, the two largest source countries, have gradually declined: from 93% to 85% for China and from 90% to 82% for India. Stay rates of those from South Korea, another large source country, have risen from 36% in 2003 to 42% in 2011.

Data from some older cohorts indicate that, among temporary visa holders receiving U.S. S&E doctorates, stated intentions to stay in the United States are reasonable indicators of actual behavior (Finn 2014). The data on stated intentions and long-term stay rates are estimated using very different data sources and methods. However, there has been a general congruence between the two. Figure 3-38 presents data on stated intentions and 1-year stay rates estimated with tax data for graduating classes of 1998 through 2006 (the data in Figure 3-38 for a given year reflect the intentions and stay rate of the graduating class from the previous year). For each graduating cohort, the proportion reporting plans to stay is slightly higher than the 1-year stay rate, which is not surprising given that some who stay do so for a period of less than 1 year, and some may change their plans. Overall, the data in Figure 3-38 suggest that the intentions data used to estimate short-term stay rates reasonably track actual stay rates, and the two series show remarkably similar patterns over time.

Figure 3-38

S&E doctorate recipients with temporary visas at graduation reporting plans to stay versus actual 1-year stay rate: 1999–2007



NOTE: Data for each year reflect the stated intentions and the stay rate for the cohort that received their doctoral degree in the previous year.

SOURCE: Finn, M. 2014. Stay Rates of Foreign Doctoral Recipients from U.S. Universities: 2011. Oak Ridge, TN: Oak Ridge Institute for Science and Education.

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Global S&E Labor Force

The rising emphasis on developing S&E expertise and technical capabilities has been a global phenomenon. S&E work is not limited to developed economies; it occurs throughout the world. However, much of the work is concentrated in developed nations, where a significant portion of R&D also takes place. The availability of a suitable labor force is an important determinant of where businesses choose to locate S&E work (Davis and Hart 2010). Concentrations of existing S&E work, in turn, spawn new employment opportunities for workers with relevant S&E knowledge and skills. As a result, governments in many countries have made increased investments in S&E-related postsecondary education a high priority. At the same time, high-skill workers, including those educated or employed in S&E fields, are increasingly mobile. In recent years, many nations, recognizing the value of high-skill workers for the economy as a whole, have changed their laws to make it easier for such workers to immigrate. These changes indicate an accelerating competition for globally mobile talent (Shachar 2006).

Data on the global S&E workforce are very limited, which makes it difficult to analyze the precise size and characteristics of this specialized workforce. Internationally comparable data are limited to establishment surveys that provide basic information about workers in S&E occupations or on workers with training in S&E disciplines. In contrast, SESTAT includes far more data on members of the U.S. S&E labor force than is available in other national statistical systems. In addition, although surveys that collect workforce data are conducted in many OECD member countries, they do not cover several countries—including Brazil and India—that have high and rising levels of science and technology capability, and they do not provide fully comparable data for China.

This section provides information about the size and growth of workforce segments whose jobs involve R&D in nations for which relevant data exist.

Size and Growth of the Global S&E Labor Force

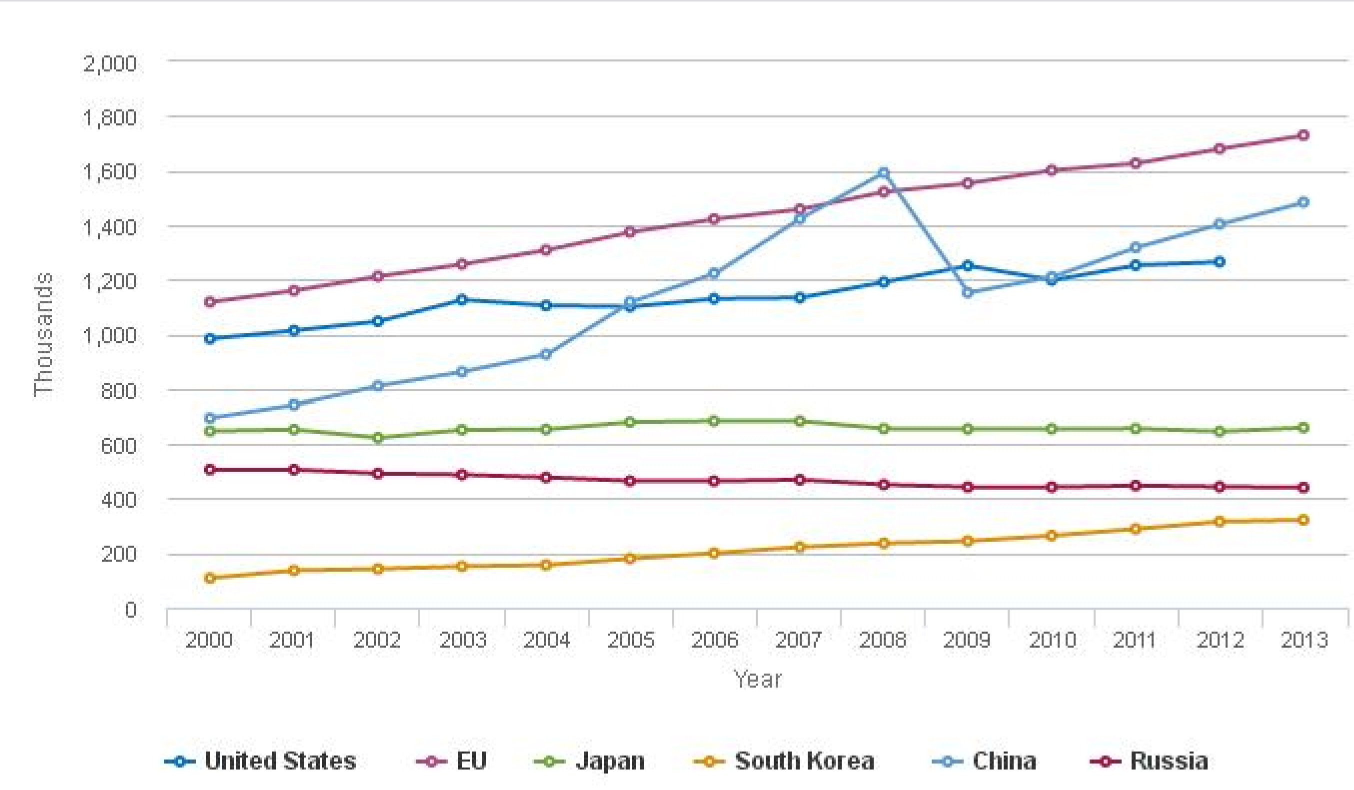
OECD data covering substantial, internationally comparable segments of the S&E workforce provide strong evidence of its widespread, though uneven, growth in the world's developed nations. OECD countries, which include most of the world's highly developed nations, compile data on researchers from establishment surveys in member and selected non-member countries. These surveys generally use a standardized occupational classification that defines researchers as "professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of the projects concerned" (OECD 2002:93). Because this definition can be applied differently when different nations conduct surveys, international comparisons should be made with caution. OECD also reports data on a broader measure of all personnel employed directly in R&D. In addition to researchers, the data on total R&D personnel include those who provide direct services to R&D such as clerical and administrative staff employed in R&D organizations.

OECD reports an estimated increase in the number of researchers in its member countries from 3.1 million in 2000 to 4.4 million in 2012. OECD also publishes estimates for seven nonmember economies, including China and Russia; adding these to the OECD member total for 2012 yields a worldwide estimate of 6.5 million researchers. However, numerous uncertainties affect this estimate, including, but not limited to, lack of coverage of countries with significant R&D enterprise as well as methodological inconsistencies over time and across countries. For example, some nonmember countries that engage in large and growing amounts of research (e.g., India, Brazil) are omitted entirely from these totals. In addition, for some countries and regions, including the United States and the European Union (EU; see "Glossary" for member countries), OECD estimates are derived from multiple national data sources and not from a uniform or standardized data collection procedure. For example, China's data from 2009 onwards are collected in accordance with OECD definitions and standards, whereas the data before 2009 are not consistent with OECD standards. South Korea's data before 2007 excludes social sciences and humanities researchers and are therefore not consistent with the data from 2007 onwards.

Despite these limitations for making worldwide estimates of the number of researchers, the OECD data provide a reasonable starting point for estimating the rate of worldwide growth. For most economies with large numbers of researchers, growth since 2000 has been substantial (Figure 3-39). China, whose pre-2009 data did not entirely correspond to the OECD definition, reported more than twice the number of researchers in 2008 compared with 2000, and likewise reported substantial growth in later years. South Korea nearly doubled its number of researchers between 2000 and 2006 and continued to grow strongly between 2007 and 2012. The United States and the EU experienced steady growth but at a lower rate; the number of researchers grew 29% in the United States between 2000 and 2012 and 55% in the EU between 2000 and 2013. Exceptions to the overall worldwide trend included Japan (which experienced little change) and Russia (which experienced a decline; see also Gokhberg and Nekipelova 2002). Trends in full-time equivalent R&D personnel were generally parallel to those for researchers in those cases for which both kinds of data are available (Appendix Table 3-22).

Figure 3-39

Estimated number of researchers in selected regions/countries: 2000–13



NA = not available.

EU = European Union.

NOTES: Data are not available for all regions/countries for all years. Researchers are full-time equivalents. Counts for China before 2009 are not consistent with Organisation for Economic Co-operation and Development (OECD) standards. Counts for South Korea before 2007 exclude social sciences and humanities researchers.

SOURCE: OECD, *Main Science and Technology Indicators* (2015/1), http://www.oecd.org/sti/msti.htm.

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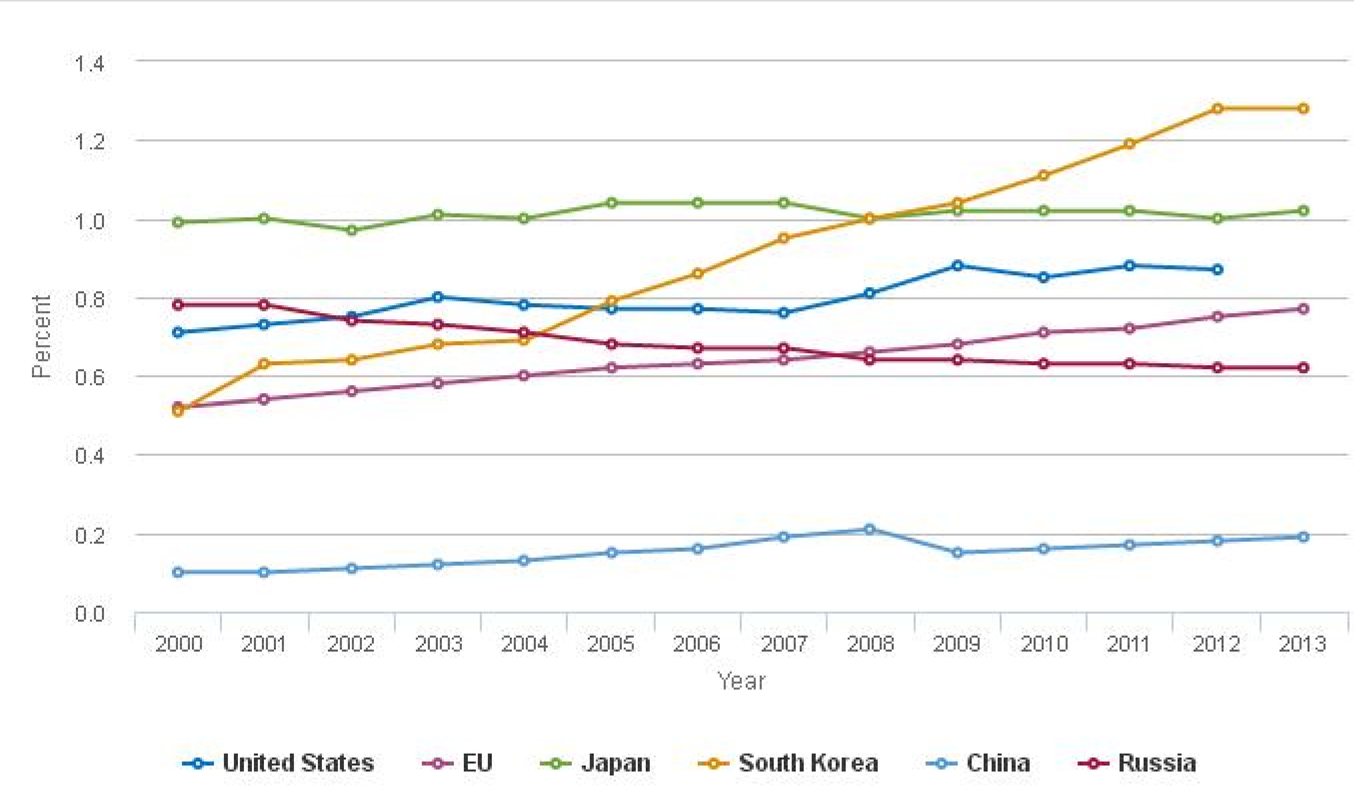
OECD also estimates the proportion of researchers in the workforce. In OECD's most recent estimates, small economies in Scandinavia (Denmark, Finland, Norway, Sweden) reported that between 1% and 2% of their employed workforce are researchers; small economies in East Asia (Singapore, Taiwan) reported that about 1% of their workforce are researchers (Appendix Table 3-23). Among economies with more than 200,000 researchers, OECD's latest estimates are that researchers make up the highest proportions of the workforce in South Korea (1.3%), Japan (1.0%), the United States (0.9%), and the United Kingdom (0.9%). Although China reported a large number of researchers, these workers represent a much smaller percentage of China's workforce (0.2%) than in OECD member countries. Additionally, China and South Korea have shown marked and continuous increases in the percentage of their workforce employed as researchers (Figure 3-40). Since 2000, this percentage remained mostly steady in Japan, rose slightly in the United States, and rose steadily in the EU.

Figure 3-40

Researchers as a share of total employment in selected regions/countries: 2000–13



NA = not available.

EU = European Union.

NOTES: Data are not available for all regions/countries for all years. Researchers are full-time equivalents. Counts for China before 2009 are not consistent with Organisation for Economic Co-operation and Development (OECD) standards. Counts for South Korea before 2007 exclude social sciences and humanities researchers.

SOURCE: OECD, *Main Science and Technology Indicators* (2015/1), http://www.oecd.org/sti/msti.htm.

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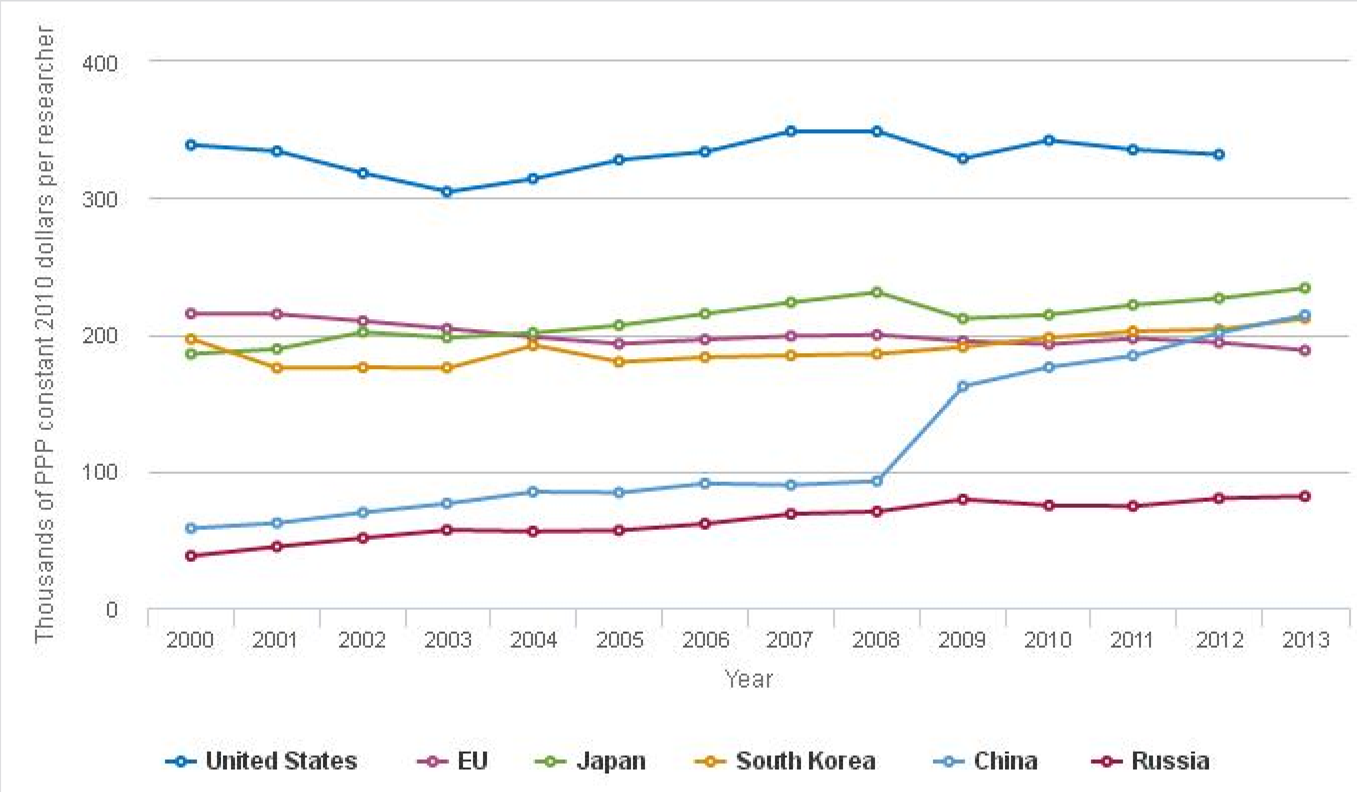
The proportion of female researchers varies considerably across OECD economies. According to the most recent estimates for the selected OECD countries for which data by sex are available, Japan (15% women) and South Korea (18% women) have a significant imbalance among researchers. By comparison, several European countries such as Belgium, Italy, Finland, Sweden, Spain, Norway, United Kingdom, Russia, and Poland, and several other countries such as Turkey and Singapore are more balanced with women representing between 30% and 40% of researchers. In France and Germany, about one-quarter of researchers are women.

OECD also provides data on gross domestic expenditures on R&D (GERD), which cover all R&D performed within the region/country/economy in a given year. The data on GERD may be combined with the data on researchers to get an estimate of R&D spending per researcher, which is another useful indicator of national resources devoted to advancing science and engineering. According to the most recent estimates, the United States, Germany, and Austria have the highest R&D expenditures per researcher (Appendix Table 3-23). Japan, South Korea, and China spend relatively similar amounts per researcher, although the number of researchers as a proportion of total employment is significantly lower in China than in Japan and South Korea. Other countries with large numbers of researchers, such as Canada, the United Kingdom, Spain, and Russia spend much less. Additionally, since 2000, GERD per researcher (in constant prices and purchasing power parity) has fluctuated within a relatively narrow range in the United States, the EU, and South Korea (Figure 3-41). China, whose pre-2009 data did not entirely correspond to the OECD definition, reported nearly 60% more GERD per researcher in 2008 compared with 2000, and this number continued to grow between 2009 and 2013.

Figure 3-41

Gross domestic R&D expenditures (GERD) per researcher in selected regions/countries: 2000–13



NA = not available.

EU = European Union; PPP = purchasing power parity.

NOTES: Data are not available for all regions/countries for all years. Researchers are full-time equivalents. The data for China before 2009 are not consistent with Organisation for Economic Co-operation and Development (OECD) standards. The data for South Korea before 2007 exclude social sciences and humanities R&D.

SOURCE: OECD, *Main Science and Technology Indicators* (2015/1), http://www.oecd.org/sti/msti.htm.

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Conclusion

The S&E workforce may be defined in a variety of ways. At its core are individuals in S&E occupations, but those with S&E degrees who are employed in a variety of other jobs make important contributions to the nation's welfare. Many more individuals hold S&E degrees than work in S&E occupations. Indicative of a knowledge-based economy, many of those in non-S&E occupations report that their work nonetheless requires at least a bachelor's degree level of S&E knowledge and skills. This suggests that the application of S&E knowledge and technical expertise is widespread across the U.S. economy and not limited to S&E occupations.

In both the United States and the rest of the world, the S&E workforce has experienced strong growth. During the 2007–09 recession, U.S. S&E employment remained more resilient than overall employment. Policymakers with otherwise divergent perspectives agree that jobs involving S&E are good for workers and good for the economy as a whole. These jobs pay more, even when compared to non-S&E jobs requiring similar levels of education and comparably specialized skills. Although S&E workers are not totally shielded from joblessness, workers with S&E training or in S&E occupations are less often exposed to periods of unemployment.

Innovation based on S&E R&D is globally recognized as an important vehicle for a nation's economic growth and competitive advantage, and growing numbers of workers worldwide are engaged in research. Growth has been especially marked in rapidly developing economies, such as China and South Korea, that have either recently joined the ranks of the world's developed economies or are poised to do so. Mature developed economies in North America and Europe have maintained slower growth, but the number of researchers in the struggling Japanese economy has somewhat stagnated.

The demographic composition of the S&E workforce in the United States is changing. The baby boom portion of the S&E workforce continues to age into retirement. However, increasing proportions of scientists and engineers are postponing retirement to somewhat later ages. At the same time, members of historically underrepresented groups—women and, to a lesser degree, blacks and Hispanics—have played an increasing role in the S&E labor force; although this has been more the case in some fields (e.g., life sciences and social sciences) than in others (e.g., computer and mathematical sciences, physical sciences, and engineering). Despite the recent increases in S&E participation by women and by racial and ethnic minorities, both groups remain underrepresented in S&E compared to their overall labor force participation. For example, women account for less than one-third of all workers employed in S&E occupations in the United States despite representing half of the college-educated workforce.

The United States has remained an attractive destination for foreign students and workers with advanced S&E training. In the wake of the 2001 recession, there were increases in both temporary work visas and stay rates of foreign recipients of S&E doctorates. Although declines occurred during the 2007–09 economic downturn—a period marked by rising unemployment in the United States among workers in S&E as well as in other occupations—data since the downturn suggest that the decline may have been temporary.

In today's dynamic marketplace, where information flows rapidly and technology is always evolving, labor market conditions change fast. Numerous factors—such as global competition, demographic trends, aggregate economic activities, and S&E training pathways and career opportunities—will affect the availability of workers equipped with S&E expertise as well as the kinds of jobs that the U.S. economy generates in the future. As a result, comprehensive and timely analysis of current labor force and demographic trends will play a critical role in providing the information needed to understand the dynamic S&E landscape both in the United States and globally.

Glossary

European Union (EU): As of September 2015, the EU comprised 28 member nations: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom. Unless otherwise noted, Organisation for Economic Co-operation and Development data on the EU include all of these 28 members.

Involuntarily out of field (IOF) employment: Employment in a job not related to the field of one's highest degree because a job in that field was not available. The IOF rate is the proportion of all employed individuals who report IOF employment.

Labor force: A subset of the population that includes both those who are employed and those who are not working but seeking work (unemployed); other individuals are not considered to be in the labor force.

Organisation for Economic Co-operation and Development (OECD): An international organization of 34 countries headquartered in Paris, France. The member countries are Australia, Austria, Belgium, Canada, Chile, Czech Republic, Estonia, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, South Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States. Among its many activities, the OECD compiles social, economic, and science and technology statistics for all member and selected nonmember countries.

Postdoc: A temporary position awarded in academia, industry, government, or a nonprofit organization, primarily for gaining additional education and training in research after completion of a doctorate.

Scientists and Engineers Statistical Data System (SESTAT): A system of surveys conducted by the National Science Foundation that measure the educational, occupational, and demographic characteristics of the S&E workforce. The surveys are the National Survey of College Graduates (NSCG) and the Survey of Doctorate Recipients (SDR).

Stay rate: The proportion of foreign recipients of U.S. S&E doctoral degrees who stay in the United States after receiving their doctorate.

Workforce: A subset of the labor force that includes only employed individuals.

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Chapter 4.

Research and Development: National Trends and International Comparisons

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Highlights

Recent Trends in U.S. R&D Performance

R&D performed in the United States totaled $427.8 billion (current dollars) in 2011, $435.3 billion in 2012, and $456.1 billion in 2013. In 2008, just ahead of the onset of the main economic effects of the national/international financial crisis and the Great Recession, U.S. R&D totaled $407.0 billion. The total of U.S. R&D performance returned to current dollar increases in 2011, 2012, and 2013.

- Inflation-adjusted growth in total U.S. R&D averaged only 0.8% annually over the 2008–13 period, behind the 1.2% annual average for U.S. gross domestic product (GDP). Even so, the single-year metrics for 2010–11 and 2012–13 were markedly more favorable than this 5-year average: 2.7% in real growth for total R&D in 2010–11 versus 1.6% for GDP; 3.2% for R&D in 2012–13 versus 2.2% for GDP.
- By comparison, the growth of U.S. R&D averaged 3.9% annually in 2003–08, ahead of GDP at 2.2%, and over 1993–2003, U.S. R&D growth averaged 3.9% compared with GDP at 3.4%. On this basis, the R&D growth figures in 2010–11 and 2012–13 were more like those before 2008, but the longstanding U.S. trend of substantial real growth annually in R&D, well ahead of the pace of GDP, still has not returned.

The business sector continued to account for most of U.S. R&D performance and U.S. R&D funding.

- The business sector performed $322.5 billion of R&D in 2013, or 71% of the U.S. total, drawing on business, federal, and other sources of R&D funding. The business sector itself provided $297.3 billion of funding for R&D in 2013, or 65% of the U.S. total, most of which supported R&D performed by business. The level of business R&D noticeably declined in 2009 and 2010, compared with the 2008 level but returned to an expansionary path in 2011, 2012, and 2013. Even with these declines, business R&D performance has continued to account for most of the nation’s R&D growth over the last 10 years.
- The academic sector was the second-largest performer of U.S. R&D, accounting for $64.7 billion in 2013, or about 14% of the national total.
- The federal government was the second-largest funder of U.S. R&D, accounting for an estimated $121.8 billion, or 27% of U.S. total R&D performance in 2013.

Most of U.S. basic research is conducted at universities and colleges and is funded by the federal government. However, the largest share of U.S. total R&D is development, which is mainly performed by the business sector. The business sector also performs the majority of applied research.

- In 2013, basic research was about 18% ($80.5 billion) of total U.S. R&D performance, applied research was about 20% ($90.6 billion), and development was about 63% ($285 billion).
- Universities and colleges historically have been the main performers of U.S. basic research, and they accounted for about 51% of all U.S. basic research in 2013. The federal government remained the largest funder of basic research, accounting for about 47% of all such funding in 2013.
- The business sector was the predominant performer of applied research, accounting for 56% of all U.S. applied research in 2013. Business also provided 51% of the funding for the applied research total, with most of this support remaining within the sector. The federal government accounted for 37% of the funding.
- Development was by far the largest component of U.S. R&D. The business sector performed 88% of it in 2013 and provided 81% of the funding. Federal funding accounted for only 18% of this, with the business

sector (especially defense-related industries) and federal intramural laboratories being the largest recipients.

Cross-National Comparisons of R&D Performance

Worldwide R&D performance totaled an estimated $1.671 trillion in 2013, up from $1.269 trillion in 2008 and $836 billion in 2003. Fifteen countries/economies expended $19 billion or more on R&D in 2013, accounting for 86% of the global total. The top rankings at present are dominated by the United States and China.

- The United States remained the largest R&D-performing country in 2013, with total expenditures of $456.1 billion, a 27% share of the global total, and an R&D/GDP ratio of 2.7%. China was a decisive second, with R&D expenditures of $336.5 billion, a 20% global share, and an R&D/GDP ratio of 2.0%.
- Japan ($160.2 billion, 10% global share, ratio of 3.5%) and Germany ($101.0 billion, 6% global share, ratio of 2.9%) were the comparatively distant third and fourth. The other 11 countries/economies in the top 15 were South Korea, France, Russia, the United Kingdom, India, Taiwan, Brazil, Italy, Canada, Australia, and Spain—with the annual national R&D expenditure totals ranging from about $69 billion (South Korea) down to $19 billion (Spain).
- Total global R&D doubled (current dollars) from 2003 to 2013. About 20% of this increase reflected the growth of U.S. R&D over this period, 16% from the European Union (EU) as a whole (including Germany, France, and the United Kingdom, as well as 5%–6% each from Japan and South Korea). Nonetheless, the largest contributor by far was China, accounting for nearly 34% of the decade increase. The pace of growth over the decade in China's overall R&D remained exceptionally high, at just under 20% annually (or around 17% adjusted for inflation).
- Regionally, the U.S. share of worldwide R&D was notably higher in 2003 (35%) but continued to decline over the subsequent 10 years (down to 27% in 2013). The EU also exhibited a decline over the same period: from 25% of the global total in 2003, down to 20% in 2013. The expansion was clearly within the economies of East/Southeast and South Asia—including China, Japan, South Korea, India, and Taiwan—which represented 27% of the global R&D total in 2003, rising to about 40% in 2013.

U.S. Business R&D

The business sector is by far the largest performer in the U.S. R&D system. R&D is performed across a wide range of manufacturing and nonmanufacturing sectors. R&D intensity is concentrated, however, in a few industries.

- The R&D performed domestically by U.S. businesses occurs mainly in five business sectors: chemicals manufacturing (particularly the pharmaceuticals industry); computer and electronic products manufacturing; transportation equipment manufacturing (particularly the automobiles and aerospace industries); information (particularly the software publishing industry); and professional, scientific, and technical services (particularly the computer systems design and scientific R&D services industries).
- In 2013, these five business sectors accounted for 82% of the $322.5 billion of total domestic business R&D performance that year. Similarly, in 2008, the five sectors accounted for 84% of the business total.
- Considering U.S. business as a whole, domestic R&D is mainly funded through performing companies' own funds: 82% in 2013 (and similar shares for recent years). For the remaining 18%, where the R&D is performed by companies but funded by others, the largest source of funding is the federal government, whose funding accounted for about 9% of the business R&D performance total in 2013. Other companies

located domestically provided about 4% of the funding; foreign companies also provided about 4% of the funding. Nonfederal governments and both domestic and foreign nonprofit organizations also were sources, but at very small levels. (Some notable departures from these aggregate average shares occur when specific sectors and industries are considered.)

- Large companies (those with 25,000 or more domestic employees) accounted for 37% of all U.S. business R&D performance in 2013. Small companies (those with fewer than 500 domestic employees) accounted for 16%. This distribution of business R&D performance share by size has not greatly changed in recent years.

Recent Trends in Federal Support for U.S. R&D

Federal funding for the R&D performed by federal departments and agencies, as well as most of the other major U.S. R&D performers, increased annually (in both current and constant dollar terms) from the late 1990s through FY 2010. In the several years since, however, the levels of this federal support have dropped noticeably.

- Federal obligations for the total of R&D and R&D plant were $129 billion in FY 2008, $145 billion in FY 2009, and $147 billion in FY 2010. But the years thereafter have been mostly marked by funding declines: FYs 2011 and 2012 were down $6–$7 billion from the FY 2010 peak and then declined further to $127 billion in FY 2013. In FY 2014, the total increased to $131 billion. Nonetheless, the drop from the FY 2010 level to that in FY 2014 is a current dollar decline of 11%—and when inflation is factored in, it is steeper still, at 17%.
- Fifteen federal departments and 12 other agencies engage in and/or fund R&D in the United States. Seven of these departments/agencies reported R&D obligations in FY 2013 in excess of $1 billion: the U.S. Department of Agriculture (USDA), the Department of Commerce (DOC), the Department of Defense (DOD), the Department of Energy (DOE), the Department of Health and Human Services (HHS), the National Science Foundation (NSF), and the National Aeronautics and Space Administration (NASA). These together accounted for 97% of all federal obligations for R&D that year.
- DOD has historically accounted for well over half of annual federal R&D funding. Health-related R&D accounts for the majority of federal nondefense R&D funding. DOD and HHS have borne the brunt of the federal R&D funding decline since FY 2010, with the other nondefense categories being notably less affected.

Federal Programs to Promote the Transfer and Commercialization of Federal R&D

The federal government has been active since the early 1980s in establishing policies and programs to improve the transfer and economic exploitation of the results of federally funded R&D.

- The data show continued active use by the federal departments/agencies accounting for the largest portion of federal R&D (including USDA, DOC, DOD, DOE, HHS, and NASA) of the technology transfer authorities provided by the Stevenson-Wydler Technology Innovation Act of 1980 and the subsequent amplifying legislation.
- Federal funding to small, entrepreneurial companies engaged in R&D with eventual commercialization objectives, through the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, is now considerably larger than when these programs were first initiated in the early 1980s and the mid-1990s, respectively. At its start in FY 1983, the SBIR program (across all

participating agencies) made 789 awards (all Phase I) for a total of $38 million in funding; in FY 2013, 4,452 awards (Phases I and II) were made, with funding totaling $1.772 billion. For STTR, the program started in FY 1995, with a single Phase I award for $100,000. In FY 2013, 640 STTR awards (Phases I and II) were made, with funding totaling $206 million.

- Furthermore, beyond these well-known programs and authorities with essentially federalwide application, particular departments/agencies have their own technology transfer and early-stage development programs more narrowly directed at their own mission objectives. Notable here are DOC's Hollings Manufacturing Extension Partnership, DOE's Advanced Research Projects Agency–Energy, and NSF's Industry/University Cooperative Research Centers Program.

Introduction

Chapter Overview

The discovery of new knowledge, technological advances that improve on what we can already do or expand the horizon of the possible, and their creative exploitation have become ever more essential for success in the competitive global economy. The strength of a country's overall R&D enterprise—from both the public and private realms of this system—serves as an important marker of current and future national economic advantage.

This chapter identifies the key recent developments in the current performance and funding of the U.S. R&D system. The discussion covers the sectors mainly responsible for present U.S. R&D performance and funding: the business sector, federal government, nonfederal government, universities and colleges, and other nonprofit organizations. At numerous points, the chapter directly contrasts these U.S. R&D indicators with broadly comparable data from the world's other major economies.

Chapter Organization

This chapter is organized into five principal sections on the following discussion topics: the recent trends (particularly over the last 5 to 10 years) in overall U.S. R&D performance, comparison of U.S. R&D performance to that of other leading countries, the U.S. business sector's large role in the nation's overall R&D activity, the federal government's roles in supporting and conducting U.S. R&D, and an examination of federal programs and policies promoting the transfer and commercialization of federal R&D.

Recent Trends in U.S. R&D Performance

The U.S. R&D system consists of the R&D activities of a number of differing performers and sources of funding. Included here are private businesses, the federal government, other government (nonfederal) organizations, universities and colleges, and nonprofit organizations. The organizations that perform R&D often receive significant levels of outside funding; furthermore, those that fund R&D may also be significant performers. This section discusses the current levels and notable recent trends in overall U.S. R&D performance and the sources funding these activities. (Definitions for key terms in this section appear in this chapter's glossary. The sidebar Measured and Unmeasured R&D discusses the main sources for the indicator data and analyses in this section of the chapter.)

Measured and Unmeasured R&D

The statistics on U.S. R&D discussed in this section reflect the National Science Foundation's (NSF's) periodic National Patterns of R&D Resources reports and data series, which provide a comprehensive account of total U.S. R&D performance. The National Patterns data, in turn, derive from six major NSF surveys of the organizations that perform the bulk of U.S. R&D:

- Business R&D and Innovation Survey
- Higher Education Research and Development Survey
- Survey of Federal Funds for Research and Development
- Survey of R&D Expenditures at Federally Funded R&D Centers
- Survey of State Government Research and Development
- Survey of Research and Development Funding and Performance by Nonprofit Organizations

The National Patterns analysis integrates R&D spending and funding data from these separate surveys into U.S. R&D performance totals, which are then reported on a calendar year basis and for the main performing sectors and funding sources.

Because of practical constraints in the surveys, some elements of R&D performance are omitted from the U.S. totals. In evaluating R&D performance trends over time and in international comparisons, it is important to be aware of these omissions.

The U.S. business R&D estimates are derived from a survey of R&D-performing companies with five or more employees. No estimates of R&D performance currently are available for companies with fewer than five employees. (NSF is in the process of designing and implementing the Survey of Microbusiness Innovation Science and Technology, which will collect data from companies with fewer than five employees.)

Until recently, the U.S. statistics for business R&D did not include social science R&D, and likewise, R&D in the humanities and other non-S&E fields (such as law) were excluded from the U.S. academic R&D statistics. Other countries include both of these R&D components in their national statistics, making their national R&D expenditures relatively larger when compared with those of the United States. Both of these shortfalls are now addressed in the U.S. statistics. NSF's Business R&D and Innovation Survey—which replaced the previous Survey of Industrial Research and Development, starting with the 2008 data year—includes social science R&D. Also, the Higher Education Research and Development Survey—which replaced the previous Survey of Research and Development Expenditures at Universities and Colleges, starting with the 2010 academic fiscal year—directly includes non-S&E R&D expenditures in the reported academic R&D totals. (The academic R&D totals reported by the National Patterns statistics have been revised back to 2003 to include the non-S&E R&D expenditures.)

The statistics for academic R&D track research expenditures that are separately accounted for in both sponsored research and institutionally funded research. U.S. universities do not report funds for research that are not separately accounted for, such as estimates of faculty time spent on research beyond formally tracked research projects. This can be a limitation in international R&D comparisons because such estimates are often included in the national statistics of other countries.

Likewise, the activity of individuals performing R&D on their own time and not under the auspices of a corporation, university, or other organization is omitted from official U.S. R&D statistics.

Statistics on R&D performed by state governments are collected in a biennial NSF/U.S. Census Bureau survey. Although these data represent small amounts (typically totaling only several hundred million dollars annually), they are now included in the National Patterns totals. Finally, NSF has not fielded a full survey on R&D performance by nonprofit organizations since 1998—the National Patterns performance figures for this sector in the national R&D totals are estimated.

U.S. Total R&D and R&D Intensity

R&D performed in the United States totaled $456.1 billion (current dollars) in 2013 (Table 4-1), compared with $435.3 billion in 2012 and $427.8 billion in 2011. In 2008, just ahead of the onset of the main economic effects of the national/international financial crisis and the Great Recession, U.S. R&D totaled $407.0 billion.

Table 4-1 U.S. R&D expenditures, by performing sector and source of funds: 2008–13

Sector	2008	2009	2010	2011	2012	2013[a]
	Current $millions					
All performing sectors	406,952	405,136	408,197	427,833	435,347	456,095
Business	290,680	282,393	278,977	294,092	302,251	322,528
Federal government	45,649	47,363	49,955	52,668	51,318	49,859
Federal intramural[b]	29,839	30,560	31,970	34,950	34,017	33,026
FFRDCs	15,810	16,804	17,985	17,718	17,301	16,833
Nonfederal government	343	405	490	493	468	467
Universities and colleges	53,917	56,972	60,374	62,446	63,284	64,680
Other nonprofit organizations[c]	16,363	18,002	18,401	18,134	18,026	18,561
All funding sources	406,952	405,136	408,197	427,833	435,347	456,095
Business	258,131	246,770	248,314	266,606	275,892	297,279
Federal government	119,113	127,180	127,559	128,039	124,956	121,808

Sector	2008	2009	2010	2011	2012	2013[a]
Nonfederal government	4,257	4,287	4,287	4,355	4,105	4,113
Universities and colleges	11,640	11,917	12,105	12,951	14,136	15,240
Other nonprofit organizations[c]	13,811	14,983	15,932	15,882	16,258	17,655
	Constant 2009 $millions					
All performing sectors	410,043	405,136	403,270	414,122	413,961	427,323
Business	292,888	282,393	275,610	284,667	287,403	302,182
Federal government	45,995	47,363	49,352	50,981	48,797	46,714
Federal intramural[b]	30,066	30,560	31,584	33,830	32,346	30,943
FFRDCs	15,930	16,804	17,768	17,150	16,451	15,771
Nonfederal government	345	405	484	477	445	438
Universities and colleges	54,327	56,972	59,645	60,445	60,176	60,600
Other nonprofit organizations[c]	16,487	18,002	18,179	17,552	17,141	17,390
All funding sources	410,043	405,136	403,270	414,122	413,961	427,323
Business	260,092	246,770	245,317	258,062	262,339	278,525
Federal government	120,017	127,180	126,019	123,936	118,817	114,124
Nonfederal government	4,289	4,287	4,235	4,216	3,904	3,853
Universities and colleges	11,728	11,917	11,959	12,536	13,442	14,278
Other nonprofit organizations[c]	13,916	14,983	15,739	15,373	15,459	16,542

FFRDC = federally funded R&D center.

[a] Data for 2013 include some estimates and may later be revised.

[b] Includes expenditures of federal intramural R&D and costs associated with administering extramural R&D.

[c] Some components of the R&D performed by other nonprofit organizations are projected and may later be revised.

NOTES: Data are based on annual reports by performers, except for the nonprofit sector. Expenditure levels for academic, federal government, and nonfederal government performers are calendar-year approximations based on fiscal year data.

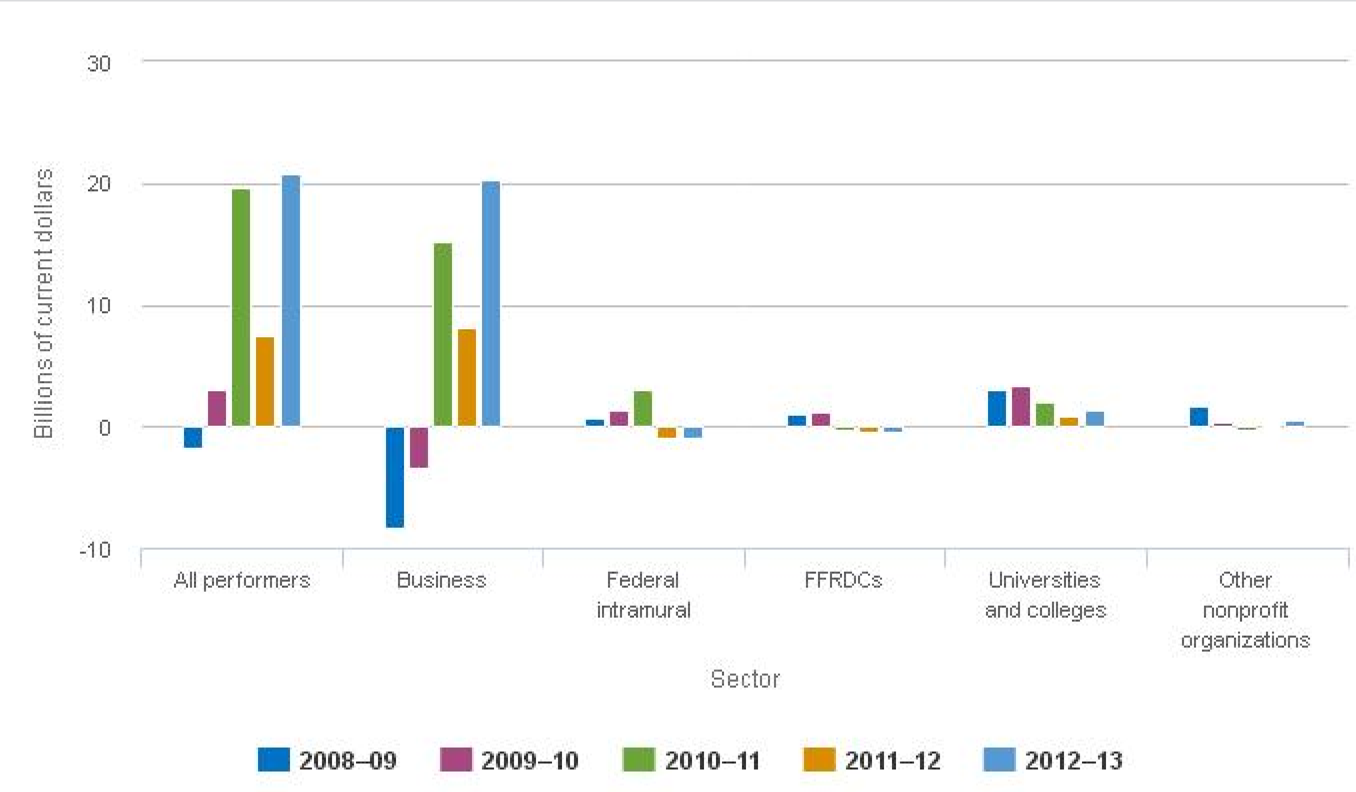
SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series).

Science and Engineering Indicators 2016

In 2013, U.S. total R&D increased by $20.7 billion over the year-end 2012 level (Figure 4-1). This was in addition to increases of $7.5 billion in 2012 and $19.6 billion in 2011—in contrast to the several billion dollar decline in 2009 and little gain in 2010. As the figure indicates, much of the increase in the U.S. total in these most recent years owes to the return of sizable yearly increases in business R&D performance.

Figure 4-1

Year-to-year changes in U.S. R&D expenditures, by performing sector: 2008–13



FFRDC = federally funded R&D center.

NOTES: Data are calculated from R&D expenditure data reported for performers in table 4-1. Expenditures by nonfederal government performers are negligible, and specific bars for this sector are excluded.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series).

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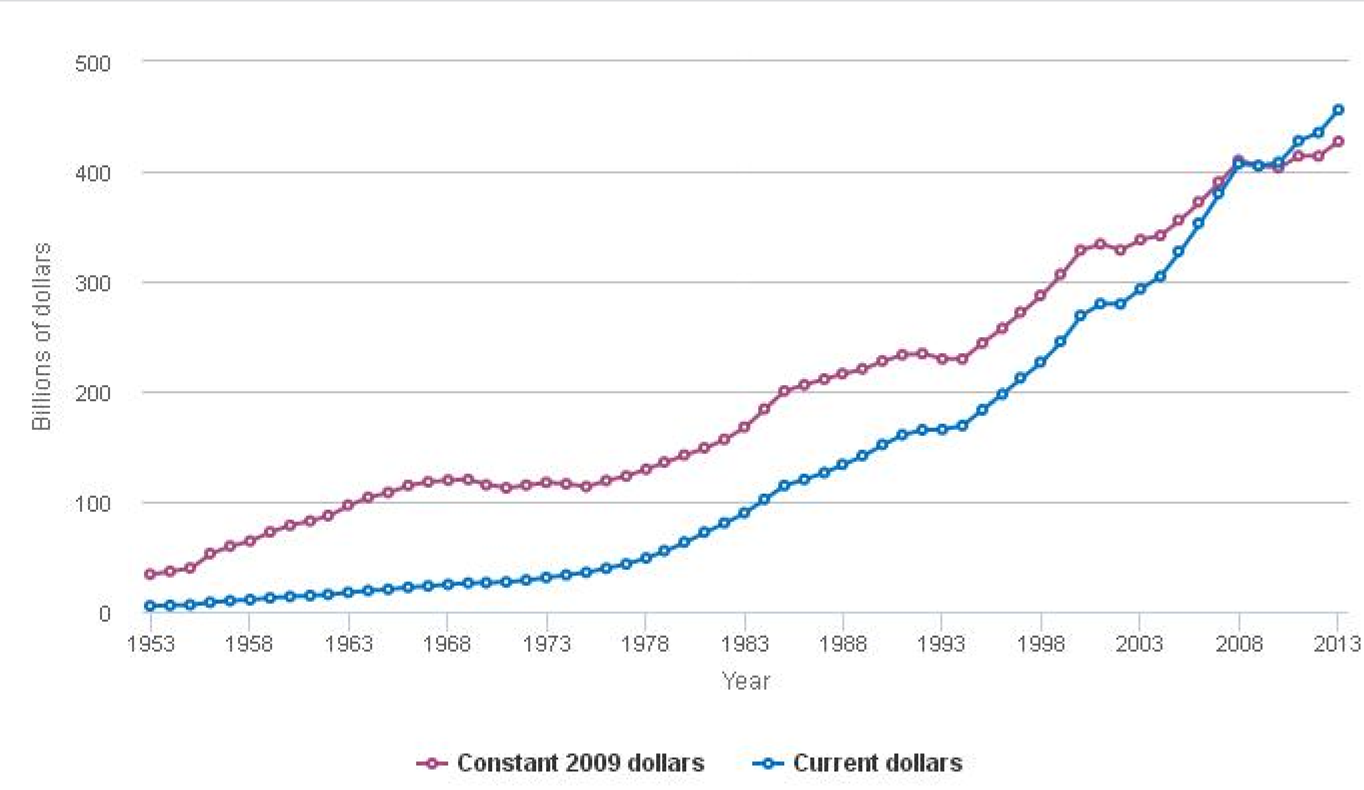
National Science Foundation (NSF) statistics on U.S. R&D performance go back to 1953 (see Appendix Table 4-1, Appendix Table 4-2, Appendix Table 4-3, Appendix Table 4-4, Appendix Table 4-5, Appendix Table 4-6, Appendix Table 4-7, Appendix Table 4-8, and Appendix Table 4-9). From then to 2013, the total of U.S. R&D performance has exhibited sizable growth, whether judged in current or inflation-adjusted dollar terms (Figure 4-2; Appendix Table 4-1).[i] Annual growth in the U.S. R&D total over this 60-year period averaged 7.8% in current dollars, or 4.3% when adjusted for inflation. (As a comparative yardstick, a 7% average annual rate of growth yields a doubling of the quantity in 10 years.) Additionally, the expansion rate for R&D substantially outpaced that for U.S. gross domestic product (GDP) over the same period, which was 6.5% annually in current dollars or 3.1% adjusted for inflation.

[i] In this chapter, dollars adjusted for inflation (i.e., constant dollars) are based on the GDP implicit price deflator (currently in 2009 dollars) as published by the Department of Commerce's Bureau of Economic Analysis (http://www.bea.gov/iTable/index_nipa.cfm). A 1953–2013 time series for this deflator appears in Appendix Table 4-1. Note that GDP deflators are calculated on an economy-wide scale and do not explicitly focus on R&D.

Figure 4-2

U.S. total R&D expenditures: 1953–2013



NOTE: Data for 2013 include some estimates and may later be revised.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series).

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Average annual growth of U.S. R&D over the more recent period of 2008–13 has been less favorable than these long-run rates and their relationships. The expansion of U.S. total R&D over this 5-year period has averaged only 2.3% (or 0.8%, when adjusted for inflation) and was behind the pace of GDP expansion (which averaged 2.6% annually in current dollars, or 1.2% when adjusted for inflation) (Table 4-2).

Table 4-2 Annual rates of growth in U.S. R&D expenditures, total and by performing sectors: 1993–2013

(Percent)

	Longer-term trends			Most recent 5 years				
Expenditures and gross domestic product	1993–2003	2003–08	2008–13	2008–09	2009–10	2010–11	2011–12	2012–13
	Current $							
Total R&D, all performers	5.9	6.8	2.3	-0.4	0.8	4.8	1.8	4.8
Business	5.7	7.7	2.1	-2.9	-1.2	5.4	2.8	6.7

	Longer-term trends			Most recent 5 years				
Expenditures and gross domestic product	1993–2003	2003–08	2008–13	2008–09	2009–10	2010–11	2011–12	2012–13
Federal government	4.3	4.2	1.8	3.8	5.5	5.4	-2.6	-2.8
Federal intramural[a]	4.2	3.6	2.1	2.4	4.6	9.3	-2.7	-2.9
FFRDCs	4.4	5.2	1.3	6.3	7.0	-1.5	-2.4	-2.7
Nonfederal government	NA	NA	6.4	NA	20.9	0.6	-5.1	-0.1
Universities and colleges	7.4	5.1	3.7	5.7	6.0	3.4	1.3	2.2
Other nonprofit organizations [b]	9.6	4.5	2.6	10.0	2.2	-1.5	-0.6	3.0
Gross domestic product	5.3	5.0	2.6	-2.0	3.8	3.7	4.2	3.7
				Constant 2009$				
Total R&D, all performers	3.9	3.9	0.8	-1.2	-0.5	2.7	0.0	3.2
Business	3.8	4.8	0.6	-3.6	-2.4	3.3	1.0	5.1
Federal government	2.4	1.4	0.3	3.0	4.2	3.3	-4.3	-4.3
Federal intramural[a]	2.3	0.9	0.6	1.6	3.4	7.1	-4.4	-4.3
FFRDCs	2.5	2.4	-0.2	5.5	5.7	-3.5	-4.1	-4.1
Nonfederal government	NA	NA	4.9	NA	19.4	-1.4	-6.8	-1.6
Universities and colleges	5.5	2.3	2.2	4.9	4.7	1.3	-0.4	0.7
Other nonprofit organizations [b]	7.6	1.7	1.1	9.2	1.0	-3.4	-2.3	1.5
Gross domestic product	3.4	2.2	1.2	-2.8	2.5	1.6	2.3	2.2

NA = not available.

FFRDC = federally funded R&D center.

[a] Includes expenditures of federal intramural R&D and costs associated with administering extramural R&D.

[b] Some components of the R&D performed by other nonprofit organizations are projected and may later be revised.

NOTES: Longer-term trend rates are calculated as compound annual growth rates. Data for 2013 include some estimates and may later be revised. As a further aid to interpretation, the National Science Foundation's data series on U.S. R&D performance dates back to 1953. The average annual rate of growth of total R&D for the 1953–2013 period was 7.8%, compared with 6.5% for U.S. gross domestic product over the same period. Adjusted for inflation, these average annual rates were, respectively, 4.3% and 3.1%.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series).

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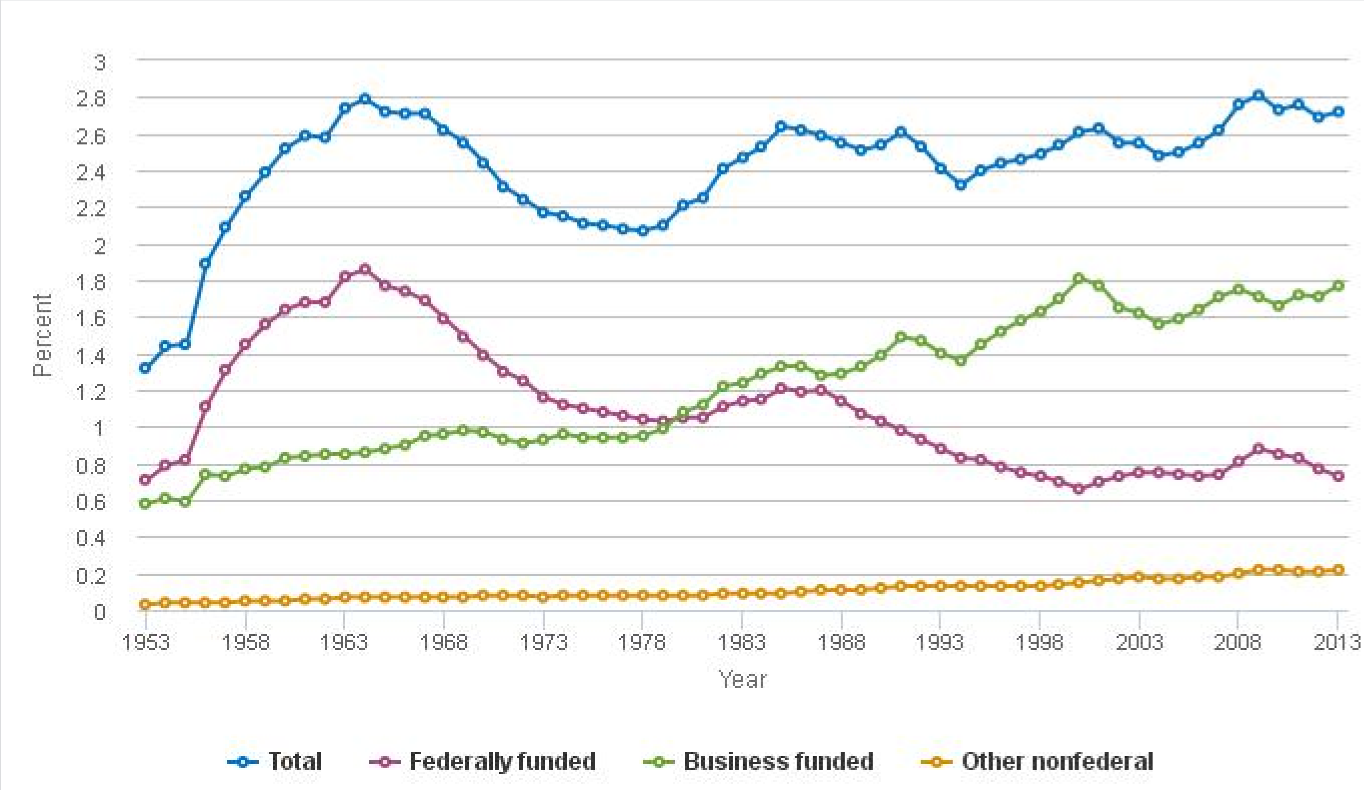
The 2008–10 period was a challenging time for U.S. R&D expansion—and the little change in U.S. R&D levels throughout this period weighed down the 5-year averages. With the business sector routinely accounting for two-thirds or more of the U.S. R&D total, the declines in its R&D performance in the 2008–10 period were clearly a significant factor in the stagnant pace of expansion in the national R&D totals over this period (Table 4-1; Figure 4-1).

By comparison, the pace of expansion in the second half of the 2008–13 period has been more favorable—but issues remain. The year-over-year increases in U.S. total R&D in 2010–11 ($20 billion) and 2012–13 ($21 billion) approximate the $15–$20 billion (or more) annual increases that prevailed from the mid-1990s to 2008 (Figure 4-1; Appendix Table 4-1). Further, the growth in total U.S. R&D well outpaced the growth of GDP in 2011 and 2013 (Table 4-2). Business R&D returned in these same 2 years to the comparatively high rates of expansion that have prevailed on average since the early 1990s (Table 4-2). Even so, the 2011–12 increase in the U.S. total was relatively weak—matching only the pace of inflation and well behind the expansion of GDP. Additionally, the data show absolute declines (both current and constant dollars) in federal government R&D performance (federal intramural and federally funded R&D centers [FFRDCs]) in 2012 and 2013. The data also suggest a slowing pace of growth of R&D performed by universities and colleges in 2012 and 2013—the result of the more challenging federal budget environment for R&D support. The data for 2014 and 2015—not yet available—will be of more than normal interest in gauging what new trends may be emerging.

A consequence of these shifting growth rates is that the R&D intensity of the national economy (the ratio of R&D expenditures to GDP), which reached a long-term peak in 2009, has been declining somewhat more recently (Figure 4-3; Appendix Table 4-1). (The ratio of total national R&D expenditures to GDP is often reported as a measure of the intensity of a nation's overall R&D effort and is widely used as an international benchmark for comparing countries' R&D systems.)

Figure 4-3

Ratio of U.S. R&D to gross domestic product, by roles of federal, business, and other nonfederal funding for R&D: 1953–2013



NOTES: Data for 2013 include some estimates and may later be revised. The federally funded data represent the federal government as a funder of R&D by all performers; the business-funded data have a similar function. The Other nonfederal category includes R&D funded by all other sources—mainly universities and colleges, nonfederal government, and other nonprofit organizations. The gross domestic product data used reflect the U.S. Bureau of Economic Analysis's comprehensive revisions of the national income and product accounts of July 2013.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series).

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(Note: The Department of Commerce's Bureau of Economic Analysis [BEA] introduced a comprehensive set of revisions to the U.S. national income and product accounts in July 2013—including explicitly recognizing R&D as investment in the measure of U.S. GDP. These changes resulted in modest revisions to the U.S. GDP time series back to 1929. The R&D/GDP ratio data NSF reports here reflect BEA's revised GDP data series, both in the present and the past, and differ somewhat from data reported in previous editions of *Science and Engineering Indicators*. For further information, see the sidebar R&D in the U.S. National Income and Product Accounts.)

U.S. expenditures on R&D totaled 2.76% of GDP in 2011, 2.69% in 2012, and 2.72% in 2013. These numbers are lower, but only somewhat, than the 2.81% that prevailed in 2009—which was the highest level of this ratio since the start of the time series in 1953. Over the 10-year period from 2003 to 2013, the ratio has fluctuated to some degree from year to year, between a low of 2.48% in 2004 and the high of 2.81% in 2009. The apparent trend since the later 1990s is a generally rising R&D/GDP ratio (Figure 4-3). Whether the somewhat lower levels arising since 2009 represent merely a short-term reversal or something more permanent remains to be seen.

Most of the rise of the R&D/GDP ratio over the past several decades has come from the increase of nonfederal spending on R&D, particularly that by the business sector (Figure 4-3). This reflects the growing role of business R&D in the national R&D system and, in turn, the growing prominence of R&D-derived goods and services in the national and global economies. By contrast, the ratio of federal R&D spending to GDP declined from the mid-1980s to the late 1990s, notably from cuts in defense-related R&D. The gradual uptick through 2009 was the result of increased federal spending on biomedical and national security R&D and the one-time incremental funding for R&D provided by the American Recovery and Reinvestment Act of 2009 (ARRA).

R&D in the U.S. National Income and Product Accounts

Comprehensive revisions of the U.S. GDP and related national income and product accounts (NIPA), released by BEA in July 2013, included a change to treat R&D as a fixed investment with long-term benefits. R&D investment is now recognized in the NIPA in a new asset category called "intellectual property products," or intangible assets, along with software and entertainment, literary, and artistic originals. Before this change, the NIPA considered R&D as an expense or as an intermediate input cost in the business sector and as consumption in the government and nonprofit sectors (BEA 2013). This update is one of several NIPA changes aimed at capturing the role of intangible assets in economic growth. NSF's regular surveys of U.S. R&D expenditures serve as the primary data source for the R&D component of these revisions. (For a further discussion, see NSF's recent InfoBrief on this topic: http://www.nsf.gov/statistics/2015/nsf15315/.)

As a part of these July 2013 revisions (and for all subsequent releases), BEA provided a revised time series for GDP and its components going back to 1929. After these comprehensive revisions, GDP levels are somewhat higher in this revised time series than previously reported. An implication is that the R&D/GDP ratios previously reported by NSF in *Indicators* and related publications on U.S. R&D are somewhat smaller because of this higher reported GDP. For example, the U.S. R&D/GDP ratio for 2000, previously reported as 2.70%, is now 2.61% under the revised NIPA, or what was 2.84% in 2011 under the previous methodology is revised to 2.76%. The U.S. R&D statistics reported throughout in this chapter now fully reflect BEA's revised GDP data series.

Performers of R&D

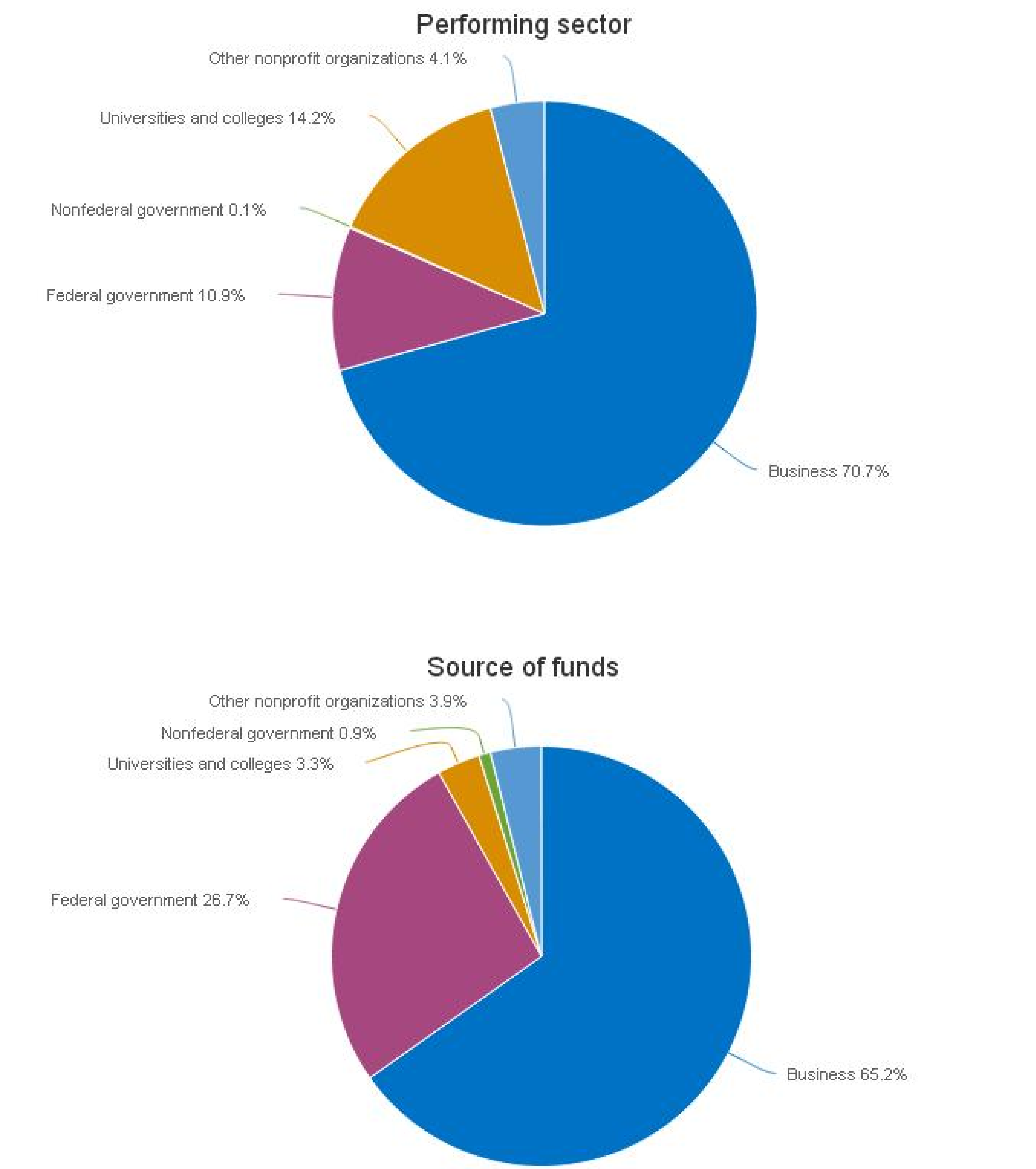
NSF tracks the R&D spending patterns of the major performers in the overall U.S. R&D system. Included here are businesses, the intramural R&D activities of federal agencies, FFRDCs, nonfederal government organizations (mainly state government), universities and colleges, and other nonprofit organizations.

Business Sector

In 2013, the business sector continued to be the largest performer of U.S. R&D, conducting $322.5 billion, or almost 71%, of the national total (Table 4-1; Figure 4-4). The 2013 level of business R&D performance was markedly above the 2012 level ($302.3 billion) and, along with the increases of 2011–12 and 2010–11, suggests this sector's return to annual R&D growth and reversal of the declines in 2009 and 2010. Over the 5-year period of 2008–13, business R&D performance grew an average of 2.1% annually, although somewhat behind the 2.3% rate of growth of overall U.S. R&D (Table 4-2).

Figure 4-4

Shares of U.S. total R&D expenditures, by performing sector and source of funds: 2013



NOTES: U.S. R&D expenditures totaled $456.1 billion in 2013. The federal government performing sector includes federal agencies and federally funded R&D centers.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series).

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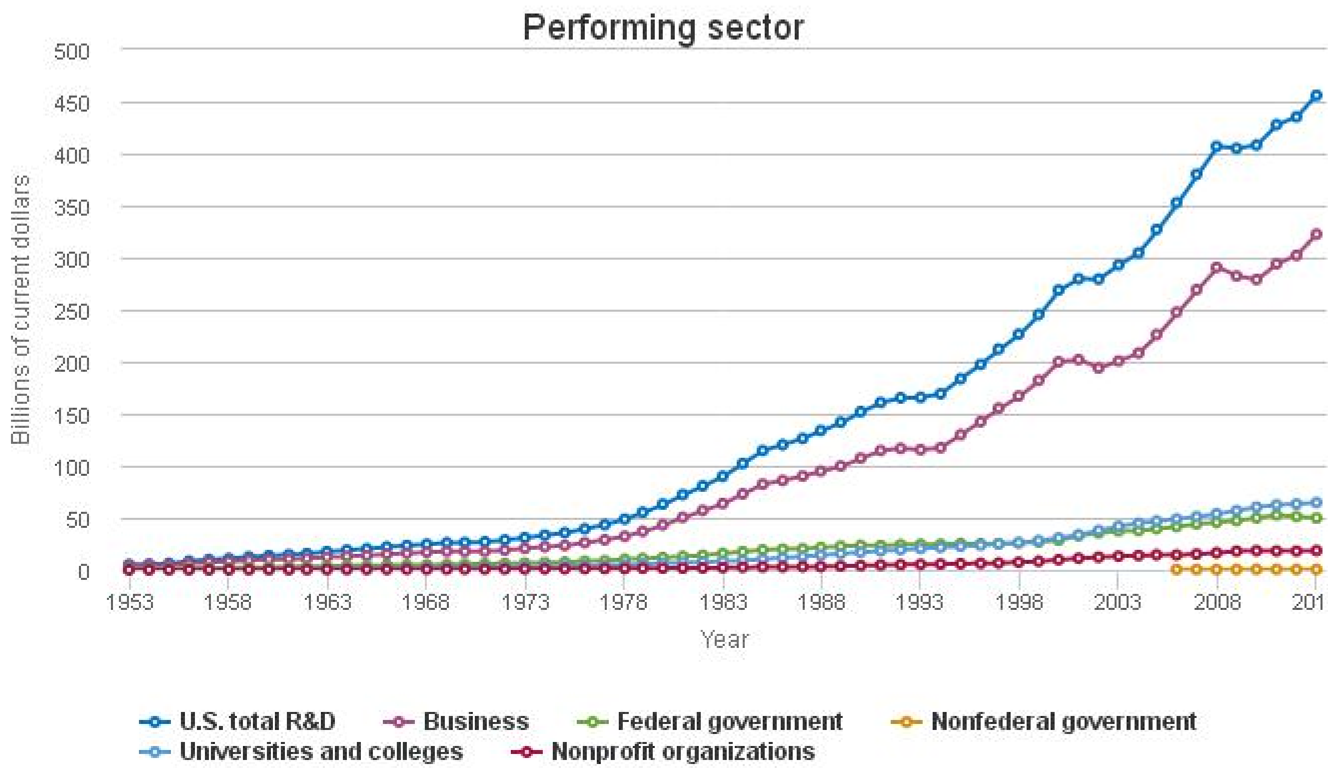
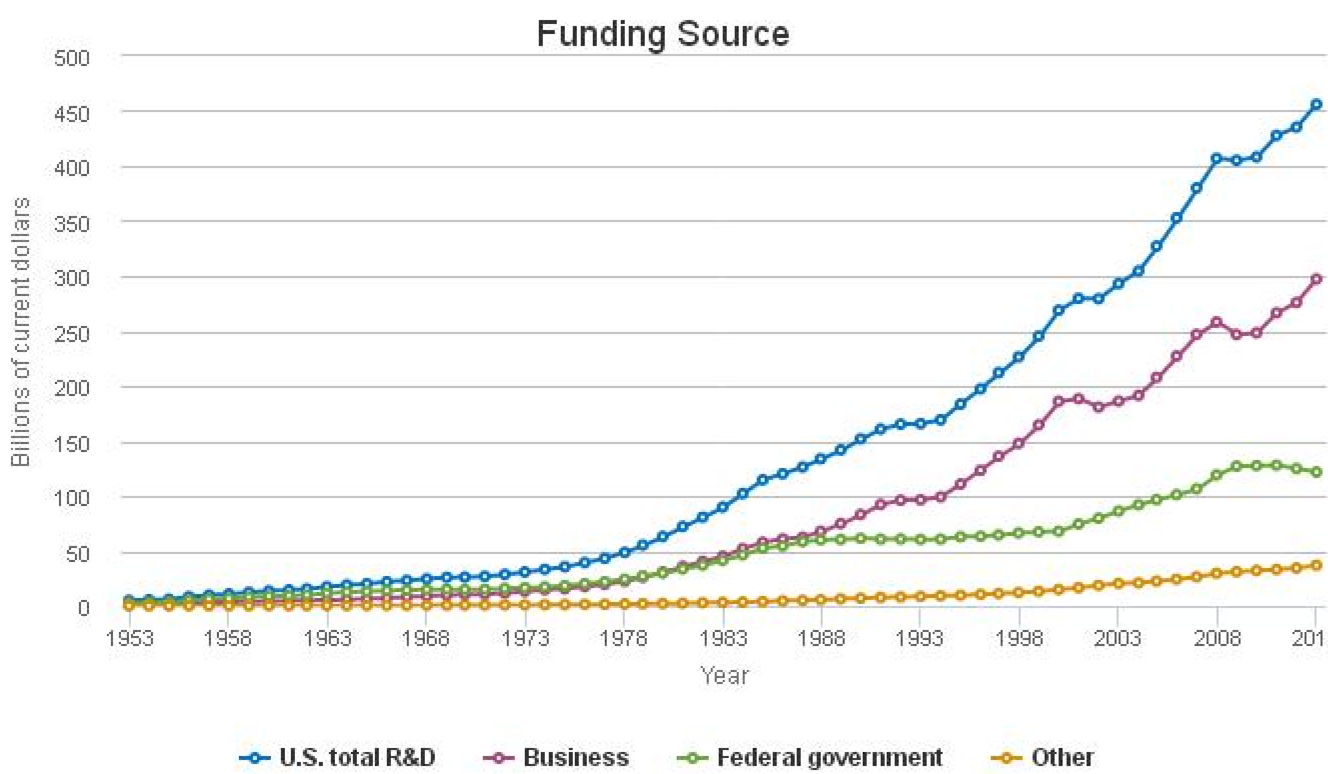
The business sector has long been prominent in the composition of national R&D, with its annual share ranging between 68% and 74% over the 20-year period of 1993–2013 (Figure 4-5 and Figure 4-6; Appendix Table 4-2).

Figure 4-5

U.S. R&D, by performing sector and source of funds: 1953–2013





NOTES: Data for 2013 include some estimates and may later be revised. Some components of the R&D performed by other nonprofit organizations are projected and may later be revised. Federal performers of R&D include federal agencies and federally funded R&D centers. Performance by nonfederal government includes mainly state and local governments (data in this series are not available before 2006). Other funding includes support from universities and colleges, nonfederal government, and nonprofit organizations.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series).

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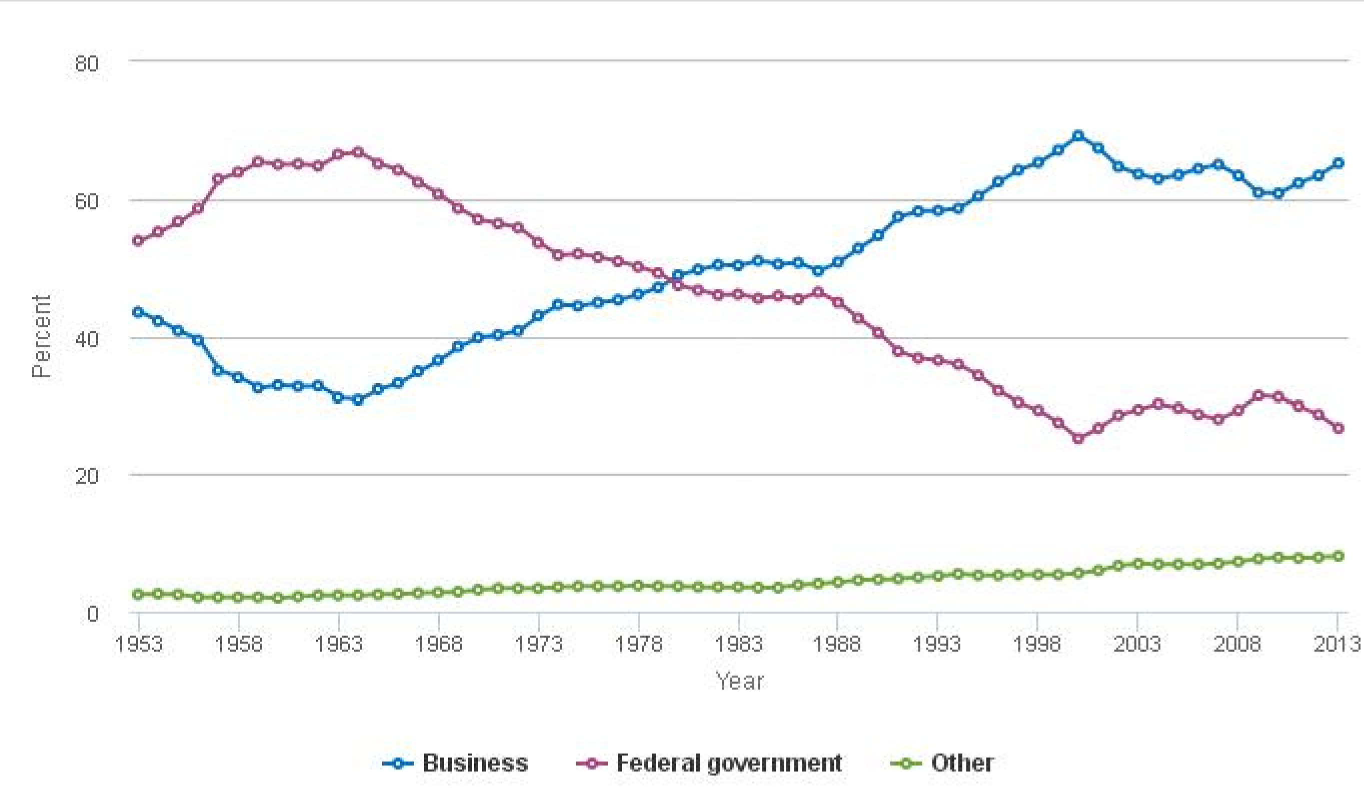
Figure 4-6

U.S. total R&D expenditures, by source of funds: 1953–2013



NOTES: Data for 2013 include some estimates and may later be revised. Other includes nonfederal government, universities and colleges, other nonprofit organizations, and other not elsewhere classified.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series).

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Universities and Colleges

Academia is the second-largest performer of U.S. R&D. Universities and colleges performed $64.7 billion, or 14%, of U.S. R&D in 2013 (Table 4-1; Figure 4-4).[i] The total of academic R&D performance has increased by several billion dollars each year since 2008. Annual growth of R&D in this sector has averaged 3.7% over the period of 2008–13, well ahead of the rate of total national R&D (Table 4-2).

Over the 20-year period of 1993–2013, the academic sector's share in U.S. R&D has ranged between 11% and 15% annually. Importantly, universities and colleges have a special niche in the nation's R&D system: They performed just over half (51%) of the nation's basic research in 2013.

Federal Agencies and FFRDCs

R&D performed by the federal government includes the activities of agency intramural laboratories and FFRDCs. Federal intramural R&D performance includes the spending for both agency laboratory R&D and for agency activities to plan and administer intramural and extramural R&D projects. FFRDCs are R&D-performing organizations that are exclusively or substantially financed by the federal government. An FFRDC is operated to provide R&D capability to serve agency mission objectives or, in some cases, to provide major facilities at universities for research and associated training purposes. (There were 40 FFRDCs in 2013.)[ii] Each FFRDC is administered by an industrial firm, a university, a nonprofit institution, or a consortium.[iii]

The federal government conducted $49.9 billion, or 11%, of U.S. R&D in 2013 (Table 4-1; Figure 4-4). Of this amount, $33.0 billion (7% of the U.S. total) was intramural R&D performed by federal agencies in their own research facilities, and $16.8 billion (4%) was R&D performed by the 40 FFRDCs.

The federal total in 2013 was down by about $1.4 billion over the 2012 level, and the 2012 level was lower than the 2011 level by a similar amount, with the declines affecting both federal intramural and the FFRDCs (Table 4-1). From 2008 to 2011, the story was much the opposite: year-over-year increases of $1–$2 billion in the federal total. This reversal reflected both the waning of the ARRA incremental funding after 2010 and the more challenging budget environment for increases in R&D funding after 2011. In 1993, the federal performance share was about 15%, but it gradually declined in subsequent years.

This volume of the federal government's R&D performance is small compared with that of the U.S. business sector. Even so, the $49.9 billion performance total in 2013 exceeded the total national R&D expenditures of every country except China, Japan, Germany, South Korea, and France.[iv]

Other Nonprofit Organizations and Nonfederal Government

R&D performed in the United States by nonprofit organizations other than universities and nonprofit-administered FFRDCs is estimated at $18.6 billion in 2013 (Table 4-1). This was 4% of U.S. R&D in 2013, a share that has been largely the same since the late 1990s (Figure 4-4).

NSF started to track the annual intramural R&D performance of state agencies in 2006. The total of this for all 50 states and the District of Columbia in 2013 is estimated to be $467 million—a small share (about 0.1%) of the U.S. total.

Geographic Location of R&D

The sidebar Location of R&D Performance, by State summarizes the leading geographic locations of U.S. R&D performance. For additional R&D indicators at the state level, see the State Data Tool.

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[i] The data for academic R&D reported in this chapter adjust the academic fiscal year basis of NSF's Higher Education Research and Development Survey data to calendar year and net out pass-throughs of research funds from one academic institution to another. Accordingly, the academic data reported in this chapter may differ from those cited in chapter 5.

[ii] NSF maintains a current Master Government List of Federally Funded R&D Centers. For information on the current FFRDC count, along with its history, see http://www.nsf.gov/statistics/ffrdclist/.

[iii] The R&D data cited are for all the FFRDCs as an aggregate. For data on the individual FFRDCs, see NSF's annual FFRDC Research and Development Surveys at http://www.nsf.gov/statistics/srvyffrdc/.

[iv] Furthermore, this figure does not include federal government investments in R&D infrastructure and equipment, which support the maintenance and operation of unique research facilities and the conduct of research activities that would be too costly or risky for a single company or academic institution to undertake.

Location of R&D Performance, by State

Distribution of R&D expenditures among the U.S. states

In 2012, the 10 states with the largest R&D expenditure levels accounted for about 64% of U.S. R&D expenditures that can be allocated to the states: California, Massachusetts, Texas, Maryland, New York, Michigan, Washington, New Jersey, Illinois, and Pennsylvania (Table 4-A).* California alone accounted for 24% of the U.S. total, almost 4 times as much as Massachusetts, the next highest state. The top 20 states accounted for 84% of the R&D total; the 20 lowest-ranking states accounted for around 5% (Appendix Table 4-10 and Appendix Table 4-11).

The states with the biggest R&D expenditures are not necessarily those with the greatest intensity of R&D. Among those with the highest R&D/GDP ratios in 2012 were New Mexico, Massachusetts, Maryland, California, and Washington (Table 4-A). New Mexico is the location of a number of major government research facilities. Massachusetts benefits from both leading research universities and thriving high-technology industries. Maryland is the site of many government research facilities and growing research universities. California has relatively high R&D intensity and benefits from the presence of Silicon Valley, other high-technology industries, federal R&D, and leading research universities, but it is still fourth on this list. Washington State is home to government research facilities, leading research universities, and high-technology industries.

U.S. R&D performance, by sector and state

The proportion of R&D performed by each of the main R&D-performing sectors (business, universities and colleges, federal intramural R&D facilities, and FFRDCs) varies across the states, but the states that lead in total R&D also tend to be well represented in each of these sectors (Table 4-A).

In 2012, R&D performed by the business sector accounted for about 71% of the U.S. total R&D that could be allocated to specific states. Of the top 10 states in total R&D performance, 9 are also in the top 10 in industry R&D. Ohio, 10th in business sector R&D, surpasses Maryland in the business R&D ranking.

University-performed R&D accounts for 16% of the allocable U.S. total. Only New Jersey and Washington fall out of the top 10 of total R&D states, replaced by North Carolina and Florida.

Federal R&D performance (including both intramural R&D facilities and FFRDCs)—about 11% of the U.S. total—is more concentrated geographically than that in other sectors. Only five jurisdictions—Maryland, California, New Mexico, Virginia, and the District of Columbia—account for 61% of all federal R&D performance.† This figure rises to 78% when the other 5 of the top 10 performers—Massachusetts, Alabama, Tennessee, Illinois, and Washington—are included.

Federal R&D accounts for the bulk of total R&D in several states, including New Mexico (85%), which is home to the nation's two largest FFRDCs (Los Alamos and Sandia National Laboratories), and Tennessee (41%), which is home to Oak Ridge National Laboratory. The high figures for Maryland (58%), the District of Columbia (66%), and Virginia (38%) reflect the concentration of federal facilities and federal R&D administrative offices in the national capital area.

* The latest data available on the distribution of U.S. R&D performance by state are for 2012 (Appendix Table 4-10). Total U.S. R&D expenditures that year are estimated at $435.3 billion. Of this total, $410.9

billion could be attributed to one of the 50 states or the District of Columbia. This state-attributed total differs from the U.S. total for a number of reasons: Some business R&D expenditures cannot be allocated to any of the 50 states or the District of Columbia because respondents did not answer the question related to location, nonfederal sources of nonprofit R&D expenditures (about $12 billion in 2012) could not be allocated by state, state-level university R&D data have not been adjusted for double-counting of R&D passed from one academic institution to another, and state-level university and federal R&D performance data are not converted from fiscal to calendar years.

† Federal intramural R&D includes costs associated with the administration of intramural and extramural programs by federal personnel, as well as actual intramural R&D performance. This is a main reason for the large amount of federal intramural R&D in the District of Columbia.

Table 4-A Top 10 states in U.S. R&D performance, by sector and intensity: 2012

	All R&D[a]		Sector ranking			R&D intensity (R&D/GDP ratio)		
Rank	State	Amount (current $millions)	Business	Universities and colleges	Federal intramural and FFRDCs[b]	State	R&D/GDP (%)	GDP (current $billions)
1	California	97,531	California	California	Maryland	New Mexico	6.62	89.2
2	Massachusetts	24,129	Massachusetts	New York	California	Massachusetts	5.59	431.9
3	Texas	20,673	New Jersey	Texas	New Mexico	Maryland	5.45	336.5
4	Maryland	18,354	Texas	Maryland	Virginia	California	4.59	2,125.7
5	New York	18,249	Michigan	Pennsylvania	District of Columbia	Washington	4.52	390.9
6	Michigan	17,844	Washington	Massachusetts	Massachusetts	Delaware	4.31	60.7
7	Washington	17,678	Illinois	North Carolina	Alabama	Michigan	4.28	416.8
8	New Jersey	17,630	New York	Illinois	Tennessee	Connecticut	3.57	242.9
9	Illinois	16,736	Pennsylvania	Michigan	Illinois	New Hampshire	3.55	66.1
10	Pennsylvania	13,210	Ohio	Florida	Washington	New Jersey	3.33	528.8

FFRDC = federally funded R&D center; GDP = gross domestic product.

[a] Includes in-state total R&D performance of the business sector, universities and colleges, federal agencies, FFRDCs, and federally financed nonprofit R&D.

[b] Includes costs associated with administration of intramural and extramural programs by federal personnel and actual intramural R&D performance.

NOTES: Small differences in parameters for state rankings may not be significant. Rankings do not account for the margin of error of the estimates from sample surveys.

SOURCES:	National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series). State GDP data are from the U.S. Bureau of Economic Analysis. See appendix table 4-10. *Science and Engineering Indicators 2016*

Sources of R&D Funding

Funds that support the conduct of R&D in the United States come from a variety of sources, including businesses, federal and nonfederal government agencies, academic institutions, and other nonprofit organizations. For the most part, the mix of funding sources varies by performer.

R&D Funding by Business

The business sector is the predominant source of funding for the R&D performed in the United States. In 2013, business sector funding accounted for $297.3 billion, or 65% of the $456.1 billion of total U.S. R&D performance (Table 4-1; Figure 4-4).

Nearly all of the business sector's funding for R&D (98%) is directed toward business R&D performance (Table 4-3).[i] The small remainder goes to higher education, other nonprofit organizations, and FFRDC performers.

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[i]R&D funding by business in this section refers to nonfederal funding for domestic business R&D plus business funding for FFRDCs and U.S. academic and nonprofit R&D performers.

Table 4-3 **U.S. R&D expenditures, by performing sector, source of funds, and type of work: 2013**

	Source of funds ($millions)						
Performing sector and type of work	Total	Business	Federal government	Nonfederal government	Universities and colleges	Other nonprofit organizations	Percent distribution by performer
R&D	456,095	297,279	121,808	4,113	15,240	17,655	100.0
Business	322,528	292,153	29,362	194	*	819	70.7
Federal government	49,859	180	49,448	50	*	181	10.9
Federal intramural	33,026	0	33,026	0	0	0	7.2
FFRDCs	16,833	180	16,422	50	*	181	3.7
Nonfederal government	467	*	193	274	*	*	0.1
Universities and colleges	64,680	3,502	36,867	3,594	15,240	5,477	14.2
Other nonprofit organizations	18,561	1,444	5,939	*	*	11,178	4.1
Percent distribution by funding source	100.0	65.2	26.7	0.9	3.3	3.9	na

	Source of funds ($millions)						
Performing sector and type of work	Total	Business	Federal government	Nonfederal government	Universities and colleges	Other nonprofit organizations	Percent distribution by performer
Basic research	80,460	21,213	37,826	2,317	9,384	9,720	100.0
Business	19,508	18,203	1,196	21	*	88	24.2
Federal government	9,531	52	9,413	14	*	52	11.8
Federal intramural	5,355	0	5,355	0	0	0	6.7
FFRDCs	4,176	52	4,058	14	*	52	5.2
Nonfederal government	NA	*	NA	NA	*	*	NA
Universities and colleges	41,275	2,156	24,148	2,213	9,384	3,373	51.3
Other nonprofit organizations	10,029	802	3,021	*	*	6,207	12.5
Percent distribution by funding source	100.0	26.4	47.0	2.9	11.7	12.1	na
Applied research	90,629	46,290	33,357	1,340	4,801	4,841	100.0
Business	51,013	44,738	6,028	47	*	200	56.3
Federal government	15,103	82	14,915	23	*	83	16.7
Federal intramural	8,337	*	8,337	*	0	*	9.2
FFRDCs	6,766	82	6,578	23	*	83	7.5
Nonfederal government	NA	*	NA	NA	*	*	NA
Universities and colleges	18,608	1,103	9,845	1,132	4,801	1,726	20.5
Other nonprofit organizations	5,671	366	2,472	*	*	2,833	6.3
Percent distribution by funding source	100.0	51.1	36.8	1.5	5.3	5.3	na

	Source of funds ($millions)						
Performing sector and type of work	Total	Business	Federal government	Nonfederal government	Universities and colleges	Other nonprofit organizations	Percent distribution by performer
Development	285,007	229,776	50,625	456	1,054	3,096	100.0
Business	252,007	229,212	22,137	126	*	532	88.4
Federal government	25,225	46	25,120	13	*	46	8.9
Federal intramural	19,334	*	19,334	*	0	*	6.8
FFRDCs	5,890	46	5,786	13	*	46	2.1
Nonfederal government	NA	*	NA	NA	*	*	NA
Universities and colleges	4,797	242	2,874	249	1,054	379	1.7
Other nonprofit organizations	2,861	276	446	*	*	2,139	1.0
Percent distribution by funding source	100.0	80.6	17.8	0.2	0.4	1.1	na

* = small to negligible amount, included as part of the funding provided by other sectors; na = not applicable; NA = not available.

FFRDC = federally funded R&D center.

NOTES: Data for 2013 include some estimates and may later be revised. Some components of R&D performance and funding by other nonprofit organizations are projected and may later be revised.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series).

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The business sector's predominant role in the nation's R&D funding began in the early 1980s, when the support it provided started to exceed 50% of all U.S. R&D funding (Figure 4-5 and Figure 4-6). This business sector share moved up annually until reaching 69% in 2000. However, this share has declined somewhat in the years since, to around 61% in 2009 and 2010, but rebounded to 65% in 2013.

R&D Funding by the Federal Government

The federal government is the second-largest source of overall funding for U.S. R&D. It is a major source for most U.S. performer sectors except businesses, where the federal role, although not negligible, is substantially overshadowed by the business sector's own funds.

Funds from the federal government accounted for $121.8 billion, or 27%, of U.S. total R&D in 2013 (Table 4-1; Figure 4-4). This funding was mainly directed to federal, business, and higher education performers, but other nonprofit organizations were also recipients (Table 4-3).

Federal funding accounted for all of the $33.0 billion of federal intramural R&D performance in 2013 and mostly all of the $16.8 billion of R&D performed by FFRDCs. (Nonfederal support for FFRDC R&D has been around $0.4 billion or so in recent years, or less than 1% of total support; see Appendix Table 4-2).

Federal funding to the business sector accounted for $29.4 billion of business R&D performance in 2013, or 9% of the sector's R&D total that year (Table 4-3). Federal funds to academia supported $36.9 billion (57%) of the $64.7 billion spent on academic R&D in 2013. For the R&D performed by other nonprofit organizations, $5.9 billion (about 32%) of this sector's $18.6 billion of performance was supported by federal funds.

The federal government was once the leading sponsor of the nation's R&D, funding some 67% of all U.S. R&D in 1964 (Figure 4-6). The federal share decreased in subsequent years to 49% in 1979, on down to a historical low of 25% in 2000. However, changing business conditions and expanded federal funding for health, defense, and counterterrorism R&D pushed the federal funding share above 31% in 2009 and 2010. But the federal share has declined somewhat in the subsequent years, reaching 27% in 2013—reflecting again the particularly challenging federal budget environment in the most recent years. Similarly, through the early 1960s, the federal government had funded more than half of the nation's business-performed R&D. This share then declined in subsequent years to around 9% in 2000, increasing again to 12%–14% from 2008 to 2010, but going back down to 9% by 2013 (Appendix Table 4-2).

R&D Funding from Other Sources

The balance of R&D funding from other sources is small: $37.0 billion in 2013, or about 8% of all U.S. R&D performance that year. Of this amount, $15.2 billion (3%) was academia's own institutional funds, most all of which remain in the academic sector; $4.1 billion (1%) was from state and local governments, primarily supporting academic research; and $17.7 billion (4%) was from other nonprofit organizations, the majority of which funds this sector's own R&D. In addition, some funds from the nonprofit sector support academic R&D.

The share of R&D funding from these sources has been marginally increasing over the 2008–13 period (Figure 4-5). In 2008, these other sources accounted for slightly more than 7% of U.S. total R&D, growing to about 8% in 2013.

R&D, by Type of Work

R&D encompasses a wide range of activities: from research yielding fundamental knowledge in the physical, life, and social sciences; to research addressing national defense needs and such critical societal issues as global climate change, energy efficiency, and health care; to the development of platform or general-purpose technologies that can enable the creation and commercial application of new and improved goods and services. The most widely applied classification of these activities characterizes R&D as "basic research," "applied research," or "(experimental) development" (Office of Management and Budget 2012; Organisation for Economic Co-operation and Development [OECD] 2002; NSF 2006). (For definitions of these terms, see this chapter's glossary).

This trio of categories has been criticized as reinforcing the idea that creating new knowledge and innovation is a linear process beginning with basic research, followed by applied research and then development, and ending with the production and diffusion of new technology. However, alternative classifications that involve measurable distinctions, capture major differences in types of R&D, and are widely deemed to be superior by the global science and technology statistical and policy communities have yet to emerge. Despite the recognized limitations of the basic research-applied research-development classification framework, it remains useful in providing indications of differences in the motivation, expected time horizons, outputs, and types of investments associated with R&D projects.

The most recent type-of-work cross-section in NSF's R&D expenditures and funding data covers 2013.[i] Basic research activities accounted for $80.5 billion (18%) of the $456.1 billion of total U.S. R&D that year. Applied research was $90.6 billion (20%); development was $285.0 billion (63%) (Table 4-3). (For years earlier than 2013, see Appendix Table 4-3, Appendix Table 4-4, and Appendix Table 4-5.)

Basic Research

Universities and colleges continued to be the primary performers of U.S. basic research in 2013, accounting for 51% of the $80.5 billion of basic research performance that year (Table 4-3). The business sector performed about 24%, the federal government (agency intramural laboratories and FFRDCs) performed 12%, and other nonprofit organizations performed 13%.

The federal government remains the largest source of funding for basic research, accounting for about 47% of the $80.5 billion funding total in 2013 (Table 4-3). The business sector was also a substantial funder, providing 26% of the total.

Applied Research

The business sector performed 56% of the $90.6 billion of applied research in 2013 (Table 4-3). Universities and colleges accounted for 21%, the federal government (federal agency intramural laboratories and FFRDCs) accounted for 17%, and nonprofit organizations for 6%.

The business sector provided 51% of the funding for applied research in 2013, with the vast majority remaining within the sector (Table 4-3). The federal government accounted for about 37%, spread broadly across the performers, with the largest amounts going to universities and colleges, federal intramural laboratories, and FFRDCs.

Development

The business sector predominates in development, performing 88% of the $285.0 billion the United States devoted to development in 2013 (Table 4-3).[ii] The federal government (agency intramural laboratories, FFRDCs) accounted for another 9%—much of it defense related, with the federal government being the main consumer. By contrast, academia and other nonprofit organizations perform very little development, respectively 2% and 1% of the total in 2013.

The business sector provided 81% of the funding for the $285.0 billion of U.S. development in 2013, most of which remained in the sector (Table 4-3). Federal funding accounted for about 18% of the development total—with the business sector (especially defense-related industries) and federal intramural laboratories being the largest recipients.

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[i] The arithmetic is straightforward, based on the data in Appendix Table 4-2, Appendix Table 4-3, Appendix Table 4-4, and appendix table 4-5, to calculate similar type-of-R&D shares for years earlier than 2013. Nonetheless, care must be taken in describing the trends for these shares over time. Although NSF's sectoral surveys of R&D expenditures have consistently used the OECD Frascati Manual's type-of-R&D definitions, the survey instruments

have occasionally been revised to improve the reliability of the responses received, most notably in the academic, business, and FFRDC R&D expenditure surveys. Accordingly, some differences observed in the shares directly calculated from the appendix table time series data more nearly reflect the effects of these improvements in the type-of-R&D survey questions than changes in the type-of-R&D shares among R&D performers.

[ii] The OECD notes that in measuring R&D, the greatest source of error is typically the difficulty of locating the dividing line between experimental development and the further downstream activities needed to realize an innovation (OECD 2002, paragraph 111). Most definitions of R&D set the cutoff at the point when a particular product or process reaches “market readiness.” At this point, the defining characteristics of the product or process are substantially set—at least for manufactured goods, if not also for services—and further work is primarily aimed at developing markets, engaging in preproduction planning, and streamlining the production or control system.

Cross-National Comparisons of R&D Performance

Data on R&D expenditures and intensity by country and region provide a broad picture of the global distribution of R&D capabilities and activities and changes under way. Data provided periodically by the OECD (covering its 34 member countries and 7 selected nonmembers) and by the United Nations Educational, Scientific and Cultural Organization's (UNESCO's) Institute for Statistics (covering more than 100 other countries) are useful for this comparative task (OECD 2015; UNESCO 2015).

Cross-national comparisons of R&D expenditures and funding necessarily involve currency conversions. The analysis in this section follows the international convention of converting all foreign currencies into U.S. dollars via purchasing power parity (PPP) exchange rates. (For a discussion of this methodology, see sidebar, Comparing International R&D Expenditures.)

Comparing International R&D Expenditures

Comparisons of international R&D statistics are hampered by the lack of R&D-specific exchange rates. Two approaches are commonly used: (1) express national R&D expenditures as a percentage of GDP, or (2) convert all expenditures to a single currency. The first method is straightforward but permits only gross comparisons of R&D intensity. The second method permits absolute level-of-effort comparisons and finer-grain analyses but entails selecting an appropriate method of currency conversion. The choice is between market exchange rates (MERs) and PPPs, both of which are available for a large number of countries over an extended period.

MERs represent the relative value of currencies for cross-border trade of goods and services but may not accurately reflect the cost of nontraded goods and services. They are also subject to currency speculation, political events, wars or boycotts, and official currency intervention. PPPs were developed to overcome these shortcomings (Ward 1985). They take into account the cost differences of buying a similar market basket of goods and services covering tradables and nontradables. The PPP basket is assumed to be representative of total GDP across countries. PPPs are the preferred international standard for calculating cross-country R&D comparisons and are used in all official R&D tabulations of the OECD.*

Because MERs tend to understate the domestic purchasing power of developing countries' currencies, PPPs can produce substantially larger R&D estimates than MERs for these countries. For example, China's R&D expenditures in 2010 (as reported to the OECD) were $178 billion in PPP terms but only $104 billion using MERs.

However, PPPs for large developing countries such as China and India are often rough approximations and have other shortcomings. For example, structural differences and income disparities between developing and developed countries may result in PPPs based on markedly different sets of goods and services. In addition, the resulting PPPs may have very different relationships to the cost of R&D in different countries.

R&D performance in developing countries often is concentrated geographically in the most advanced cities and regions in terms of infrastructure and level of educated workforce. The costs of goods and services in these areas can be substantially greater than for the country as a whole.

* Recent research raises some unresolved questions about the use of GDP PPPs for deflating R&D expenditures. In analyzing the manufacturing R&D inputs and outputs of six industrialized OECD countries, Dougherty and colleagues (2007:312) concluded that "the use of an R&D PPP will yield comparative costs and R&D intensities that vary substantially from the current practice of using GDP PPPs, likely increasing the real R&D performance of the comparison countries relative to the United States."

Country and Regional Patterns in Total National R&D

The global total of R&D expenditures continues to rise at a significant pace. NSF's latest estimate puts the worldwide total at $1.671 trillion (current PPP dollars) in 2013.[i] The corresponding estimate for 5 years earlier in 2008 was $1.269 trillion. Ten years earlier, in 2003, it was $836 billion. By these figures, the annual increase in total global R&D averaged 5.7% over the 5-year period and 7.2% over the decade, doubling in size. (As a point of comparison, U.S. GDP totaled $16.768 trillion in 2013.)

Global R&D performance continues to remain concentrated in three geographic regions: North America, Europe, and the southern and eastern areas of Asia (Figure 4-7). North America (United States, Canada, and Mexico) accounted for 29% ($492 billion) of worldwide R&D performance in 2013; Europe, including (but not limited to) the EU (see "Glossary" for a list of the EU member countries), accounted for 22% ($367 billion); the combination of the East/Southeast and South regions of Asia (including China, Japan, South Korea, India, and Taiwan) accounted for 40% ($660 billion). The remaining 9% of global R&D comes from the regions of Central and South America, Central Asia, the Middle East, Australia and Oceania, and Africa.

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[i] The figures cited here for total global R&D in 2003, 2008, and 2013 are NSF estimates. R&D expenditures for all countries are denominated in U.S. dollars, based on PPPs. These estimates are based on data from the OECD's (2015) *Main Science and Technology Indicators* (Volume 2015/1) and from R&D statistics for additional countries assembled by UNESCO's Institute for Statistics (as of late February 2015). Presently, no database on R&D spending is comprehensive and consistent for all nations performing R&D. The OECD and UNESCO databases together provide R&D performance statistics for 154 countries, although the data are not current or complete for all. NSF's estimate of total global R&D reflects 93 countries, with reported annual R&D expenditures of $50 million or more, which accounts for most of current global R&D.

Figure 4-7

Global R&D expenditures, by region: 2013

PPP = purchasing power parity.

NOTES: Foreign currencies are converted to dollars through PPPs. Some country data are estimated. Countries are grouped according to the regions described by *The World Factbook*, www.cia.gov/library/publications/the-world-factbook/.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics estimates, August 2015. Based on data from the Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2015/1), and the United Nations Educational, Scientific and Cultural Organization Institute for Statistics Data Centre, http://www.uis.unesco.org/DataCentre/Pages/BrowseScience.aspx, accessed 23 January 2015.

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The geographic concentration of R&D is more sharply apparent when the profiles of specific countries/economies are considered (Table 4-4). The United States remains the largest R&D performer ($457 billion in 2013), accounting for 27% of the global total. China was the second-largest performer ($336 billion) in 2013, accounting for about 20% of the global total. Japan is third at 10% ($160 billion); Germany is fourth at 6% ($101 billion). South Korea ($69 billion), France ($55 billion), Russia ($41 billion), the United Kingdom ($40 billion), and India ($36 billion) make up a third tier of performers—each accounting for 2% to 4% of the global R&D total. Taiwan, Brazil, Italy, Canada, Australia, and Spain make up a fourth tier, with annual R&D expenditures ranging from $19 billion to $31 billion; each accounting for 1% to 2% of the global total. The United States and China together account for about 47% of the global R&D total in 2013, the top 9 countries account for 78%, and all of the 15 countries mentioned account for 87% of the global total.

Table 4-4 **International comparisons of gross domestic expenditures on R&D and R&D share of gross domestic product, by region/country/economy: 2013 or most**

recent year

Region/country/economy	GERD (PPP $millions)	GERD/GDP (%)
North America		
United States (2013)[a]	456,977.1	2.73
Canada (2013)	24,565.4	1.62
Mexico (2013)	11,543.1	0.50
South America		
Brazil (2011)	27,430.0	1.21
Argentina (2013)	5,437.9	0.58
Chile (2013)	1,494.2	0.39
Colombia (2012)	859.6	0.17
Europe		
Germany (2013)	100,991.4	2.85
France (2013)	55,218.2	2.23
United Kingdom (2013)	39,858.8	1.63
Italy (2013)	26,520.4	1.25
Spain (2013)	19,133.4	1.24
Netherlands (2013)	15,377.4	1.98
Sweden (2013)	14,151.3	3.30
Switzerland (2012)	13,251.4	2.96
Austria (2013)	10,603.4	2.95
Belgium (2013)	10,603.4	2.28
Poland (2013)	7,918.1	0.87
Denmark (2013)	7,513.4	3.06
Finland (2013)	7,175.6	3.32
Czech Republic (2013)	5,812.9	1.91
Norway (2013)	5,513.8	1.65
Portugal (2013)	3,942.7	1.36
Ireland (2012)	3,271.5	1.58
Hungary (2013)	3,249.6	1.41
Ukraine (2011)	2,404.1	0.74
Greece (2013)	2,213.4	0.78
Slovenia (2013)	1,537.8	2.59
Romania (2013)	1,452.9	0.39

Region/country/economy	GERD (PPP $millions)	GERD/GDP (%)
Slovak Republic (2013)	1,190.6	0.83
Belarus (2011)	984.0	0.70
Serbia (2012)	841.3	0.99
Bulgaria (2012)	749.1	0.64
Croatia (2012)	672.4	0.75
Lithuania (2012)	656.1	0.90
Estonia (2013)	592.2	1.74
Luxembourg (2013)	571.5	1.16
Middle East		
Turkey (2013)	13,315.1	0.95
Israel (2013)	11,032.9	4.21
Iran (2008)	5,969.6	0.75
United Arab Emirates (2011)	1,755.3	0.49
Saudi Arabia (2009)	503.2	0.07
Africa		
South Africa (2012)	4,870.7	0.76
Egypt (2011)	2,200.5	0.43
Morocco (2010)	1,108.1	0.73
Tunisia (2009)	1,042.4	1.10
Kenya (2010)	646.3	0.98
Nigeria (2007)	644.0	0.22
Central Asia		
Russian Federation (2013)	40,694.5	1.12
South Asia		
India (2011)	36,195.5	0.81
Pakistan (2011)	1,526.9	0.33
East and Southeast Asia		
China (2013)	336,495.4	2.08
Japan (2013)	160,246.8	3.47
South Korea (2013)	68,937.0	4.15
Taiwan (2013)	30,511.2	2.99
Singapore (2012)	8,176.9	2.00
Malaysia (2011)	4,902.9	1.07
Thailand (2009)	1,339.9	0.25

Region/country/economy	GERD (PPP $millions)	GERD/GDP (%)
Indonesia (2009)	794.9	0.08
Australia and Oceania		
Australia (2011)	20,955.6	2.13
New Zealand (2013)	1,828.5	1.17
Selected country groups		
European Union (2013)	342,431.5	1.91
OECD (2013)	1,128,468.2	2.36
G20 (2013)	1,551,393.7	2.00

G20 = Group of Twenty; GDP = gross domestic product; GERD = gross expenditures (domestic) on R&D; OECD = Organisation for Economic Co-operation and Development; PPP = purchasing power parity.

[a] Data for the United States in this table may differ slightly from those cited earlier in the chapter. Data here reflect international standards for calculating GERD, which vary slightly from the National Science Foundation's protocol for tallying U.S. total R&D.

NOTES: Year of data is listed in parentheses. Foreign currencies are converted to dollars through PPPs. Countries in this table have an annual GERD of $500 million or more. Countries are grouped according to the regions described by *The World Factbook*, www.cia.gov/library/publications/the-world-factbook/. No countries in the Central America and Caribbean region had annual GERD of $500 million or more. Data for Israel are civilian R&D only. See sources below for GERD statistics on additional countries.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series); OECD, *Main Science and Technology Indicators* (2015/1); United Nations Educational, Scientific and Cultural Organization Institute for Statistics Data Centre, http://www.uis.unesco.org/DataCentre/Pages/BrowseScience.aspx, accessed 23 January 2015.

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The 2013 R&D total for the EU as a whole was $342 billion—only somewhat greater than China's level for the year. Among the EU countries, Germany is by far the largest R&D performer: $101 billion in 2013. France ($55 billion), the United Kingdom ($40 billion), and Italy ($27 billion) are next in order.

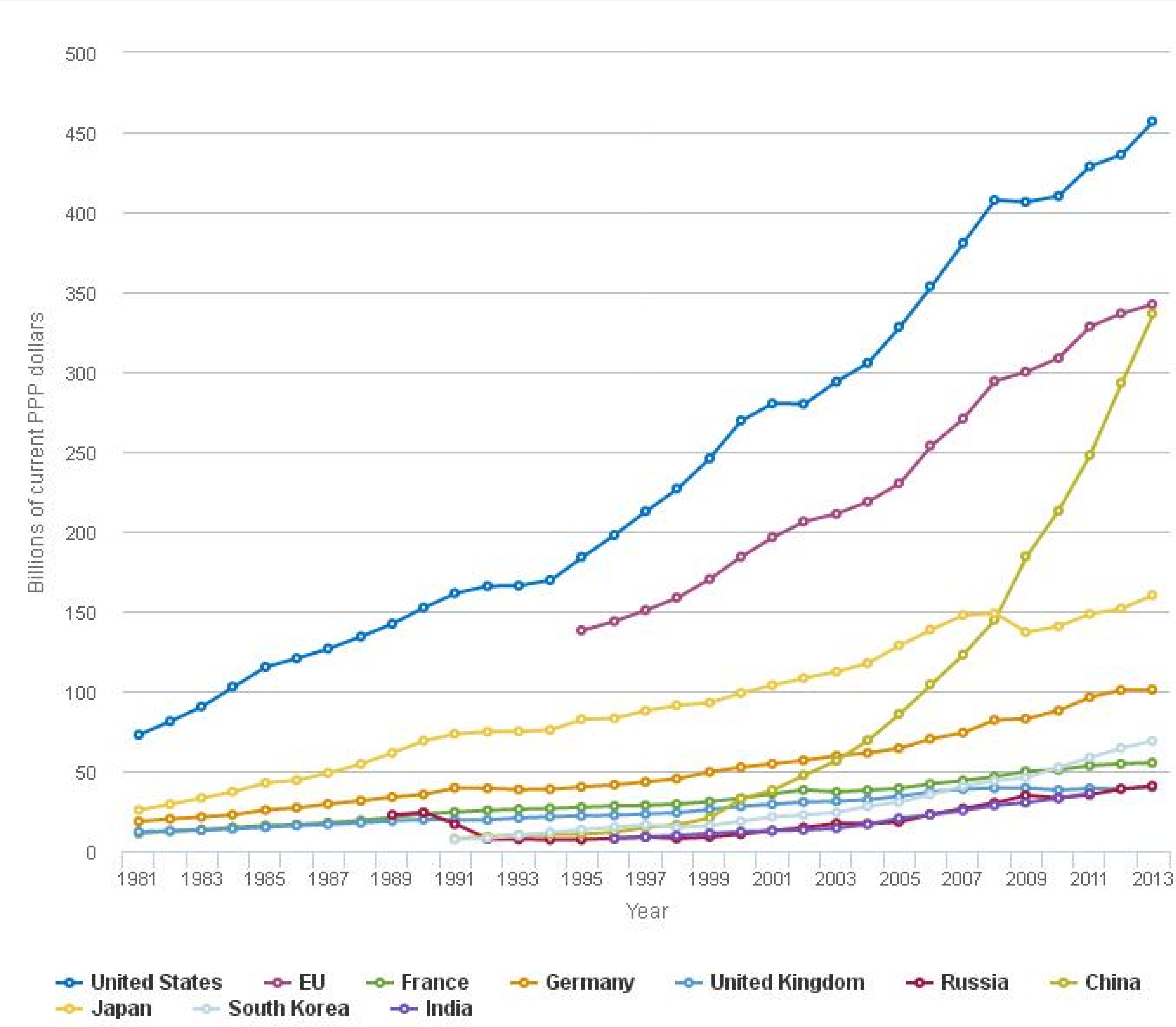
The generally vigorous pace at which total global R&D has doubled over a decade and continues to grow is certainly one of the prominent developments—a direct reflection of the escalating knowledge-intensiveness of the economic competition among the world's nations (see chapter 6 for a further discussion). Nonetheless, another major trend comprises the substantially growing levels of R&D performance in the regions of East/Southeast and South Asia compared with the other major R&D-performing areas. R&D performed in the North American region accounted for 38% of the global total in 2003 but, as noted earlier, declined to 29% in 2013. Europe accounted for 27% in 2003 but 22% in 2013. The East/Southeast and South Asian areas comprised 27% of the global total in 2003 but rose to a striking 40% in 2013. The present regional growth trends in R&D performance suggest that the growing primacy of Asia is unlikely to soon end.

Total global R&D increased some $836 billion (current dollars) from 2003 to 2013—as noted earlier, the 2003 total was $836 billion, rising to $1.671 trillion in 2013. Over this 10-year period, China alone accounted for 34% ($280 billion) of the global increase. The United States accounted for 20% ($163 billion) and the EU for 16% ($134 billion). The increases of several other major Asian R&D performers were also noticeable: Japan accounted for 6% of the increase ($48 billion), and South Korea accounted for 5% ($45 billion).

China continues to exhibit the world's most dramatic R&D growth pattern (Figure 4-8). The pace of its increase in R&D performance over the past 10 years (2003–13) remains exceptionally high, averaging 19.5% annually over this period (or 17.2% per year, when adjusted for inflation). The rate of growth in South Korea's R&D has also been quite high, averaging 11.1% annually over the same 10-year period. Japan's growth rate has been slower, at 3.6% annually.

Figure 4-8

Gross domestic expenditures on R&D, by the United States, the EU, and selected other countries: 1981–2013



NA = not available.

EU = European Union; PPP = purchasing power parity.

NOTES: Data are for the top nine R&D-performing countries and the EU. Data are not available for all countries for all years. Data for the United States in this figure reflect international standards for calculating gross expenditures on R&D, which vary slightly from the National Science Foundation's protocol for tallying U.S. total R&D. Data for Japan for 1996 onward may not be consistent with earlier data because of changes in methodology. Data for Germany for 1981–90 are for West Germany.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series); Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2015/1); United Nations Educational, Scientific and Cultural Organization Institute for Statistics Data Centre, http://www.uis.unesco.org/DataCentre/Pages/BrowseScience.aspx, accessed 23 January 2015. See appendix table 4-12.

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Although the United States remains well atop the list of the world's R&D-performing nations, its pace of growth in R&D performance has averaged 4.5% over the same 2003–13 period, and its share of global R&D has declined from 35% to 27%. Total R&D by EU nations has been growing over the same 10 years at an annual average rate of 5.0%—with Germany at 5.7%, France at 4.1%, and the United Kingdom at 2.5%. The EU countries accounted for 25% of total global R&D in 2003 but dropped to 20% of global R&D in 2013.

Country and Regional Patterns in National R&D Intensity

As discussed earlier in this chapter, the U.S. R&D/GDP ratio has exhibited over the preceding 10 years both an extended period of increase, reaching a historical peak, and a gradual drop in the most recent years (Figure 4-3). The U.S. R&D/GDP ratio peaked at 2.81% in 2009, but dropped to 2.72% by 2013.

At the 2013 level, the United States is 11th among the economies tracked by the OECD and UNESCO data. Israel and South Korea are essentially tied for the top spot, with ratios of 4.2% each. (Although Israel's data exclude expenditures for defense R&D, whereas South Korea's include them.) Israel has long been at the top of the R&D /GDP indicator ranking (Table 4-4). But South Korea's upward movement has been particularly rapid; furthermore, it is one of the world's largest R&D performers, with annual R&D expenditures many times that of Israel. Japan is third, at 3.5%. Several smaller countries/economies with comparatively high R&D/GDP ratios follow: Finland (3.3%), Sweden (3.3%), Denmark (3.1%), Taiwan (3.0%), Switzerland (3.0%), and Austria (3.0%). Germany is 10th at 2.9%.

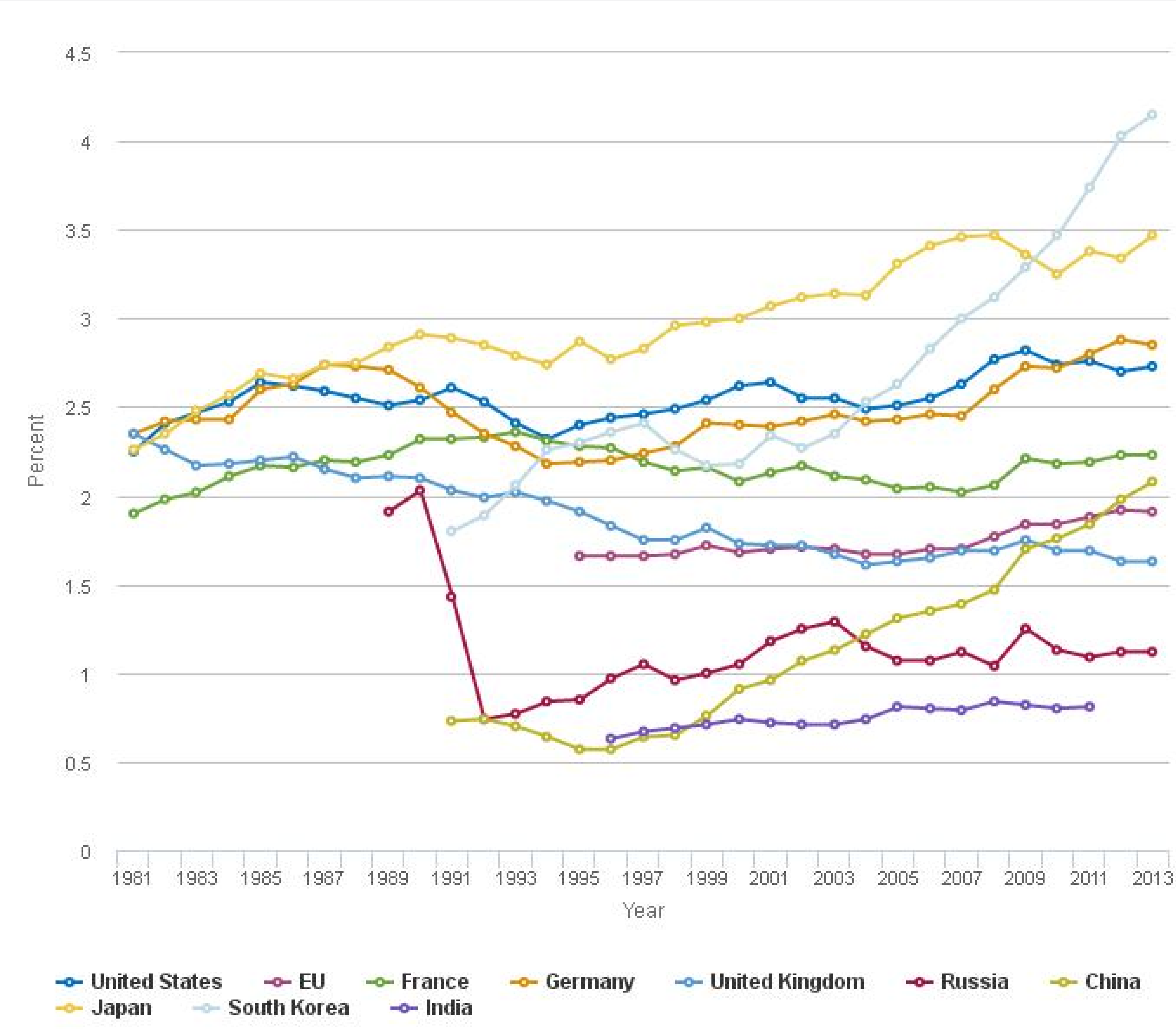
The other top R&D performers include France at 2.2%, China at 2.0%, the United Kingdom at 1.6%, Russia at 1.1%, and India at 0.8%.

The U.S. rank in this indicator has been falling in recent years. The U.S. rank was 10th in 2011 (as reported in *Science and Engineering Indicators 2014*). It was eighth in 2009 (as reported in *Science and Engineering Indicators 2012*).

The ratio has been rising gradually for the EU as a whole over the past decade: from about 1.7% in 2003 to 1.9% in 2013 (Figure 4-9). For the largest R&D performers among the EU countries, ratios for Germany and France have gradually risen, but the United Kingdom has exhibited little to no growth.

Figure 4-9

Gross domestic expenditures on R&D as a share of gross domestic product, by the United States, the EU, and selected other countries: 1981–2013



NA = not available.

EU = European Union; GDP = gross domestic product.

NOTES: Data are for the top nine R&D-performing countries and the EU. Data are not available for all countries for all years. Data for the United States in this figure reflect international standards for calculating gross expenditures on R&D, which vary slightly from the National Science Foundation's protocol for tallying U.S. total R&D. Data for Japan for 1996 onward may not be consistent with earlier data because of changes in methodology. Data for Germany for 1981–90 are for West Germany.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series); Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2015/1); United Nations Educational, Scientific and Cultural Organization Institute for Statistics Data Centre, http://www.uis.unesco.org/DataCentre/Pages/BrowseScience.aspx, accessed 23 January 2015. See appendix table 4-12.

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Among the large Asian R&D performers, Japan's R&D/GDP ratio has moved mainly upward in the last 10 years: 3.1% in 2003 to 3.5% in 2013—to a degree, reflecting sluggish GDP growth. The high risers—across all the 11 countries considered here—have been China and South Korea. China's ratio doubled over the period: from just over 1.0% in 2003 to slightly above 2.0% in 2013 (Appendix Table 4-12). South Korea's ratio increased from 2.4% in 2003 to 4.2% in 2013.

Comparisons of the Composition of Country R&D Performance

The business sector is the predominant R&D performer for nearly all of the current top 11 R&D-performing nations (Table 4-5). For the United States, the business sector accounted for 71% of gross expenditures on R&D in 2013. The shares are even higher in the leading Asian R&D performers: China, where the business sector accounted for 77% of the country's total in 2013; Japan, where it accounted for 76%; and South Korea, where it accounted for 79%. Germany, at 68% in 2013, was closer to the level of the United States. France and the United Kingdom were somewhat lower, both at about 65% in 2013. Russia's business sector accounted for about 61% of the country's total R&D in 2013. The exception is India, where the country's business sector accounts for a much smaller share of the national R&D total—36% in 2011 (the most recent year for which data are available).

Table 4-5 **Gross expenditures on R&D for selected countries, by performing sector and source of funds: 2013 or most recent year**

(Country)

		Share of total (%)			
R&D performance	GERD (PPP $billions)	Business	Government	Higher education	Private nonprofit
United States (2013)[a]	457.0	70.6	11.2	14.2	4.1
China (2013)	336.5	76.6	16.2	7.2	na
Japan (2013)	160.3	76.1	9.2	13.5	1.3
Germany (2013)	101.0	67.8	14.7	17.5	**
South Korea (2013)	68.9	78.5	11.2	9.2	1.2
France (2013)	55.2	64.8	13.2	20.8	1.4
Russia (2013)	40.7	60.6	30.3	9.0	0.1
United Kingdom (2013)	39.9	64.5	7.3	26.3	1.9
India (2011)	36.2	35.5	4.1	60.5	na
		Share of total (%)			
R&D source of funds	GERD (PPP $billions)	Business	Government	Other domestic	From abroad
United States (2013)[a]	457.0	60.9	27.7	6.9	4.5
China (2013)	336.5	74.6	21.1	NA	0.9
Japan (2013)	160.3	75.5	17.3	6.7	0.5
Germany (2013)	101.0	66.1	29.2	0.4	4.3
South Korea (2013)	68.9	75.7	23.9	1.1	0.3

		Share of total (%)			
R&D performance	GERD (PPP $billions)	Business	Government	Higher education	Private nonprofit
France (2013)	55.2	55.4	35.0	2.0	7.6
Russia (2013)	40.7	28.2	67.6	1.2	3.0
United Kingdom (2013)	39.9	46.6	27.0	5.8	20.7
India (2011)	36.2	NA	NA	NA	NA

** = included in data for other performing sectors; na = not applicable; NA = not available.

GERD = gross expenditures on R&D; PPP = purchasing power parity.

[a] Data for the United States in this table reflect international standards for calculating GERD, which vary slightly from the National Science Foundation's protocol for tallying U.S. total R&D. The data for U.S. funding from abroad include funding for business R&D and academic R&D.

NOTES: This table includes the top nine R&D-performing countries. Percentages may not add to total because of rounding. Data years are listed in parentheses.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series); Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2014/2); United Nations Educational, Scientific and Cultural Organization Institute for Statistics Data Centre, http://www.uis.unesco.org/DataCentre/Pages/BrowseScience.aspx, accessed 23 February 2015.

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R&D performed by the government accounted for about 11% of the national total in the United States in 2013. This primarily includes activities by the federal government but also includes the small amount of R&D by nonfederal government (state) performers. The share ranged from 4% to 30% across the other eight countries. The government share in Russia was the highest, at 30% in 2013; the lowest was India, at 4%. The United Kingdom (7%) and Japan (9%) were on the lower end. The other countries arrayed around the United States included China (16%), Germany (15%), France (13%), and South Korea (11%).

R&D performed by the higher education sector ranged from 7% to 61% of total national R&D across these countries. This sector's performance share for the United States was about 14% in 2013. China had the lowest share that year, at 7%. South Korea and Russia were both near that level, each with 9%. Japan and Germany were near the United States, with, respectively, 14% and 18% in 2013. France (21%) and the United Kingdom (26%) were noticeably higher. India was again the exception, with the higher education sector being the predominant performer, at 61% (data for 2011).

With the exception of Russia, business sectors were the predominant source of R&D funding (Table 4-5). (Comparable data on R&D funding sources are not available for India.) For the United States, the business sector (domestic) accounted for about 61% of all U.S. R&D in 2013. China, Japan, and South Korea had substantially higher percentages, at 75%, 76%, and 76%, respectively. Germany's share was higher than that of the United States, at 66%; the United Kingdom was somewhat less, at 47%. At 28%, Russia's share of business-funded R&D was far lower.

Government was the second major source of R&D funding for these countries—but again, Russia was the particularly noticeable exception. For the United States, government (federal and nonfederal) accounted for 28% of the nation's R&D in 2013. Germany and the United Kingdom had similar shares: 29% and 27%, respectively. France was higher, at 35%. Japan (17%), China (21%), and South Korea (24%) are below the U.S. share. The 68% government funding role for Russia in 2013 was by far the highest share and the exception among this group of leading R&D performers.

Funding from abroad refers to funding from businesses, universities, governments, nonprofits, and other organizations located outside of the country. Among the top R&D-performing countries, the United Kingdom is the most notable in this category, with 21% of R&D funding coming from abroad in 2013. France is also comparatively high, at nearly 8%. Germany and the United States are both around 4%, and the rest are much lower. (For the United States, the funding from abroad reflects foreign funding for domestic R&D performance mainly by the business and higher education sectors.)

Another dimension for comparing these top R&D-performing countries is the levels and shares of overall national annual R&D performance devoted to basic research, applied research, and (experimental) development. (Note: Type-of-R&D data are not available for Germany.) With regard to basic research, the countries range between 5% and 24% in the portion of annual R&D that falls under this heading (Table 4-6). For the United States, this share is on the high side of the range: 17% of its overall R&D in 2012, which amounted to $73.1 billion of basic research performance that year. France often shows a higher share; in 2011, this share was 24%, but this amounted to $13.0 billion of basic research performance, which was well below the U.S. level. Among top R&D-performing countries, China's basic research share is the lowest, at slightly less than 5% in 2012; however, this still amounted to about $14 billion of basic research performance that year.

Table 4-6 **Gross expenditures on R&D for selected countries, by type of work: 2012 or most recent year**

Country	GERD (PPP $billions)	Basic	Applied	Experimental development	Other nec
		PPP $billions			
United States (2012)[a]	436.1	73.1	90.6	271.7	0.0
China (2012)	293.1	14.1	33.1	245.9	0.0
Japan (2011)	148.4	18.3	31.2	92.1	6.8
Germany (2012)	100.7	NA	NA	NA	NA
South Korea (2011)	58.4	10.6	11.9	36.0	0.0
France (2011)	53.4	13.0	19.7	18.6	2.0
Russia (2012)	40.7	5.9	NA	NA	NA
United Kingdom (2011)	39.1	5.8	18.9	14.5	0.0
India (2009)	30.3	4.8	6.8	7.1	11.6
		Share of total (%)			
United States (2012)[a]	--	16.8	20.8	62.3	0.0
China (2012)	--	4.8	11.3	83.9	0.0
Japan (2011)	--	12.3	21.0	62.1	4.6
Germany (2012)	--	NA	NA	NA	NA
South Korea (2011)	--	18.1	20.3	61.7	0.0
France (2011)	--	24.4	36.9	34.8	3.8

Country	GERD (PPP $billions)	Basic	Applied	Experimental development	Other nec
Russia (2012)	--	14.4	NA	NA	NA
United Kingdom (2011)	--	14.9	48.2	37.0	0.0
India (2009)	--	16.0	22.3	23.5	38.3

NA = not available.

GERD = gross expenditures on R&D; nec = not elsewhere classified; PPP = purchasing power parity.

[a] Data for the United States in this table reflect international standards for calculating GERD, which vary slightly from the National Science Foundation's protocol for tallying U.S. total R&D.

NOTES: This table includes the top nine R&D-performing countries. Percentages may not add to total because of rounding. Data years are listed in parentheses.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series); Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2014/2); United Nations Educational, Scientific and Cultural Organization Institute for Statistics Data Centre, http://www.uis.unesco.org/DataCentre/Pages/BrowseScience.aspx, accessed 23 February 2015.

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The shares for applied research for these countries ranged between 11% (China) and 48% (United Kingdom), with the U.S. share nearly in the middle, at 21%. Nonetheless, in terms of overall volume, the United States dominates this category, with $90.6 billion of applied research spending in 2012. The second and third countries in this category are comparatively far back: China, at $33.1 billion, and Japan, at $31.2 billion.

With regard to (experimental) development, China exhibits the highest share by far: nearly 84% of its R&D total in 2012, which was $245.9 billion of spending in this category that year. For the United States, the development share that year was 62%, totaling $271.7 billion of spending in this category. Japan and South Korea also exhibit comparatively high shares for development, both near 62% in 2011; however, the dollar amounts of their performances were well below the levels for China and the United States.

U.S. Business R&D

Businesses have been the predominant performers of U.S. R&D for a long time (back into the 1950s). In 2008, the business sector accounted for $290.7 billion (71.4%) of the $407.0 billion total of U.S. total R&D (Table 4-7). In 2013, the business share was $322.5 billion (70.7%) of the $456.1 billion U.S. total. Year-to-year increases and declines in the level of business R&D performance greatly influence the U.S. R&D total. Indeed, the slowed growth and declines of U.S. R&D in the 2009–11 period owe much to the slowed growth and declines of the level of domestic business R&D in these years (see Figure 4-1).[i]

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[i] See Archibugi, Filippetti, and Frenz (2013) and references therein for studies on the relationship of R&D, innovation, and business cycles.

Table 4-7 **Funds spent for business R&D performed in the United States: 2008–13**

Sector	2008	2009	2010	2011	2012	2013
	Current $millions					
U.S. total R&D	406,952	405,136	408,197	427,832	435,375	456,094
All business R&D[a]	290,680	282,393	278,977	294,093	302,250	322,528
Paid for by the company	232,505	224,920	221,706	238,768	247,280	264,913
From company-owned, U.S.-located units	225,848	221,104	218,187	235,426	242,674	259,908
From foreign subsidiaries	6,657	3,816	3,519	3,342	4,606	5,005
Paid for by others	58,176	57,473	57,271	55,324	54,970	57,615
Federal	36,360	39,573	34,199	31,309	30,621	29,362
Domestic companies	12,181	9,567	11,013	11,124	11,624	13,450
Foreign companies	8,876	7,648	11,013	12,007	12,093	13,791
Foreign parent[b]	NA	NA	7,102	7,438	8,486	10,445
Unaffiliated companies	NA	NA	3,913	4,569	3,607	3,346
All other organizations[c]	759	685	1,046	884	632	1,013
	Source of funds as a percentage of all business R&D					
All business R&D[a]	100.0	100.0	100.0	100.0	100.0	100.0
Paid for by the company	80.0	79.6	79.5	81.2	81.8	82.1
From company-owned, U.S.-located units	77.7	78.3	78.2	80.1	80.3	80.6
From foreign subsidiaries	2.3	1.4	1.3	1.1	1.5	1.6

Sector	2008	2009	2010	2011	2012	2013
Paid for by others	20.0	20.4	20.5	18.8	18.2	17.9
Federal	12.5	14.0	12.3	10.6	10.1	9.1
Domestic companies	4.2	3.4	3.9	3.8	3.8	4.2
Foreign companies	3.1	2.7	3.9	4.1	4.0	4.3
Foreign parent[b]	NA	NA	1.7	1.7	1.9	2.3
Unaffiliated companies	NA	NA	1.0	1.1	0.8	0.7
All other organizations[c]	0.3	0.2	0.4	0.3	0.2	0.3

NA = not available.

[a] Includes companies located in the United States that performed or funded R&D. Data in this table represent an aggregate of all industries in the North American Industry Classification System codes 21–33 and 42–81.

[b] Includes foreign parent companies of U.S. subsidiaries.

[c] Includes U.S. state government agencies and laboratories, foreign agencies and laboratories, and all other organizations located inside and outside the United States.

NOTES: Detail may not add to total because of rounding. Industry classification was based on the dominant business code for domestic R&D performance, where available. For companies that did not report business codes, the classification used for sampling was assigned. This table excludes data for federally funded R&D.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey (annual series).

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The business sectors of the U.S. economy are diverse, with wide differences in the goods and services provided across industries and in the various production inputs required, including roles for R&D. Historically, companies in manufacturing industries have accounted for two-thirds or more of U.S. business R&D, with the balance accounted for by companies in nonmanufacturing industries. As it turns out, however, the peaks in current U.S. business R&D stem from a relative handful of industries, classified in both the manufacturing and nonmanufacturing sectors.

Key Characteristics of Domestic Business R&D Performance

NSF's annual Business R&D and Innovation Survey (BRDIS) provides data on all for-profit, nonfarm companies that are publicly or privately held and have five or more employees in the United States.[i] U.S. business R&D is the R&D performed by companies in the domestic United States, including that paid for by the company itself (from company-owned, U.S.-located units or from company subsidiaries located overseas) and that paid by others (such as other companies—domestic or foreign, including foreign parents of U.S. subsidiaries; the federal government; nonfederal government—domestic or foreign; nonprofit or other organizations—domestic or foreign).

Presently, most domestic R&D performance occurs in five business sectors: chemicals manufacturing (North American Industry Classification System [NAICS] 325—which includes the pharmaceuticals industry); computer and electronic products manufacturing (NAICS 334); transportation equipment manufacturing (NAICS 336—which includes the automobiles and aerospace industries); information (NAICS 51—which includes the software publishing industry); and professional, scientific, and technical (PST) services (NAICS 54—which includes the computer systems design and scientific R&D services industries) (Table 4-8).[ii] Although a sector's R&D performance total is influenced by both its overall economic size and the intensity of its R&D need (usually measured as dollars of R&D performance divided by total product sales), these are all sectors and industries with R&D intensities higher than others in the national economy (Table 4-9).

[i] BRDIS does not collect data for companies with fewer than five employees. See the sidebar, earlier in this chapter, "Measured and Unmeasured R&D."

[ii] The industry-level data presented in this section are obtained by classifying a company's total R&D into a single industry, even if R&D activities occur in multiple lines of business. For example, if a company has $100 million in R&D expenses—$80 million in pharmaceuticals and $20 million in medical devices—the total R&D expense of $100 million is assigned to the pharmaceuticals industry because it is the largest component of the company's total R&D expense (Shackelford 2012). However, most companies performed R&D in only one business activity area. In 2010, 86% of companies reported domestic R&D performed by and paid for by the company related to only one business activity. See also Shackelford (2012) for an in-depth analysis of the relationship between business codes and industry codes.

Table 4-8 **Funds spent for business R&D performed in the United States, by source of funds and selected industry: 2013**

			Paid for by others				
					Companies		
Industry and NAICS code	All R&D	Paid for by the company	Total	Federal	Domestic	Foreign a	All other organizations b
	Millions of dollars						
All industries, 21–33, 42–81	322,528	264,913	57,615	29,362	13,450	13,791	1,012
Manufacturing industries, 31–33	221,476	181,170	40,306	22,958	5,174	11,427	747
Chemicals, 325	61,664	54,285	7,379	356	1,389	5,594	40
Pharmaceuticals and medicines, 3254	52,426	45,891	6,534	167	1,343	4,987	37
Other 325	9,238	8,394	845	189	46	607	3
Machinery, 333	12,650	12,092	558	128	110	309	11
Computer and electronic products, 334	67,205	57,364	9,841	4,866	1,748	2,720	507
Electrical equipment, appliances, and components, 335	4,136	3,660	475	129	83	259	4
Transportation equipment, 336	45,972	25,165	20,807	17,312	1,328	1,676	491
Automobiles, trailers, and parts, 3361–63	16,729	14,081	2,647	304	565	1,772	6
Aerospace products and parts, 3364	27,114	10,042	17,072	15,927	758	D	D

			Paid for by others				
					Companies		
Industry and NAICS code	All R&D	Paid for by the company	Total	Federal	Domestic	Foreign a	All other organizations b
Other 336	2,129	1,042	1,088	1,081	5	D	D
Manufacturing nec, other 31–33	29,849	28,604	1,246	167	516	540	23
Nonmanufacturing industries, 21–23, 42–81	101,052	83,742	17,310	6,404	8,276	2,364	266
Information, 51	57,207	56,039	1,168	203	447	512	6
Software publishers, 5112	35,333	34,296	1,037	173	386	474	4
Other 51	21,874	21,743	131	30	61	38	2
Finance and insurance, 52	4,308	4,298	10	0	10	0	0
Professional, scientific, and technical services, 54	31,017	15,617	15,400	6,033	7,610	1,525	232
Computer systems design and related services, 5415	9,268	8,107	1,161	809	175	157	20
Scientific R&D services, 5417	14,201	2,838	11,363	3,288	6,841	1,127	107
Other 54	7,548	4,672	2,876	1,936	594	241	105
Nonmanufacturing nec, other 21–23, 42–81	8,520	7,788	732	168	209	327	28
	Percentage of sector/industry totals						
All industries, 21–33, 42–81	100.0	82.1	17.9	9.1	4.2	4.3	0.3
Manufacturing industries, 31–33	100.0	81.8	18.2	10.4	2.3	5.2	0.3
Chemicals, 325	100.0	88.0	12.0	0.6	2.3	9.1	0.1
Pharmaceuticals and medicines, 3254	100.0	87.5	12.5	0.3	2.6	9.5	0.1
Other 325	100.0	90.9	9.1	2.0	0.5	6.6	0.0
Machinery, 333	100.0	95.6	4.4	1.0	0.9	2.4	0.1
Computer and electronic products, 334	100.0	85.4	14.6	7.2	2.6	4.0	0.8
Electrical equipment, appliances, and components, 335	100.0	88.5	11.5	3.1	2.0	6.3	0.1

			Paid for by others				
					Companies		
Industry and NAICS code	All R&D	Paid for by the company	Total	Federal	Domestic	Foreign [a]	All other organizations [b]
Transportation equipment, 336	100.0	54.7	45.3	37.7	2.9	3.6	1.1
Automobiles, trailers, and parts, 3361–63	100.0	84.2	15.8	1.8	3.4	10.6	0.0
Aerospace products and parts, 3364	100.0	37.0	63.0	58.7	2.8	D	D
Other 336	100.0	48.9	51.1	50.8	0.2	D	D
Manufacturing nec, other 31–33	100.0	95.8	4.2	0.6	1.7	1.8	0.1
Nonmanufacturing industries, 21–23, 42–81	100.0	82.9	17.1	6.3	8.2	2.3	0.3
Information, 51	100.0	98.0	2.0	0.4	0.8	0.9	0.0
Software publishers, 5112	100.0	97.1	2.9	0.5	1.1	1.3	0.0
Other 51	100.0	99.4	0.6	0.1	0.3	0.2	0.0
Finance and insurance, 52	100.0	99.8	0.2	0.0	0.2	0.0	0.0
Professional, scientific, and technical services, 54	100.0	50.3	49.7	19.5	24.5	4.9	0.7
Computer systems design and related services, 5415	100.0	87.5	12.5	8.7	1.9	1.7	0.2
Scientific R&D services, 5417	100.0	20.0	80.0	23.2	48.2	7.9	0.8
Other 54	100.0	61.9	38.1	25.6	7.9	3.2	1.4
Nonmanufacturing nec, other 21–23, 42–81	100.0	91.4	8.6	2.0	2.5	3.8	0.3

D = suppressed to avoid disclosure of confidential information.

NAICS = North American Industry Classification System; nec = not elsewhere classified.

[a] Includes foreign parent companies of U.S. subsidiaries.

[b] Includes U.S. state government agencies and laboratories, foreign agencies and laboratories, and all other organizations located inside and outside the United States.

NOTES: Detail may not add to total because of rounding. Statistics are representative of companies located in the United States that performed or funded R&D. Industry classification was based on the dominant business code for domestic R&D performance, where available. For companies that did not report business codes, the classification used for sampling was assigned. Excludes data for federally funded R&D centers.Detail may not add to total because of rounding. Industry classification was based on the dominant business code for domestic R&D performance, where available. For companies that did not report business codes, the classification used for sampling was assigned. Excludes data for federally funded R&D centers.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey, 2013.
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Table 4-9 Sales and R&D intensity for companies that performed or funded R&D, by selected industry: 2013

Industry and NAICS code	Domestic net sales (US$millions)[a]	R&D intensity (%)[b]
All industries, 21–33, 42–81	9,654,952	3.5
Manufacturing industries, 31–33	5,902,677	3.9
Chemicals, 325	1,361,379	4.5
Pharmaceuticals and medicines, 3254	511,393	10.3
Other 325	849,986	1.0
Machinery, 333	370,969	3.4
Computer and electronic products, 334	643,383	10.6
Electrical equipment, appliances, and components, 335	142,537	2.9
Transportation equipment, 336	1,113,141	4.3
Automobiles, trailers, and parts, 3361–63	694,029	2.6
Aerospace products and parts, 3364	355,687	7.6
Other 336	63,425	4.4
Manufacturing nec, other 31–33	2,271,268	1.6
Nonmanufacturing industries, 21–23, 42–81	3,752,275	2.8
Information, 51	1,048,039	5.5
Software publishers, 5112	394,356	9.0
Other 51	653,683	3.4
Finance and insurance, 52	646,362	0.7
Professional, scientific, and technical services, 54	371,322	8.4
Computer systems design and related services, 5415	110,779	8.4[i]
Scientific R&D services, 5417	70,480	20.3
Other 54	190,063	4.0
Nonmanufacturing nec, other 21–23, 42–81	1,686,552	0.7

i = more than 50% of value imputed.

NAICS = North American Industry Classification System; nec = not elsewhere classified.

	[a] Includes domestic net sales of companies that perform or fund R&D, transfers to foreign subsidiaries, and export sales to foreign companies; excludes intracompany transfers and sales by foreign subsidiaries.
	[b] R&D intensity is domestic R&D paid for by the company and others and performed by the company divided by domestic net sales.
NOTES:	Detail may not add to total because of rounding. Statistics are representative of companies located in the United States that performed or funded R&D. Industry classification was based on the dominant business code for domestic R&D performance, where available. For companies that did not report business codes, the classification used for sampling was assigned. Excludes data for federally funded R&D centers. The Business R&D and Innovation Survey does not include companies with fewer than five employees.Detail may not add to total because of rounding. Industry classification was based on the dominant business code for domestic R&D performance, where available. For companies that did not report business codes, the classification used for sampling was assigned. This table excludes data for federally funded R&D.
SOURCE:	National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey, 2013.
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In 2013, these five business sectors accounted for $263.1 billion (82%) of the $322.5 billion business R&D performance total that year (Table 4-8). Corresponding data for earlier years are much the same: In 2008, the five sectors accounted for $244.9 billion (84%) of the $290.6 billion business R&D performance total (Appendix Table 4-13). Computer and electronic products accounted for about 21% of the business R&D performance total in 2013. From 2012 back to 2008, its share was in the 20%–22% range. Chemicals accounted for 19% of the business R&D total in 2013—most of which arose in the pharmaceuticals and medicines industry. Chemicals' share ranged from 19% to 21% in the previous years. The information sector accounted for about 18% of the business R&D performance total in 2013—nearly two-thirds of which was in software publishing. The information sector represented only 13% of the business R&D total in 2008, but its share has been rising since then. Transportation equipment (mainly the automobiles and aerospace industries) accounted for 14% in 2013 but had a higher share, at 17%, in 2008. Finally, the PST sector represented nearly 10% of the business R&D total in 2013—about half of this is from the scientific R&D services industry, but R&D is also sizable in the computer systems design and related services industry. The PST sector's share of the total was 13% in 2008 and has been gradually declining.

Looking at U.S. business R&D as a whole, performance is funded mainly by companies' own funds: 82% in 2013—the vast majority of this came from companies' units owned and located in the United States (81%), but a small amount (less than 2%) came from companies' foreign subsidiaries (Table 4-7). The 18% remainder comes from R&D performed by the company but paid for by others. Here the federal government is the largest of these "paid for by" sources: about 9% of the business R&D performance total in 2013. Companies other than the performer, both domestic and foreign (including foreign parents), account for about 4% each of the 2013 total. The "all other organizations" category spans a diverse group: state government agencies and laboratories, foreign agencies and laboratories, and any other domestic and foreign funding organizations. But this grouping accounts for a nearly negligible share: 0.3% in 2013. The relative shares of all these funding sources are not substantially different in looking back yearly to 2008 (Table 4-7).

Nonetheless, there are some noteworthy differences when more narrowly defined sectors and industries are considered, particularly for the five top R&D-performing sectors (and their main industries) previously discussed. R&D performance funded through a company's own funds was highest (in 2013) in the information sector, where the own funds share was 98%. By contrast, the own funds share was 55% in the transportation equipment sector and 50% in the PST sector. Even lower shares are evident when specific industries are considered: 20% in scientific R&D services are own funds, and 37% in aerospace products and parts are own funds.

The federal funding share is greatest in the transportation equipment sector (38%), particularly in this sector's aerospace products and parts industry (59%). It is also markedly higher than the all-business aggregate in the PST sector (20%). The next highest share is that of the computer and electronic products sector, at 7%.

Funding provided by other domestic companies, for most of the sectors and industries, were at or below the 4% aggregate average. The exception is PST, where it is 25% for the sector, but an even higher 48% in scientific R&D services. Funding provided by foreign companies was at about the 4% aggregate average for the computer and electronic products, transportation equipment, and PST sectors, but it was well below in the information section (1%) and well above in chemicals (9%).

Apart from direct funding for R&D in the form of contracts and grants to businesses, the U.S. government offers indirect R&D support via fiscal incentives such as tax credits. For recent statistics, see the sidebar Federal R&E Tax Credit and Appendix Table 4-14.

Finally, with regard to domestic business R&D performance and company size (as measured by the number of employees), Table 4-10 provides statistics for 2008–13. In 2013, large companies (i.e., those with 25,000 or more domestic employees) performed 37% of U.S. business R&D. Small companies (i.e., those with fewer than 500 domestic employees) accounted for 16%. The other 47% was spread among the size classifications between these extremes. As is apparent from the table, the distribution of all business R&D by company size has not greatly changed since 2008.

Federal R&E Tax Credit

The United States and other OECD countries offer fiscal incentives for business R&D at the national and subnational levels (Thomson 2012). For businesses, tax credits reduce after-tax costs of R&D activities. For governments, tax credits are forgone revenue, known as tax expenditures. Public incentives for R&D are generally justified by the inability of private performers to fully capture benefits from these activities, given the intangible nature of knowledge and information.

The U.S. research and experimentation (R&E) tax credit was originally established by the Economic Recovery Tax Act of 1981 on a temporary basis. The credit was extended on a temporary basis 17 times through 2014 and it was made permanent by the Protecting Americans From Tax Hikes Act of 2015 on December 18, 2015 (see Section 121 in H.R. 2029, Division Q, Title I, Subtitle A, Part 3).* The credit is designed to apply to incremental qualified research expenses by a business beyond a base amount. The bill making the credit permanent also included certain new provisions for small businesses. As of late December, details were still emerging about remaining and new features of the credit for different types of businesses. For an overview and methodologies to estimate the effectiveness of the R&E credit prior to recent changes see Guenther (2013) and Hall (1995).

Based on estimates from the Internal Revenue Service's (IRS's) Statistics of Income, R&E tax credit claims fell to $7.8 billion in 2009 from $8.3 billion in 2008 but rebounded in subsequent years, totaling $10.8 billion in 2012 (Appendix Table 4-14). Likewise, the number of corporate returns claiming the credit dropped in 2009 compared with 2008 but resumed an upward trend in the subsequent years. R&E credit claims relative to company-funded domestic R&D have fluctuated fairly narrowly between 3.0% and 4.4% since 2001 (3.6% in 2008, 3.5% in 2009, increasing gradually to 4.4% in 2012).

* See https://www.congress.gov/bill/114th-congress/house-bill/2029/text and Internal Revenue Code (IRC) Section 41, as amended. See also IRS Form 6765 at http://www.irs.gov/pub/irs-pdf/i6765.pdf and http://www.irs.gov/uac/SOI-Tax-Stats-Corporation-Research-Credit.

Funds spent for business R&D performed in the United States, by size of

Table 4-10 **company: 2008–13**

	Millions of dollars				Percentage of all business R&D			
Selected characteristic	2008	2010	2012	2013	2008	2010	2012	2013
All business domestic R&D[a]	290,680	278,977	302,250	322,530	100.0	100.0	100.0	100.0
Size of company (number of domestic employees)								
5–499	58,138	52,202	49,962	53,002	20.0	18.7	16.5	16.4
5–24	14,280	12,573	9,841	10,296	4.9	4.5	3.3	3.2
25–49	9,626	8,625	7,195	7,941	3.3	3.1	2.4	2.5
50–99	9,351	8,855	9,182	8,910	3.2	3.2	3.0	2.8
100–249	14,662	11,866	12,480	13,666	5.0	4.3	4.1	4.2
250–499	10,219	10,283	11,264	12,189	3.5	3.7	3.7	3.8
500–999	11,886	10,117	11,484	12,002	4.1	3.6	3.8	3.7
1,000–4,999	46,336	48,228	50,691	55,517	15.9	17.3	16.8	17.2
5,000–9,999	24,764	27,463	30,483	31,514	8.5	9.8	10.1	9.8
10,000–24,999	48,737	41,835	49,493	51,218	16.8	15.0	16.4	15.9
25,000 or more	100,820	99,133	110,138	119,275	34.7	35.5	36.4	37.0

[a] For companies located in the United States that performed or funded R&D.

NOTES: Detail may not add to total because of rounding. This table excludes data for federally funded R&D. The Business R&D and Innovation Survey does not include companies with fewer than five employees.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey (annual series).

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Cross-National Comparisons of Business R&D

The industries currently predominant in performing business R&D in the United States are generally also the main actors in the other largest R&D-performing countries. Table 4-11 provides cross-national comparisons for the United States, France, Germany, the United Kingdom, China, Japan, and South Korea (corresponding statistics for India and Russia are not presently available). These data come from the OECD's Analytical Business Enterprise R&D (ANBERD) database.[i] Note that the classification of industries in this table reflects the International Standard Industrial Classification of All Economic Activities (ISIC), Revision 4 for all countries (including the United States), which differs somewhat from NAICS, which is used to report U.S. data earlier in this section of the chapter.[ii] Table 4-11 is also truncated, in that only those industries with comparatively higher levels of annual R&D performance are included—for a more complete listing of industries, see Appendix Table 4-15.

[i] For a description of the OECD's ANBERD methodology and data, see http://www.oecd.org/innovation/inno /anberdanalyticalbusinessenterpriseresearchanddevelopmentdatabase.htm.

[ii] ISIC Revision 4 was released by the United Nations Statistics Division in August 2008. For an overview of the classification structure, comparisons with earlier editions, and background, see http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=27.

Table 4-11 **Business expenditures for R&D, by selected countries and top R&D-performing industries: 2012 or most recent year**

	ISIC Rev.4								
Industry	Section	Division	United States (2011)	France (2012)	Germany (2012)	United Kingdom (2012)	China (2012)	Japan (2012)	South Korea (2012)
			Millions of current PPP dollars						
Total business enterprise	A–U	1–99	294,093	35,237	68,469	24,610	223,169	116,321	50,245
Manufacturing	C	10–33	201,361	17,691	58,977	9,837	194,810	102,306	44,127
Chemicals and chemical products		20	9,375	1,060	4,450	378	17,559	7,138	2,655
Pharmaceuticals, medicinal chemical, and botanical products		21	45,949	946	5,209	725	8,062	12,484	1,214
Computer, electronic, and optical products		26	62,704	4,050	9,409	1,405	33,819	28,291	25,081
Motor vehicles, trailers, and semi-trailers		29	11,695	2,212	22,098	2,126	16,238	26,839	5,688
Other transport equipment		30	29,185	3,685	3,415	2,025	9,754	586	886
Air and spacecraft and related machinery		303	26,054	3,368	3,026	1,938	NA	309	185
Total services	G–U	45–99	88,945	16,532	8,975	14,300	14,156	12,403	4,391
Information and communication	J	58–63	55,124	3,845	4,042	3,483	NA	5,164	2,364
Publishing activities		58	28,435	930	NA	74	NA	6	1,518
Software publishing		582	27,965	920	NA	34	NA	NA	1,507

	ISIC Rev.4								
Industry	Section	Division	United States (2011)	France (2012)	Germany (2012)	United Kingdom (2012)	China (2012)	Japan (2012)	South Korea (2012)
Computer programming, consultancy, and related activities		62	13,259	1,877	3,072	2,250	NA	2,086	245
Professional, scientific, and technical activities	M	69–75	24,960	10,282	3,997	8,583	NA	6,280	1,037
Scientific R&D		72	15,301	4,334	2,155	6,744	NA	5,694	273
	Percentage of total business enterprise								
Total business enterprise	A–U	1–99	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Manufacturing	C	10–33	68.5	50.2	86.1	40.0	87.3	88.0	87.8
Chemicals and chemical products		20	3.2	3.0	6.5	1.5	7.9	6.1	5.3
Pharmaceuticals, medicinal chemical, and botanical products		21	15.6	2.7	7.6	2.9	3.6	10.7	2.4
Computer, electronic, and optical products		26	21.3	11.5	13.7	5.7	15.2	24.3	49.9
Motor vehicles, trailers, and semi-trailers		29	4.0	6.3	32.3	8.6	7.3	23.1	11.3
Other transport equipment		30	9.9	10.5	5.0	8.2	4.4	0.5	1.8
Air and spacecraft and related machinery		303	8.9	9.6	4.4	7.9	NA	0.3	0.4
Total services	G–U	45–99	30.2	46.9	13.1	58.1	6.3	10.7	8.7
Information and communication	J	58–63	18.7	10.9	5.9	14.2	NA	4.4	4.7
Publishing activities		58	9.7	2.6	NA	0.3	NA	0.0	3.0

Industry	ISIC Rev.4 Section	ISIC Rev.4 Division	United States (2011)	France (2012)	Germany (2012)	United Kingdom (2012)	China (2012)	Japan (2012)	South Korea (2012)
Software publishing		582	9.5	2.6	NA	0.1	NA	NA	3.0
Computer programming, consultancy, and related activities		62	4.5	5.3	4.5	9.1	NA	1.8	0.5
Professional, scientific, and technical activities	M	69–75	8.5	29.2	5.8	34.9	NA	5.4	2.1
Scientific R&D		72	5.2	12.3	3.1	27.4	NA	4.9	0.5

NOTES: NA = not available.

ISIC Rev.4 = International Standard Industrial Classification of All Economic Activities, Revision 4; PPP = purchasing power parity.

Detail may not add to total because of rounding. Industry classifications for all countries are based on main activity. The U.S. business R&D data are from the U.S. Business R&D and Innovation Survey 2011 (cross-walked to the ISIC Rev.4 classifications). In general, the table includes industries with annual R&D expenditures of $10 billion or more (i.e., each country's largest R&D performers). See appendix table 4-15 for a more comprehensive list of industries.

SOURCE: Organisation for Economic Co-operation and Development, Analytical Business Enterprise R&D, Statistical Analysis Database, R&D Expenditures in Industry, http://stats.oecd.org/Index.aspx?DataSetCode=ANBERD_REV4, accessed 9 April 2015.

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Based on ISIC, the manufacturing section (ISIC 10–33) accounted for about 69% of the $294.1 billion of overall business R&D performance in the United States in 2011. As apparent in Table 4-11, this stemmed in large part from the relatively high levels of R&D performed in the computer, electronic, and optical products division (ISIC 26—$62.7 billion, or 21% of all business-performed R&D in the United States in 2011); the pharmaceuticals, medicinal chemical, and botanical products division (ISIC 21—$45.9 billion, 16%); and the air and spacecraft and related machinery industry (ISIC 303—$26.1 billion, 9%). (The shares reported here are not materially different from those reported earlier in this section based on the NAICS categories.)

Outside of manufacturing, a comprehensive group encompassing all services divisions (ISIC 45–99) accounted for most of the rest ($88.9 billion, or 30%) of U.S. business R&D in 2011 (Table 4-11). The information and communication section (ISIC 58–63) itself accounted for 19%—including software publishing (ISIC 582, 10%). The PST activities section (ISIC 69–75) represented 9%—including scientific research and development (ISIC 72, 5%).

For Germany, Japan, South Korea, and China, the manufacturing sector accounts for a substantially higher share of overall business R&D: 86%–88%, depending on the country (Table 4-11). With Germany, the motor vehicles, trailers, and semi-trailers division (ISIC 29) accounted for 32% of the $68.5 billion of business R&D in 2012. The next-largest share was computer, electronic, and optical products (ISIC 26) at 14%. For Japan, with $116.3 billion of business R&D in 2012, the R&D preponderances were 24% in computer, electronic, and optical products (ISIC 26); 23% in motor vehicles, trailers, and semi-trailers (ISIC 29); and 11% in pharmaceuticals, medicinal chemical, and botanical products (ISIC 21). For South Korea, 50% of its $50.2 billion of business R&D in 2012 was in computer, electronic, and optical products (ISIC 26); the next highest share was 11% in motor vehicles, trailers, and semi-trailers (ISIC 29). China's business R&D, $223.2 billion in 2012, although conducted mainly in manufacturing, is more diverse: 15% in computer, electronic, and optical products (ISIC 26); 8% in chemicals and chemical products (ISIC 20); and 7% in motor vehicles, trailers, and semi-trailers (ISIC 29), with the rest widely spread.

France and the United Kingdom are exceptions to this manufacturing emphasis, given the quite large shares of R&D that occur in services industries (Table 4-11). For France, 50% of its $35.2 billion of business R&D in 2012 was in manufacturing, with peaks in computer, electronic, and optical products (12%) and in air and spacecraft and related machinery (10%). But 47% of France's business R&D total comes from services, with 29% in the PST activities section (ISIC 69–75) and 11% in the information and communication section (ISIC 58–63). Somewhat similarly, for the United Kingdom, with $24.6 billion of business R&D in 2012, 40% is manufacturing, with modest peaks in motor vehicles, trailers, and semi-trailers (9%) and air and spacecraft and related machinery (8%). But 58% is in services: 35% in PST activities (ISIC 69–75) and 14% in information and communication (ISIC 58–63).

R&D by Multinational Enterprises

The extent and geographic spread of R&D by multinational enterprises (MNEs) are useful markers of the increasing global character of supply chains for production and innovation in R&D-intensive sectors. These business activities reflect a mix of international economic trends, including the increased complexity of global supply chains, the deepening arrays of scientific/technological capabilities and resources around the globe, and the need to economically and strategically strengthen internal technological capabilities (Moncada-Paternò-Castello, Vivarelli, and Voigt 2011; OECD 2008).

This section is based on MNE operations data collected in annual foreign direct investment surveys conducted by BEA. These cover majority-owned affiliates (those owned more than 50% by their parent companies) of foreign MNEs located in the United States (Survey of Foreign Direct Investment in the United States) and U.S. MNEs and their majority-owned foreign affiliates (Survey of U.S. Direct Investment Abroad).[i]

R&D Performed in the United States by Affiliates of Foreign MNEs

Affiliates of foreign MNEs located in the United States (hereafter, U.S. affiliates) performed $48.0 billion of R&D in the United States in 2012 (Table 4-12). This was equivalent to 16% of the $302.3 billion of business R&D performed in the United States that year (comparing data in Table 4-1 and Table 4-12). Both the level of U.S. affiliate R&D and its share of the total of U.S. business R&D have generally increased since the later 1990s. In 1997, U.S. affiliate R&D was $17.2 billion, or equivalent to 11% of the U.S. business total; in 2007, it was $41.0 billion, or equivalent to 15% of the U.S. business R&D total (Appendix Table 4-2 and Appendix Table 4-16).

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[i] For further information on these BEA surveys, see http://www.bea.gov/international.

Table 4-12 R&D performed by majority-owned affiliates of foreign companies in the United States, by selected industry of affiliate and investor country: 2012

(Millions of current U.S. dollars)

		Manufacturing						Nonmanufacturing		
Country	All industries	Total	Chemicals	Machinery	Computer and electronic products	Electrical equipment, appliances, and components	Transportation equipment	Wholesale trade	Information	Professional, scientific, and technical services
All countries	47,994	33,953	18,281	2,711	4,339	637	4,787	7,448	1,347	4,174
Canada	631	365	1	D	62	0	203	66	77	97
Europe	36,821	29,349	16,573	2,415	3,347	547	3,814	3,044	789	3,062
France	6,501	5,632	D	D	1,584	D	D	160	558	95
Germany	5,839	4,478	1,629	D	147	26	1,046	377	D	D
Netherlands	1,882	1,289	215	D	D	0	D	422	D	33
Switzerland	9,387	7,408	D	52	D	D	D	D	5	1,427
United Kingdom	6,753	6,359	4,491	84	400	32	650	94	172	109
Other	6,459	4,184	390	647	201	D	D	D	D	D
Asia and Pacific	7,900	2,741	957	D	339	D	D	3,729	D	D
Japan	6,209	2,108	874	152	263	D	485	3,124	209	661
Other	1,691	633	82	D	77	0	D	606	D	D
Other	2,642	1,498	751	D	589	D	D	608	D	D

D = suppressed to avoid disclosure of confidential information.

NOTES: Data are preliminary and are for majority-owned (> 50%) affiliates of foreign companies by country of ultimate beneficial owner and industry of affiliate. Includes R&D conducted by foreign affiliates, whether for themselves or others under contract; excludes R&D conducted by others for affiliates.

SOURCE: U.S. Bureau of Economic Analysis, Survey of Foreign Direct Investment in the United States (annual series), http://www.bea.gov/internationa /fdius2012_preliminary.htm, accessed 19 August 2015.

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About three-quarters of this U.S. affiliate R&D in 2012 was performed by firms owned by parent companies based in five countries: Switzerland (20%), the United Kingdom (14%), France (14%), Japan (13%), and Germany (12%) (Table 4-12). Although the relative rankings have shifted somewhat from year to year, these have been the predominant countries throughout the last 5 years.

U.S. affiliates classified in manufacturing accounted for 71% of the U.S. affiliate R&D total in 2012 (Table 4-12). This manufacturing share has generally been 70% or more since 2007 (Appendix Table 4-17). The chemicals subsector had 38%, with 35% pharmaceuticals. Other manufacturing subsectors with appreciable shares in 2012 included transportation equipment (10%), computer and electronic products (9%), and machinery (6%) (Appendix Table 4-17). For nonmanufacturing, the most notable sectors in 2012 were wholesale trade (16%) and PST services (9%).

U.S. MNE Parent Companies and Their Foreign Affiliates

R&D performed outside the United States by majority-owned foreign affiliates of U.S. MNEs totaled $45.0 billion in 2012 (Table 4-13). The parent companies of these U.S. MNEs performed $233.0 billion of R&D in the United States (Appendix Table 4-20), which was equivalent to about 77% of the total of business R&D conducted in the United States that year. In 1997, these foreign affiliates' R&D performance abroad was $14.6 billion; in 2007, it was $34.4 billion (Appendix Table 4-18).

Table 4-13 R&D performed abroad by majority-owned foreign affiliates of U.S. parent companies, by selected industry of affiliate and host region/country/economy: 2012

(Millions of current U.S. dollars)

		Manufacturing						Nonmanufacturing		
Region/country /economy	All industries	Total	Chemicals	Machinery	Computer and electronic products	Electrical equipment, appliances, and components	Transportation equipment	Wholesale trade	Information	Professional, scientific, and technical services
All countries	44,983	30,497	9,153	2,214	7,074	681	7,700	2,510	3,214	8,065
Canada	2,864	1,702	267	25	593	D	584	D	D	616
Europe	26,742	19,448	6,245	1,636	3,752	328	5,044	1,717	1,304	3,852
Austria	257	205	23	119	8	D	1	D	0	D
Belgium	2,547	2,140	D	13	50	1	D	11	*	390
Denmark	237	123	9	D	74	*	0	D	D	2
Finland	191	163	11	D	D	3	2	2	1	25
France	2,031	1,749	357	161	494	8	284	140	77	56
Germany	8,027	6,628	431	415	1,878	186	3,165	524	71	713
Ireland	1,465	836	319	*	315	D	2	D	424	188
Italy	683	458	155	99	68	10	59	33	2	187
Luxembourg	302	D	D	*	*	0	0	*	D	D
Netherlands	1,489	1,207	729	26	55	23	D	16	65	195
Norway	299	89	6	D	D	0	0	D	D	D
Poland	207	124	11	2	D	1	52	2	2	78
Russia	130	104	D	1	D	0	D	9	D	D
Spain	272	213	D	7	D	9	D	10	0	37

		Manufacturing						Nonmanufacturing		
Region/country /economy	All industries	Total	Chemicals	Machinery	Computer and electronic products	Electrical equipment, appliances, and components	Transportation equipment	Wholesale trade	Information	Professional, scientific, and technical services
Sweden	572	436	46	D	75	4	132	D	46	59
Switzerland	2,364	1,297	475	D	225	10	D	589	255	222
United Kingdom	5,206	3,169	1,350	229	326	28	938	203	225	1,393
Latin America and OWH	2,747	1,616	509	97	71	D	685	133	D	167
Argentina	161	83	45	*	D	0	D	2	*	D
Brazil	1,285	1,131	336	89	D	*	589	60	D	D
Mexico	405	250	70	5	D	D	70	D	*	31
Africa	129	52	17	4	*	0	27	3	0	D
South Africa	102	D	17	4	0	0	D	3	0	D
Middle East	2,033	899	27	140	604	0	0	D	D	D
Israel	2,012	895	26	140	604	0	0	D	D	874
Asia and Pacific	10,470	6,779	2,088	314	2,053	278	1,361	341	801	2,505
Australia	1,153	921	199	15	29	9	D	30	D	142
China	2,012	956	230	47	327	116	109	D	D	717
India	2,289	655	305	D	224	D	37	D	248	1,206
Japan	2,314	1,933	1,185	141	204	D	112	53	123	205
Malaysia	655	640	2	*	596	*	0	D	0	D
Singapore	509	391	55	19	274	D	D	15	37	62
South Korea	898	833	51	25	117	0	D	32	D	19
Taiwan	274	168	16	4	129	9	5	4	D	D

* = ≤ $500,000; D = suppressed to avoid disclosure of confidential information.

	OWH = other Western Hemisphere.
NOTES:	Data are for majority-owned (> 50%) affiliates of U.S. parent companies by host country and industry of affiliate. Includes R&D conducted by foreign affiliates, whether for themselves or others under contract; excludes R&D conducted by others for affiliates.
SOURCE:	U.S. Bureau of Economic Analysis, Direct Investment and Multinational Enterprises (annual series), http://www.bea.gov/iTable/index_MNC.cfm, accessed 18 August 2015.
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European countries hosted $26.7 billion (59%) of this foreign affiliate R&D in 2012 (Table 4-13). The largest R&D expenditures by U.S.-owned affiliates in this region were located in Germany ($8.0 billion, 18%) and the United Kingdom ($5.2 billion, 12%). Other notable locations included Belgium ($2.5 billion, 6%), Switzerland ($2.4 billion, 5%), and France ($2.0 billion, 5%). The European share overall was 66% in 2007 and 69% in 1997 (Appendix Table 4-18). Germany and the United Kingdom were the predominant host countries over this 15-year period, although the two countries had more evenly matched shares before 2008.

Canada hosted $2.9 billion (6%) of U.S. MNE foreign affiliate R&D in 2012, a sizable amount in comparison with other countries, but its share has been gradually declining since 1997 (Appendix Table 4-18).

Countries in the Asia and Pacific regions hosted $10.5 billion (23%) of foreign affiliate R&D in 2012 (Table 4-13). Majority-owned affiliates of U.S. MNEs located in Japan and India had the largest R&D expenditures in this region (each hosting about $2.3 billion, or 5%), followed closely by affiliates located in China ($2.0 billion, 4%). Similar to other cross-national comparative indicators for R&D, the Asia/Pacific region continues to gain an increasing share as a host for U.S. parent companies' foreign affiliate R&D. The region accounted for only 13% of the total in 1997. While Japan's share has remained sizable across the 1997–2012 period, although declining somewhat since the early 2000s, the growth areas for this foreign affiliate R&D have been India and China, each of which accounted for a negligible share in the late 1990s but grew to largely match that of Japan by 2012 (Appendix Table 4-18).

Latin America and other Western Hemisphere countries accounted for $1.6 billion (3%) in R&D expenditures by U.S.-owned affiliates in 2012, mostly in Brazil. U.S.-owned affiliates in the Middle East accounted for $2.0 billion (5%) in 2012, nearly all in Israel.

With respect to economic sectors, foreign affiliate R&D of U.S. MNEs was concentrated in four industries in 2012: chemicals (manufacturing, particularly pharmaceuticals, $9.2 billion, 20%), PST services (nonmanufacturing, $8.1 billion, 18%), transportation equipment (manufacturing, $7.7 billion, 17%), and computer and electronic products (manufacturing, $7.1 billion, 16%) (Table 4-13). Other notable industries include information (nonmanufacturing, $3.2 billion), wholesale trade (nonmanufacturing, $2.5 billion), and machinery (manufacturing, $2.2 billion). These industries have been similarly prominent over the last several years (Appendix Table 4-19).

Despite a decline in the shares held by traditional locations for this foreign affiliate R&D, Europe (as a whole) and Japan remain the top R&D hosts for U.S. MNEs in major industries, reflecting both strengths of the host countries in certain technologies and the large, longstanding investments by U.S. MNEs in these locations. In transportation equipment, Germany is by far the largest location of U.S.-owned foreign affiliate R&D: $3.2 billion of the $7.7 billion total R&D in 2012 performed by majority-owned foreign affiliates of U.S. MNEs is classified in this industry (Table 4-13). Similarly, for computers and electronic products manufacturing, Germany was the leading host location, with $1.9 billion in R&D expenditures out of the $7.1 billion total R&D performed by majority-owned foreign affiliates of U.S. MNEs classified in this industry. In chemicals manufacturing, the United Kingdom and Japan were the top locations of U.S.-owned R&D in 2012: $1.4 billion and $1.2 billion, respectively, of the $9.2 billion in total U.S.-owned affiliates' R&D outside of the United States in this industry.

Finally, for R&D performed by U.S. MNE foreign affiliates classified in PST services, the host country roles reflect both older trends and the rise of Asia as a host of U.S.-owned R&D (Table 4-13). The United Kingdom hosted the largest amount of R&D performed in this industry in 2012 ($1.4 billion of the $8.1 billion total of U.S.-owned R&D outside the United States in PST services), followed by India ($1.2 billion). China and Germany were essentially tied for third largest in PST services by U.S.-owned affiliates ($0.7 billion each).

Recent Trends in Federal Support for U.S. R&D

The U.S. government supports the nation's R&D system through various policy avenues. Its most direct role is as provider of a regular funding stream for the R&D activities conducted by both federal organizations (agency intramural laboratories/facilities and FFRDCs) and by external, nonfederal organizations such as businesses and academic institutions. Fifteen federal departments and a dozen other agencies engage in and/or provide funding for R&D in the United States (Table 4-14). Even so, in recent years, the vast majority of the yearly federal funding total is accounted for by the R&D activities of a small group of departments/agencies: the Department of Defense (DOD), the Department of Health and Human Services (HHS), the Department of Energy (DOE), the National Aeronautics and Space Administration (NASA), NSF, the U.S. Department of Agriculture (USDA), and the Department of Commerce (DOC). The sections immediately following provide statistics on several topics that illuminate the key recent trend in this important federal role: the ups and downs of overall federal funding for R&D over the last 10 years in particular, how this federal financial support has been distributed across the various federal departments and agencies and by types of performers, looking at federal funding just for research (i.e., basic research and applied research) and seeing which fields of S&E predominate, and finally, how the priorities of the United States for federal R&D funding compare with those of the other large, global R&D-performing countries.

(Note: The corresponding data for federal funding of U.S. R&D cited in Table 4-1 earlier in this chapter are lower. The Table 4-1 numbers are based on performers' reports of their R&D expenditures from federal funds. This difference between performer and source of funding reports of the level of R&D expenditures has been present in the U.S. data for more than 15 years and reflects various technical issues. For a discussion, see sidebar, Tracking R&D Expenditures: Disparities in the Data Reported by Performers and Sources of Funding)

Tracking R&D Expenditures: Disparities in the Data Reported by Performers and Sources of Funding

In the United States—and in some other OECD countries—the data on government funding of R&D as reported by the government often differ from those reported by performers of R&D. Consistent with international guidelines, most countries report their national R&D expenditures based chiefly on data from R&D performers (OECD 2002). In the United States, over the last several decades, a sizable gap has opened between what the federal government and R&D performers separately report as the level of federally funded R&D (Figure 4-A; Appendix Table 4-21).

In the mid- to later 1980s, the total of federally funded R&D reported by all U.S. performers exceeded by $3–$4 billion (i.e., 6%–9% of the federally reported total) what the federal government said it funded (left panel of Figure 4-A). In 1989–91, however, the pattern reversed, with the performer-reported total of federal funding less than the federally reported total by $1–$2 billion annually. From the early 1990s through the mid-2000s, this federal report excess grew larger. In 2007, the federal report indicated $127 billion of federal funding for R&D, compared with R&D performers' report of $107 billion—a difference of almost $21 billion, or 16% of the federally reported total. As implied by Figure 4-A's right panel (which focuses on only business R&D performers), much of the disparity arose from differences in the federal and performer reports regarding business R&D.

More recently, the all-performer gap has narrowed. In 2009, the federal report showed federal funding for all R&D performers exceeding the performer-reported total by $14 billion (10% of the federal report) and in 2013, only $4 billion (3% of the federal report). Nonetheless, the federal report excess for only the business R&D performers in these most recent years has remained as sizable (see right panel of Figure 4-A). The appearance is that the federal report now includes lower estimates of the level of federally funded R&D by performers (notably in higher education and the FFRDCs) other than the business sector, which then offset the federal report's higher estimates of funding for business R&D.

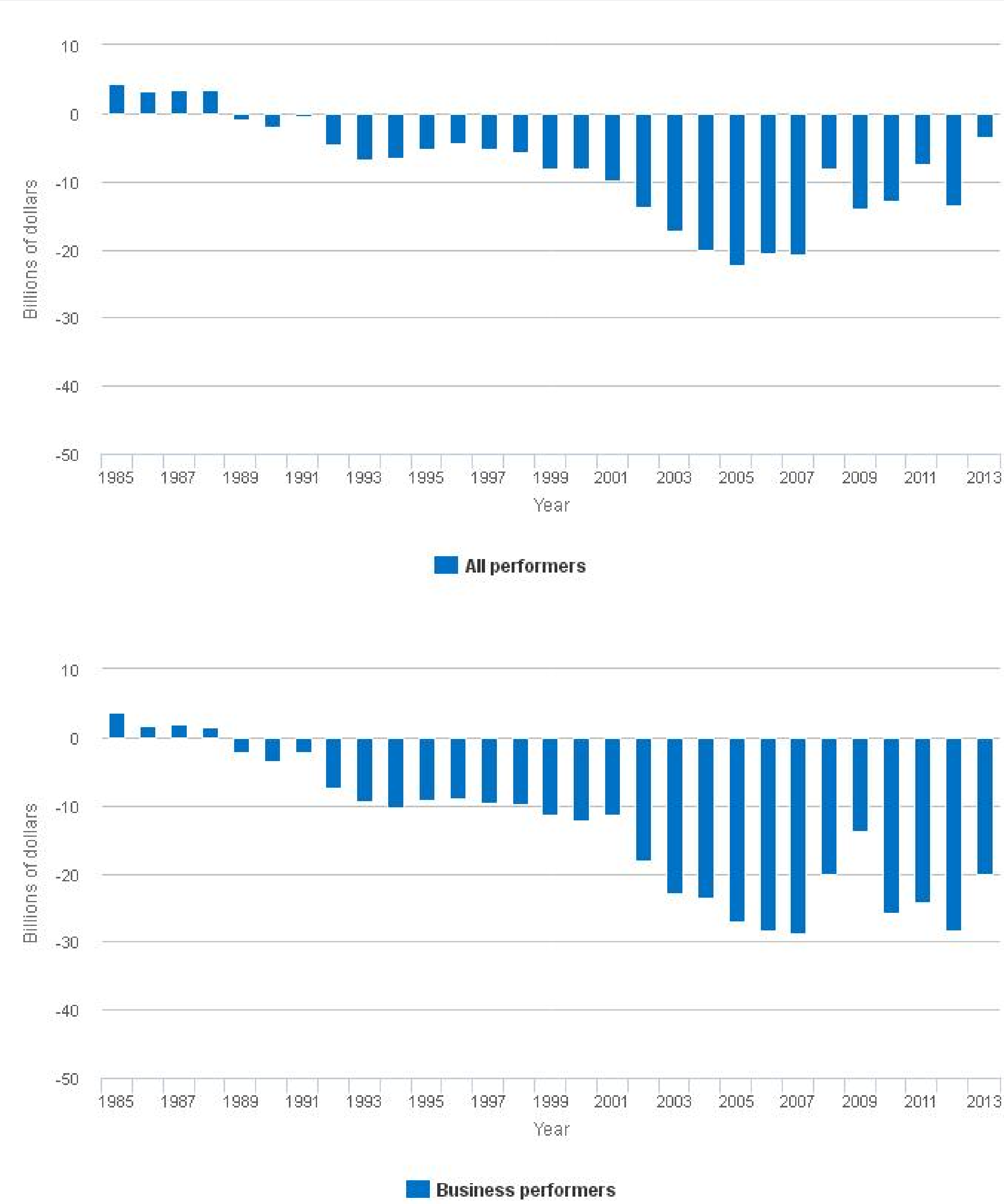
Federal R&D funding data are normally reported as obligations on a fiscal year basis; performers typically report R&D expenditures on a calendar year basis. Some of the observed discrepancies reflect this difference in reporting calendars. Nevertheless, adjusting the two data series to a common calendar does not significantly remove the observed gaps.

Several investigations into the possible causes for these data disparities have produced insights but no conclusive explanation. A General Accounting Office (GAO) investigation made the following assessment:

Because the gap is the result of comparing two dissimilar types of financial data [federal obligations and performer expenditures], it does not necessarily reflect poor quality data, nor does it reflect whether performers are receiving or spending all the federal R&D funds obligated to them. Thus, even if the data collection and reporting issues were addressed, a gap would still exist. (GAO 2001:2)

Figure 4-A

Discrepancy in federal R&D support, as reported by performers and federal agencies: 1985–2013



NOTES: Discrepancy is defined as performer-reported R&D minus federally reported R&D funding. A negative discrepancy indicates that agency-reported R&D funding exceeds performer-reported R&D.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series), and Survey of Federal Funds for Research and Development, FYs 2013–15. See appendix table 4-21.

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Table 4-14 Federal obligations for R&D and R&D plant, by agency: FYs 2007–14

(Millions of dollars)

Agency	2007	2008	2009	2010	2011	2012	2013	2014[a]
All agencies	129,431.2	129,049.5	144,758.1	146,967.8	139,661.5	140,635.8	127,297.3	130,807.7
Department of Defense	72,290.5	71,996.6	75,973.7	73,623.9	75,327.6	73,973.6	63,654.7	63,711.3
Department of Health and Human Services	29,556.1	29,700.7	35,735.9	37,616.9	30,928.0	31,335.8	29,512.8	30,422.1
National Aeronautics and Space Administration	6,205.8	5,847.1	5,957.6	8,691.3	8,429.0	10,758.3	10,494.3	11,010.0
Department of Energy	8,629.8	8,990.3	11,562.2	11,644.9	10,680.4	10,635.2	10,397.1	11,114.7
National Science Foundation	4,406.9	4,506.4	6,924.8	6,073.4	5,536.6	5,705.4	5,328.5	5,551.3
Department of Agriculture	2,372.3	2,246.0	2,344.7	2,615.4	2,376.9	2,194.3	2,037.4	2,435.7
Department of Commerce	1,145.4	1,196.4	1,533.4	1,683.2	1,308.9	1,230.7	1,293.9	1,632.7
Department of Transportation	811.0	825.2	846.2	929.2	861.8	936.1	875.8	967.1
Department of Homeland Security	1,106.4	1,056.8	983.6	1,131.8	1,127.5	832.2	718.8	973.9
Department of the Interior	624.7	645.3	738.8	728.0	716.5	742.7	717.3	753.4
Department of Veterans Affairs	446.5	480.0	510.0	563.0	612.9	614.8	639.0	600.2
Environmental Protection Agency	576.0	532.0	552.8	572.3	581.7	581.1	529.7	538.0

Agency	2007	2008	2009	2010	2011	2012	2013	2014[a]
Department of Education	333.1	328.1	322.4	362.8	346.1	338.0	309.9	324.7
Smithsonian Institution	186.0	188.0	226.7	213.0	248.7	246.2	240.3	232.3
Agency for International Development	234.5	123.8	160.1	84.3	119.2	77.4	125.5	128.0
Department of Justice	184.4	114.5	103.4	125.4	102.3	85.0	118.7	104.2
All other agencies	321.8	272.3	281.8	309.0	357.4	349.0	303.6	308.1

[a] FY 2014 data are preliminary and may later be revised.

NOTES: This table lists all agencies with R&D and R&D plant obligations greater than $100 million in FY 2013. All other agencies include Department of Housing and Urban Development, Department of Labor, Department of State, Department of the Treasury, Appalachian Regional Commission, Consumer Product Safety Commission, Federal Communications Commission, Federal Trade Commission, Library of Congress, National Archives and Records Administration, Nuclear Regulatory Commission, and Social Security Administration.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Federal Funds for Research and Development, FYs 2013–15.

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Total of Federal Funding for R&D and for Major Departments/Agencies

The federal government has long provided funding support annually for the R&D activities of its own departments and agencies, as well as all the other major U.S. R&D performers.[i] The level of overall federal support for R&D (including for both R&D conduct and R&D plant) has generally increased year to year since the early 1950s (Figure 4-10; Appendix Table 4-22). What was $2–$5 billion in the mid-1950s increased to well above $100 billion in FY 2003, to just under $130 billion in FYs 2007 and 2008. The level moved higher still in FYs 2009 and 2010, largely as a result of the $18.7 billion of incremental funding for R&D authorized by the ARRA. In fact, the 2009 and 2010 levels were the highest since the early 1950s (whether considered in current or constant dollar terms). Annual growth in federal funding averaged 6.2% in current dollars over FYs 2000–10, or 4.0% when adjusted for inflation.

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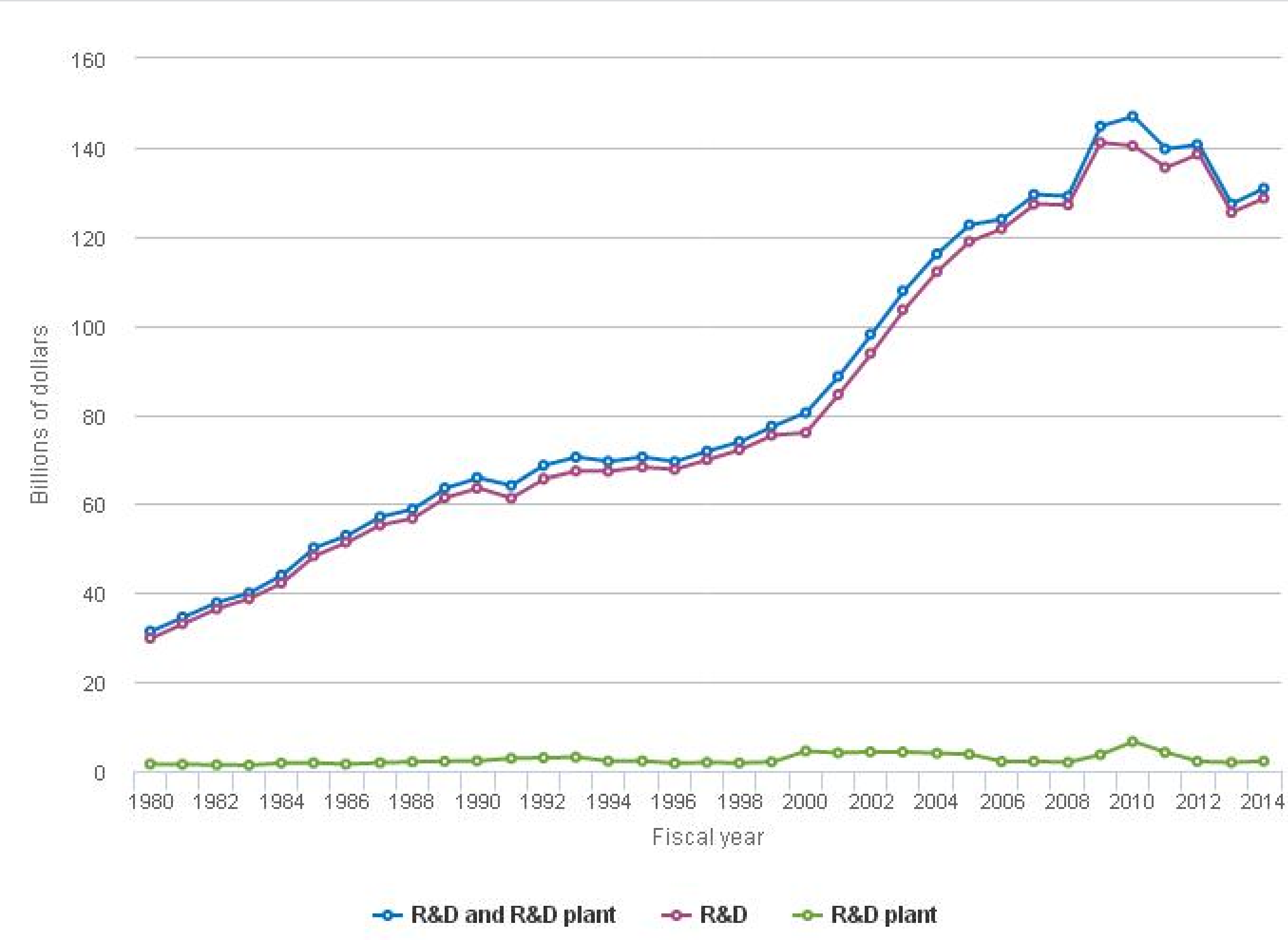
[i] The analysis in this section focuses primarily on developments in federal R&D priorities and funding support over the course of the last decade. Nevertheless, there is an important and interesting story to tell about how the comparatively minor federal role in the nation's science and research system up until World War II was reconsidered, redirected, and greatly enlarged, starting shortly after the end of the war and moving through the subsequent decades to the present. For a review of the essential elements of this evolving postwar federal role, see Jankowski (2013).

Figure 4-10

Federal obligations for R&D and R&D plant: FYs 1980–2014



NOTE: Data for FYs 2009 and 2010 include obligations from the additional federal R&D funding appropriated by the American Recovery and Reinvestment Act of 2009.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Federal Funds for Research and Development, FYs 2013–15. See appendix table 4-22.

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However, a decidedly different trend has prevailed in the years since then, as federal R&D funding has been buffeted by the more challenging policy-making circumstances for the federal budget that has prevailed over the last several years. The $147.0 obligations in FY 2010 dropped by $6–$7 billion in FYs 2011 and 2012, and then more precipitously to $127.3 in FY 2013. The more favorable budget-making circumstances in FY 2014 yielded an increase to $130.8 billion that year. Nonetheless, the drop from the FY 2010 level to the FY 2014 level is a current dollar decline of 11% and is steeper still, at 17%, when factoring in inflation.

Some of this post–FY 2010 drop in federal R&D funding is the waning of the effects of the incremental funding provided by ARRA, which showed up as R&D obligations mainly in FYs 2009 and 2010. Nonetheless, the still-sluggish U.S. economy and continuing differences among the main parties involved in negotiating and enacting the annual federal budgets (the White House and Congress) have taken a toll—with federal funding for R&D affected as part of this larger picture.[ii]

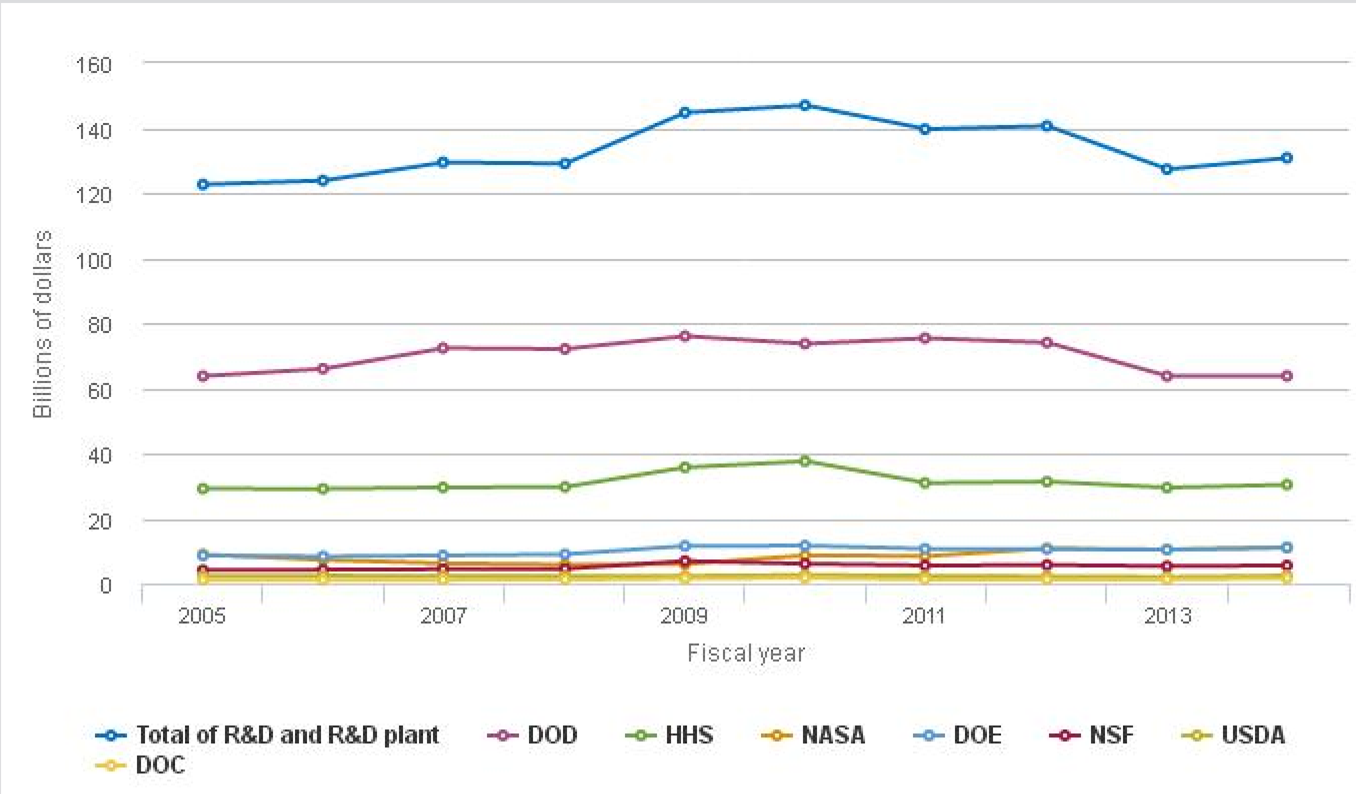
In FYs 2013 and 2014, seven departments/agencies each obligated more than $1 billion annually (current dollars): DOD, HHS, NASA, DOE, NSF, USDA, and DOC (Table 4-14). Together, these accounted for about 96% of the federal R&D and R&D plant total these years. Another five departments/agencies obligated funding in the $500 million to $900 million range that year: the Department of Transportation (DOT), the Department of Homeland Security (DHS), the Department of the Interior, the Department of Veterans Affairs (VA), and the Environmental Protection Agency (EPA).

Figure 4-11 charts the annual total federal funding for R&D and R&D plant together and that for each of the seven principal departments/agencies from FY 2005 to FY 2014. The figure shows the substantial drop in the federal funding total (current dollars) that has occurred since the peak in FY 2010. It also shows that the funding drop through FY 2014 has been borne most heavily by DOD ($9.9 billion of the $16.1 billion cumulative decline from FY 2010 to FY 2014) and HHS ($7.2 billion of the $16.1 decline). DOE and NSF sustained cumulative drops of $0.5 billion over this same period. NASA was the exception, at $2.3 billion higher in FY 2014 than in FY 2010. The other departments/agencies sustained substantially smaller losses or gains.

For a further account of this recent federal budget history, see Boroush (2014). Notable among the various interconnected developments over these years were the federalwide spending reductions imposed by the enacted FY 2011 federal budget: the Budget Control Act of 2011, intended to address the then-ongoing national debt ceiling crisis, which commanded a 10-year schedule of budget caps and spending cuts; the budget sequestration provision, which ultimately took hold in the FY 2013 federal budget; and the Bipartisan Budget Act of 2013, which provided some subsequent relief from the deepening sequestration requirements, but only for the FY 2014 and FY 2015 budgets.

Figure 4-11

Federal obligations for R&D and R&D plant, by selected agencies: FYs 2005–14



DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; USDA = U.S. Department of Agriculture.

NOTES: The departments and agencies included in this figure all had annual R&D obligations of $1 billion or more and together account for the vast majority of the R&D and R&D plant total. Data for FYs 2009 and 2010 include obligations from the additional federal R&D funding appropriated by the American Recovery and Reinvestment Act of 2009.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Federal Funds for Research and Development (annual series).

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Distribution of Federal Funding of R&D, by Performer and Type of Work

Table 4-15 and Table 4-16 provide breakdowns by departments/agencies of the $127.3 billion of federal dollars obligated for R&D and R&D plant in FY 2013 according to purpose (R&D conduct, R&D plant), performers funded (intramural, extramural), and type of work (basic research, applied research, development).

Table 4-15	Federal obligations for R&D and R&D plant, by agency and performer: FY 2013

(Millions of dollars)

				Total by performers			
Agency	Total	R&D	R&D plant	Intramural and FFRDCs	Percentage of total	Extramural performers	Percentage of total
All agencies	127,297.3	125,387.5	1,909.8	44,297.9	34.8	82,999.4	65.2
Department of Defense	63,654.7	63,557.7	97.0	21,544.6	33.8	42,110.1	66.2
Department of Health and Human Services	29,512.8	29,382.5	130.3	6,656.0	22.6	22,856.9	77.4
National Aeronautics and Space Administration	10,494.3	10,368.1	126.2	2,953.3	28.1	7,540.9	71.9
Department of Energy	10,397.1	9,841.0	556.1	7,749.0	74.5	2,648.0	25.5
National Science Foundation	5,328.5	4,955.9	372.6	251.4	4.7	5,077.2	95.3
Department of Agriculture	2,037.4	2,020.6	16.8	1,407.9	69.1	629.6	30.9
Department of Commerce	1,293.9	1,092.2	201.7	1,008.4	77.9	285.3	22.1
Department of Transportation	875.8	855.0	20.9	255.4	29.2	620.4	70.8
Department of Homeland Security	718.8	390.8	327.9	441.7	61.4	277.2	38.6
Department of the Interior	717.3	709.3	8.0	635.9	88.6	81.3	11.3
Department of Veterans Affairs	639.0	639.0	0.0	639.0	100.0	0.0	0.0
Environmental Protection Agency	529.7	522.8	7.0	253.8	47.9	276.0	52.1
Department of Education	309.9	309.9	0.0	14.1	4.5	295.8	95.5
Smithsonian Institution	240.3	195.0	45.3	240.3	100.0	0.0	0.0
Agency for International Development	125.5	125.5	0.0	3.8	3.0	121.8	97.1
Department of Justice	118.7	118.7	0.0	45.0	37.9	73.7	62.1
All other agencies	303.7	303.7	0.0	198.6	65.4	105.0	34.6

	FFRDC = federally funded R&D center.
NOTES:	This table lists all agencies with R&D obligations greater than $100 million in FY 2013. R&D is basic research, applied research, and development and does not include R&D plant. Intramural activities include actual intramural R&D performance and costs associated with planning and administering both intramural and extramural programs by federal personnel. Extramural performers include federally funded R&D performed in the United States and U.S. territories by businesses, universities and colleges, other nonprofit institutions, state and local governments, and foreign organizations. All other agencies include Department of Housing and Urban Development, Department of Labor, Department of State, Department of the Treasury, Appalachian Regional Commission, Consumer Product Safety Commission, Federal Communications Commission, Federal Trade Commission, Library of Congress, National Archives and Records Administration, Nuclear Regulatory Commission, and Social Security Administration.
SOURCE:	National Science Foundation, National Center for Science and Engineering Statistics, Survey of Federal Funds for Research and Development, FYs 2013–15.
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Table 4-16 Federal obligations for R&D, by agency and type of work: FY 2013

(Millions of current dollars)

					Percentage of total R&D		
Agency	Total R&D	Basic research	Applied research	Development	Basic research	Applied research	Development
All agencies	125,387.5	29,779.4	29,420.4	66,187.8	23.7	23.5	52.8
Department of Defense	63,557.7	1,862.8	4,092.5	57,602.4	2.9	6.4	90.6
Department of Health and Human Services	29,382.5	15,288.3	14,026.3	67.9	52.0	47.7	0.2
National Aeronautics and Space Administration	10,368.1	2,824.2	2,598.2	4,945.7	27.2	25.1	47.7
Department of Energy	9,841.0	3,851.1	3,482.3	2,507.6	39.1	35.4	25.5
National Science Foundation	4,955.9	4,361.5	594.4	0.0	88.0	12.0	0.0
Department of Agriculture	2,020.6	844.2	1,025.2	151.2	41.8	50.7	7.5
Department of Commerce	1,092.2	190.6	832.6	69.0	17.4	76.2	6.3
Department of Transportation	855.0	7.2	647.5	200.3	0.8	75.7	23.4
Department of Homeland Security	390.8	0.0	140.7	250.2	0.0	36.0	64.0
Department of the Interior	709.3	51.4	551.9	106.0	7.2	77.8	14.9
Department of Veterans Affairs	639.0	249.0	355.0	35.0	39.0	55.6	5.5

					Percentage of total R&D		
Agency	Total R&D	Basic research	Applied research	Development	Basic research	Applied research	Development
Environmental Protection Agency	522.8	0.0	446.2	76.6	0.0	85.4	14.6
Department of Education	309.9	24.4	177.8	107.7	7.9	57.4	34.8
Smithsonian Institution	195.0	195.0	0.0	0.0	100.0	0.0	0.0
Agency for International Development	125.5	9.0	116.5	0.0	7.1	92.9	0.0
Department of Justice	118.7	20.7	57.1	41.0	17.4	48.1	34.5
All other agencies	303.6	0.1	276.4	27.1	0.0	91.0	8.9

NOTES: This table lists all agencies with R&D obligations greater than $100 million in FY 2013. Detail may not add to total because of rounding. All other agencies include Department of Housing and Urban Development, Department of Labor, Department of State, Department of the Treasury, Appalachian Regional Commission, Consumer Product Safety Commission, Federal Communications Commission, Federal Trade Commission, Library of Congress, National Archives and Records Administration, Nuclear Regulatory Commission, and Social Security Administration.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Federal Funds for Research and Development, FYs 2013–15.

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The vast majority ($125.4 billion) was for R&D conduct, whether performed by the intramural R&D facilities of the departments/agencies themselves or by one or more of various extramural performers receiving federal R&D funding (the FFRDCs, private businesses, universities and colleges, state and local governments, other nonprofit organizations, or foreign performers) (Table 4-15). Barely 2% of the annual total ($1.9 billion) funded R&D plant, with most of the obligations in this category coming from a few agencies.

For the $125.4 billion of obligations that year for R&D, 24% was for basic research, 24% for applied research, and 53% for development (Table 4-16). These proportions vary widely, however, when specific departments/agencies are considered.

Department of Defense

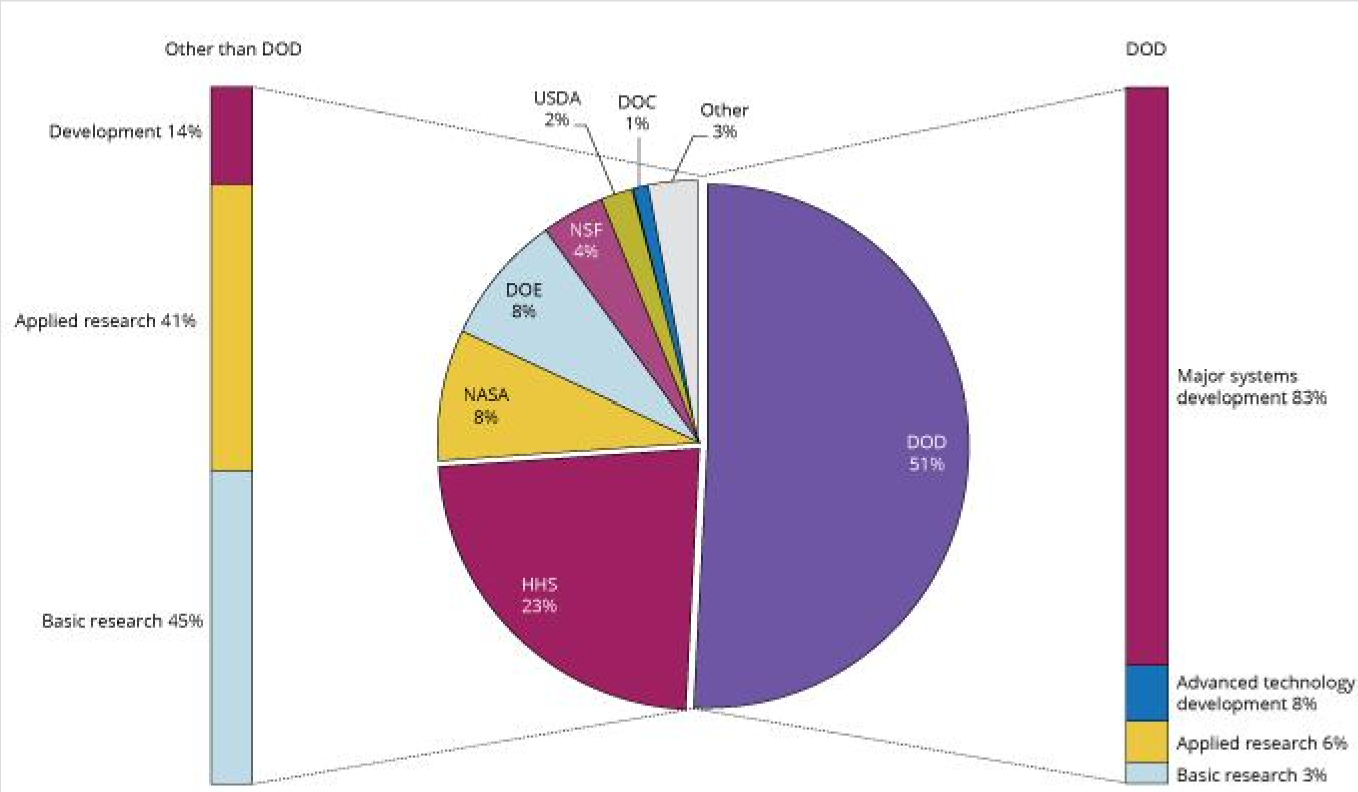
In FY 2013, DOD obligated a total of $63.7 billion for R&D and R&D plant (Table 4-15), which represented about 50% of all federal spending on R&D and R&D plant that year. Nearly the entire DOD total was R&D spending ($63.6 billion), with the remainder spent on R&D plant.

Of the total, 34% ($21.5 billion) was spending by the department's intramural laboratories, related agency R&D program activities, and FFRDCs (Table 4-15). Extramural performers accounted for 66% ($42.1 billion) of the obligations, with the bulk going to business firms ($39.2 billion) (Appendix Table 4-23).

Considering just the R&D, relatively small amounts were spent on basic research ($1.9 billion, 3%) and applied research ($4.1 billion, 6%) in FY 2013 (Table 4-16). The vast majority of obligations, $57.6 billion (91%), went to development. Furthermore, the bulk of this DOD development ($52.7 billion) was allocated for major systems development, which includes the main activities in developing, testing, and evaluating combat systems (Figure 4-12). The remaining DOD development ($4.9 billion) was allocated for advanced technology development, which is more similar to other agencies' development obligations.

Figure 4-12

Federal obligations for R&D, by agency and type of work: FY 2013



DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; USDA = U.S. Department of Agriculture.

NOTE: Detail may not add to total because of rounding.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Federal Funds for Research and Development, FYs 2013–15.

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Department of Health and Human Services

HHS is the main federal source of spending for health-related R&D. In FY 2013, the department obligated $29.5 billion for R&D and R&D plant, or 23% of the total of federal obligations that year. Nearly all of this was for R&D ($29.4 billion). Furthermore, the vast majority, $28.2 billion, supported the R&D activities of the National Institutes of Health (NIH).

For the department as a whole, R&D and R&D plant obligations for agency intramural activities and FFRDCs accounted for 23% ($6.7 billion) of the total. Extramural performers accounted for 77% ($22.9 billion). Universities and colleges ($16.6 billion) and other nonprofit organizations ($4.4 billion) conducted the most sizable of these extramural activities (Appendix Table 4-23).

Nearly all of HHS R&D funding was allocated to research: 52% for basic research and 48% for applied research. Only a tiny fraction, 0.2%, funded development.

National Aeronautics and Space Administration

NASA obligated $10.5 billion to R&D in FY 2013, which was 8% of the federal total. Nearly all of it ($10.4 billion) was for R&D. Of these obligations, 72% were for extramural R&D, which was conducted chiefly by business performers. Agency intramural R&D and that done by FFRDCs represented 28% of the total NASA obligations.

By type-of-R&D, 48% of the NASA R&D obligations funded development activities, 27% funded basic research, and 25% funded applied research.

Department of Energy

DOE obligated $10.4 billion for R&D and R&D plant in FY 2013 or, like NASA, about 8% of the total of federal obligations that year. Of this amount, $9.8 billion was for R&D, and $0.6 billion was for R&D plant.

The department's intramural laboratories and FFRDCs accounted for 75% of the total obligations, a substantially higher percentage than most other agencies. Many of DOE's research activities require specialized equipment and facilities available only at its intramural laboratories and FFRDCs, which are used by scientists and engineers from other agencies and sectors as well as by DOE researchers. The remaining 26% of obligations to extramural performers went chiefly to businesses and to universities and colleges.

Basic research accounted for 39% of the $9.8 billion obligated to R&D, applied research for 35%, and development for 26%.

DOE R&D activities are distributed among domestic energy systems, defense (much of it funded by the department's National Nuclear Security Administration), and general science (much of which is funded by the department's Office of Science).

National Science Foundation

In FY 2013, NSF obligated $5.3 billion for R&D and R&D plant (4% of the federal total): $5.0 billion for R&D and $0.4 billion for R&D plant. Extramural performers, chiefly universities and colleges, accounted for 95% of this total ($5.1 billion). Basic research was about 88% of the R&D component. NSF is the federal government's primary source of funding for academic basic S&E research and the second-largest federal source (after HHS) of R&D funds for universities and colleges.

Department of Agriculture

USDA obligated $2.0 billion for R&D and R&D plant in FY 2013, with the main focus on life sciences. The agency is also one of the largest research funders in the social sciences, particularly agricultural economics. Of USDA's total obligations for FY 2013, about 69% ($1.4 billion) funded R&D by agency intramural performers, chiefly the Agricultural Research Service. Basic research accounts for about 42%, applied research accounts for 51%, and development accounts for 8%.

Department of Commerce

DOC obligated $1.3 billion for R&D in FY 2013, most of which represented the R&D and R&D plant spending of the National Oceanic and Atmospheric Administration and the National Institute of Standards and Technology (NIST): $1.1 billion of the total was for R&D, and $0.2 billion was for R&D plant. Of this total, 78% was for agency intramural R&D; 22% went to extramural performers, primarily businesses and universities and colleges. For the R&D component, 17% was for basic research, 76% was for applied research, and 6% was for development.

Other Departments/Agencies

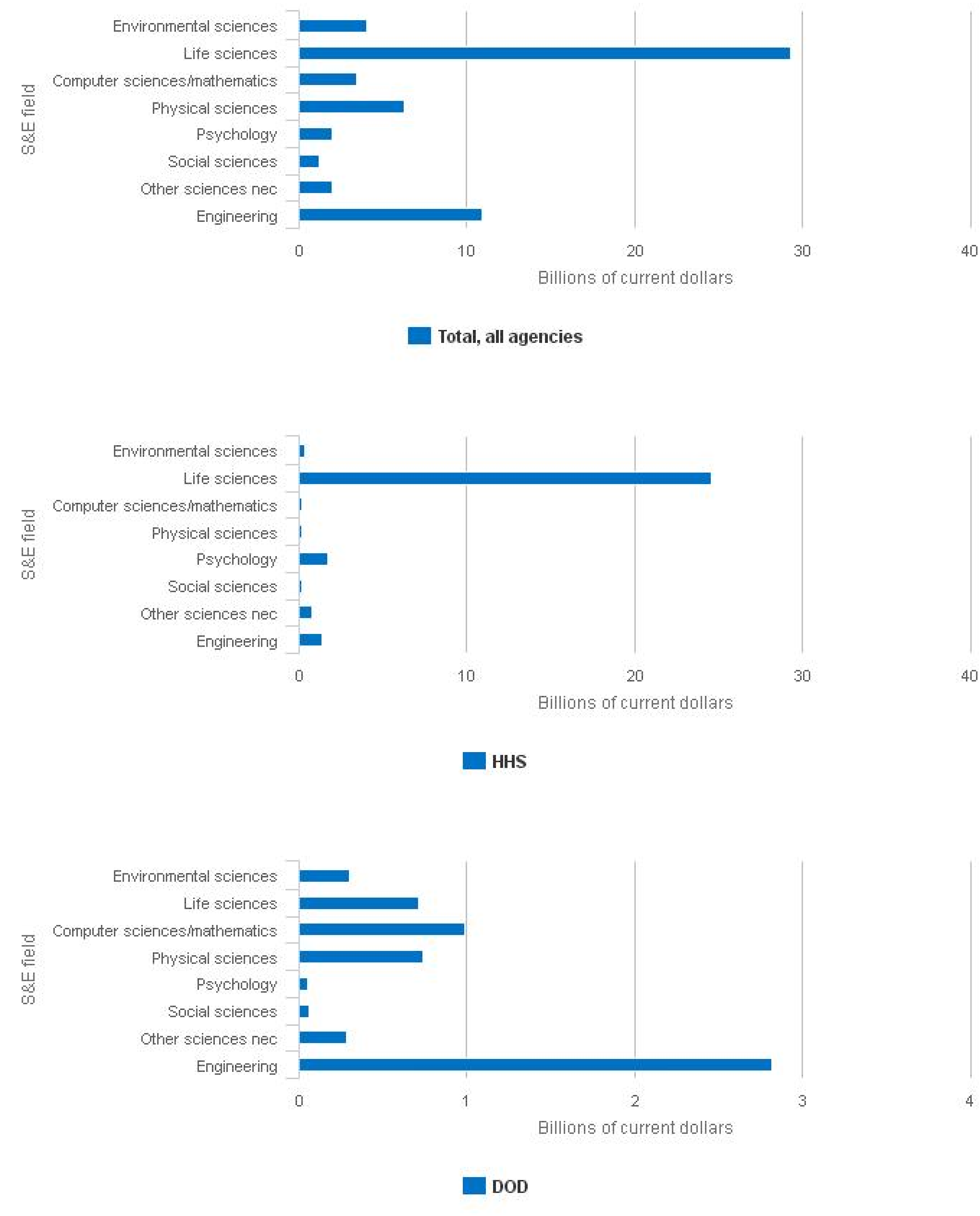
The seven departments/agencies discussed specifically accounted for slightly more than 96% of $127.3 billion of R&D and R&D plant obligations total in FY 2013. The other departments/agencies shown in Table 4-15 and Table 4-16 play significant roles in the overall U.S. R&D system, but individually, they account for comparatively small to very small levels of federal resources annually. (DHS deserves, perhaps, a particular callout in the FY 2013 data, because of its $0.3 billion obligated to R&D plant, which was sizable in comparison with that of other departments/agencies obligating funds for R&D plant that year.) As the tables show, these agencies continue to vary considerably with respect to the character of research and the roles of intramural, FFRDC, and extramural performers.

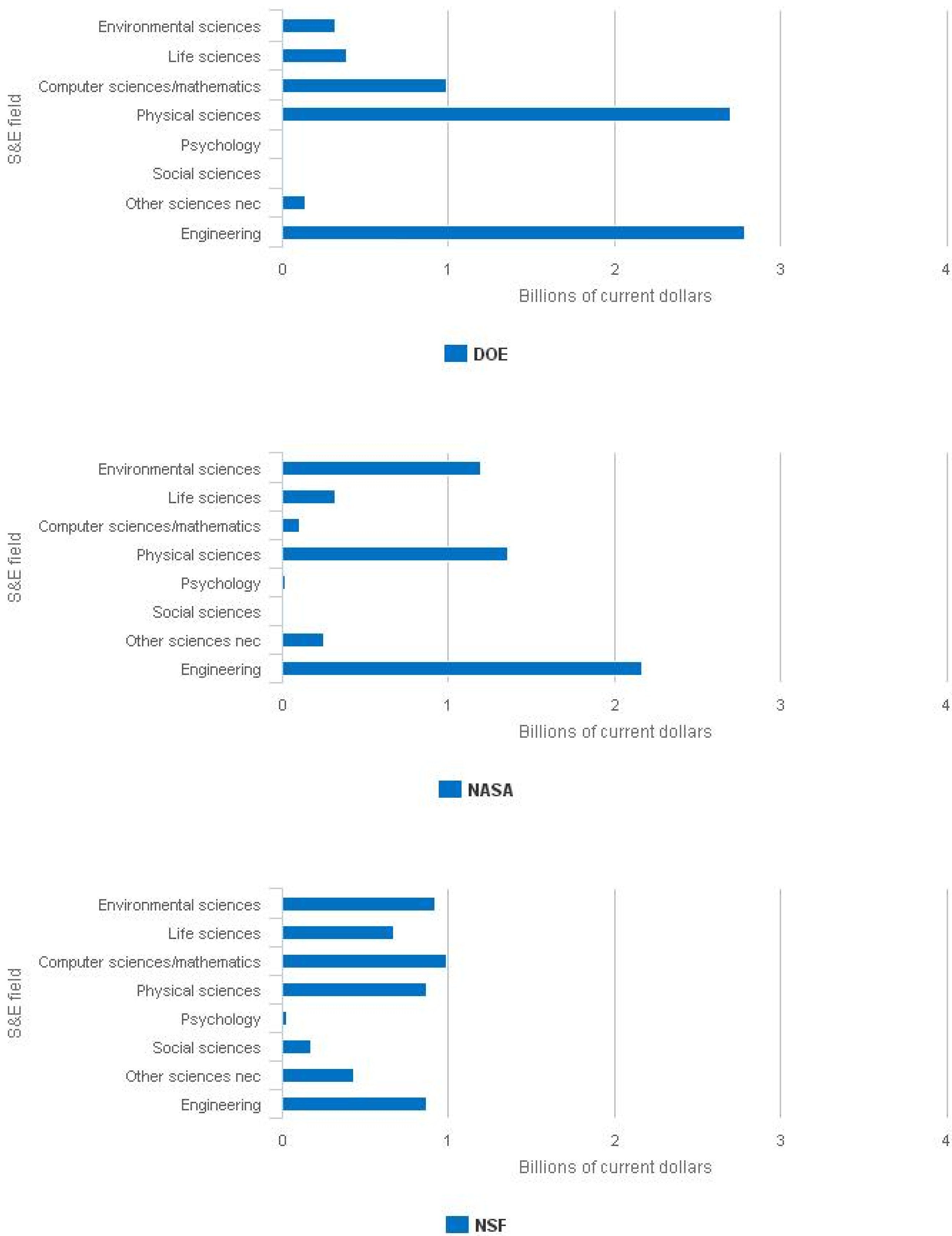
Distribution of Federal Spending for Research, by Fields of S&E

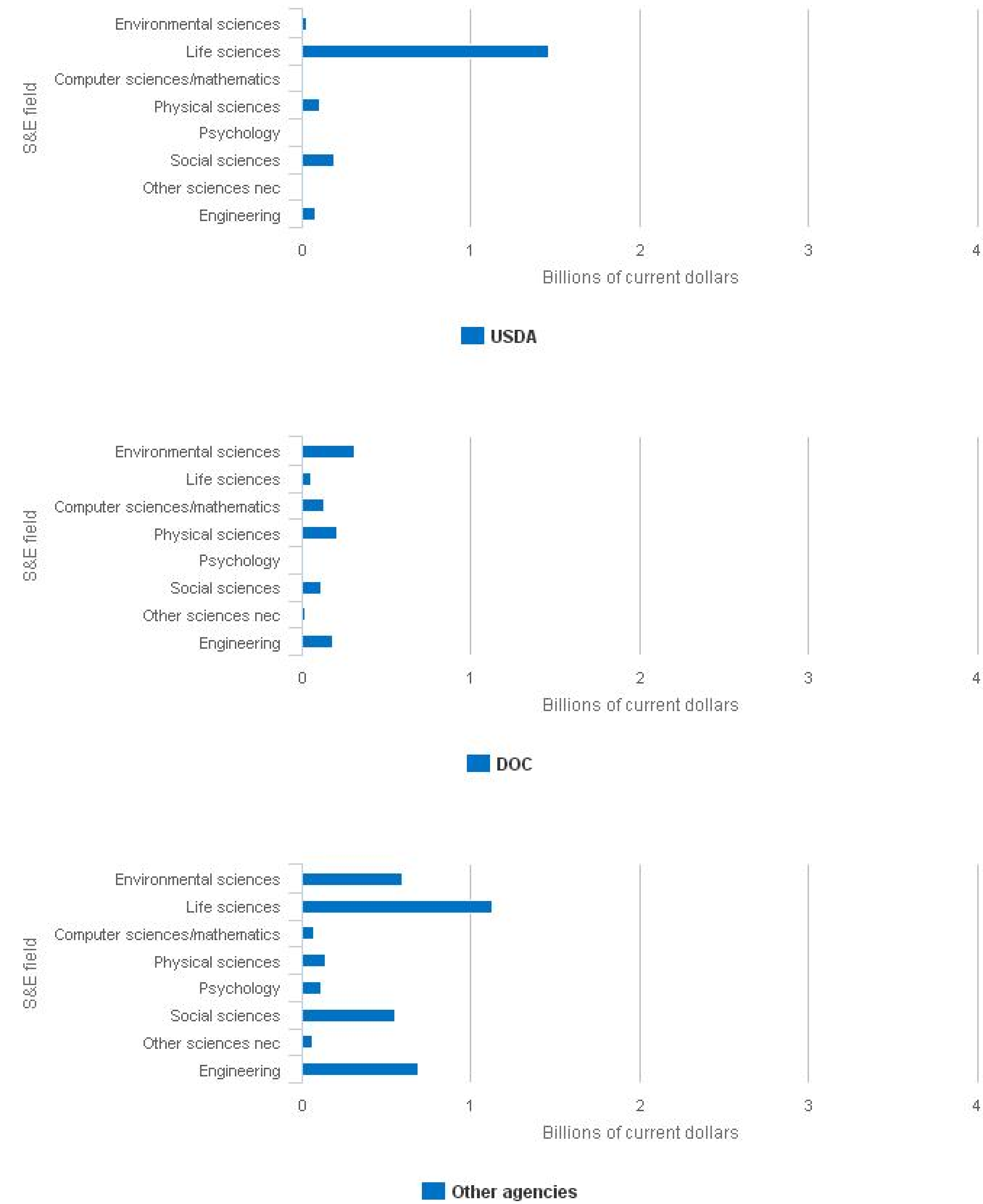
Development work cannot easily be classified by S&E field, but research—basic and applied—can. The research conducted and/or funded by the federal government spans a full range of S&E fields (environmental sciences, computer sciences and mathematics, physical sciences, psychology, social sciences, other sciences, and engineering). The incidence of these fields varies widely with respect to their main federal support agency and current funding levels (Figure 4-13; Appendix Table 4-24 and Appendix Table 4-25).

Figure 4-13

Federal obligations for research, by agency and major S&E field: FY 2013




Environmental sciences
Life sciences
Computer sciences/mathematics
Physical sciences
Psychology
Social sciences
Other sciences nec
Engineering
S&E field
0
1
2
3
4
Billions of current dollars
DOE
Environmental sciences
Life sciences
Computer sciences/mathematics
Physical sciences
Psychology
Social sciences
Other sciences nec
Engineering
S&E field
0
1
2
3
4
Billions of current dollars
NASA
Environmental sciences
Life sciences
Computer sciences/mathematics
Physical sciences
Psychology
Social sciences
Other sciences nec
Engineering
S&E field
0
1
2
3
4
Billions of current dollars
NSF



DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; nec = not elsewhere classified; NSF = National Science Foundation; USDA = U.S. Department of Agriculture.

NOTES: The scales differ for Total, all agencies and HHS compared with the scales for the other agencies listed. Research includes basic and applied research.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Federal Funds for Research and Development, FYs 2013–15. See appendix table 4-24.

Science and Engineering Indicators 2016

In FY 2013, funding for basic and applied research combined accounted for nearly half ($59.2 billion, 47%) of the $125.4 billion total of federal obligations for R&D (Table 4-16). Half of this amount, $29.3 billion, supported research in the life sciences (Appendix Table 4-24). The fields with the next-largest amounts were engineering ($10.9 billion, 18%) and the physical sciences ($6.3 billion, 11%), followed by the environmental sciences ($4.0 billion, 7%) and computer sciences and mathematics ($3.4 billion, 6%). The balance of federal obligations for research in FY 2013 supported psychology, the social sciences, and all other sciences ($5.2 billion overall, or 9% of the total for research).

With differing missions, the federal agencies vary significantly in the types of S&E fields emphasized. HHS accounted for the largest share (50%) of federal obligations for research in FY 2013 (Appendix Table 4-24). Most of this amount funded research in life sciences, primarily through NIH. The six next-largest federal agencies for research funding that year were DOE (12%), DOD (10%), NASA (9%), NSF (8%), USDA (3%), and DOC (2%).

DOE's $7.3 billion in research obligations provided funding for research in the physical sciences ($2.7 billion) and engineering ($2.8 billion), along with computer sciences and mathematics ($1.0 billion). DOD's $6.0 billion of research funding emphasized engineering ($2.8 billion) but also included computer sciences and mathematics ($1.0 billion), physical sciences ($0.7 billion), and life sciences ($0.7 billion). NASA's $5.4 billion for research emphasized engineering ($2.2 billion), followed by the physical sciences ($1.4 billion) and environmental sciences ($1.2 billion). NSF—not a mission agency in the traditional sense—is charged with "promoting the health of science." As such, it had a comparatively diverse $5.0 billion research portfolio that allocated about $0.7 billion to $1.0 billion in each of the following fields: environmental sciences, life sciences, computer sciences and mathematics, physical sciences, and engineering. Lesser amounts were allocated to psychology, social sciences, and other sciences. USDA's $1.9 billion was directed primarily at the life (agricultural) sciences ($1.5 billion). DOC's $1.0 billion was distributed mainly in the fields of environmental sciences, physical sciences, and engineering.

Viewed over the 2000–13 time span, federal obligations for research in all S&E fields increased on average by 3.4% annually (or 1.3% when adjusted for inflation). More recently, research funding levels have been declining, starting in FY 2011, by an average of 1.5% annually through FY 2013 (or down by 2.5% yearly, adjusted for inflation) (Appendix Table 4-25).

The trends within more narrowly defined fields are more nuanced, depending on whether the base year is in the 1990s, 2000, 2005, or a more recent year (Appendix Table 4-25). Looking at only the period of FY 2005–13, the life sciences' share declines from about 52% of the research total in FY 2005 to 50% in FY 2013. (Before FY 2005, the life sciences' share had mainly been rising from year to year.) Over the same period, engineering's share increased from about 16% in FY 2005 to 18% in FY 2013. The share for the other major fields remained mainly stable.

Cross-National Comparisons of Government R&D Priorities

Government R&D funding statistics compiled annually by the OECD provide insights into how national government priorities for R&D differ across countries. Known technically as government budget appropriations or outlays for R&D (GBAORD), this indicator provides data on how a country's overall government funding for R&D splits among a set of socioeconomic categories (e.g., defense, health, space, general research).[i] GBAORD statistics for the United States and most of the other top R&D-performing countries discussed earlier appear in Table 4-17 (corresponding GBAORD data for China and India are not currently available).

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[i] GBAORD classifies total government funding on R&D into the 14 socioeconomic categories specified by the EU's 2007 edition of the Nomenclature for the Analysis and Comparison of Scientific Programmes and Budgets (NABS). These categories are exploration and exploitation of the earth; environment; exploration and exploitation of space; transport, telecommunications, and other infrastructures; energy; industrial production and technology; health; agriculture; education; culture, recreation, religion, and mass media; political and social systems, structures, and processes; general advancement of knowledge: R&D financed from general university funds; general advancement of knowledge: R&D financed from sources other than general university funds; and defense. GBAORD statistics published by the OECD in the *Main Science and Technology Indicators* series report on clusters of these 14 NABS categories.

Table 4-17 **Government R&D support by major socioeconomic objectives, by selected countries/regions and years: 2000–13**

			Percentage of GBAORD		Percentage of nondefense					
Region /country	Year	GBAORD (current PPP US$millions)	Defense	Nondefense	Economic development programs	Health and environment	Education and society	Civil space	Non-oriented research	General university funds
United States	2000	83,612.5	51.6	48.4	13.4	49.9	1.8	20.9	13.8	na
	2010	148,962.0	57.3	42.7	12.5	56.1	1.6	12.9	16.9	na
	2013	132,477.0	52.7	47.3	10.4	54.7	2.9	16.7	15.4	na
EU	2000	77,028.5	12.9	87.1	23.3	11.8	3.5	6.0	17.9	34.9
	2010	117,886.5	6.4	93.6	22.2	14.1	6.5	5.3	18.3	33.2
	2013	117,621.6	4.4	95.6	20.7	14.2	5.5	5.1	18.5	35.1
France	2000	14,747.5	21.4	78.5	17.7	9.7	1.1	13.2	27.4	28.5
	2010	19,093.2	14.7	85.3	21.1	12.6	5.3	12.7	19.6	27.0
	2013	17,540.5	6.3	93.7	17.6	11.4	5.4	10.4	21.2	27.0
Germany	2000	16,817.0	7.8	92.2	21.6	9.4	3.9	5.1	17.5	42.4
	2010	28,896.9	5.0	95.0	24.4	9.2	4.4	5.0	17.0	40.6
	2013	31,961.8	3.7	96.3	22.9	9.8	4.2	4.8	17.7	41.5
United Kingdom	2000	10,520.2	35.7	64.4	14.2	27.7	6.3	3.4	18.3	29.7
	2010	13,529.6	18.2	81.8	8.5	32.3	5.0	2.1	22.0	30.1
	2013	13,744.3	15.9	84.1	15.8	32.0	4.4	3.9	15.8	28.1
Japan	2000	21,193.4	4.1	95.9	33.4	6.6	1.0	5.8	14.6	37.0
	2010	32,150.0	4.8	95.2	27.6	7.4	0.9	7.1	21.0	35.9
	2013	34,679.3	4.6	95.4	25.2	9.0	0.7	6.5	21.7	36.9
South Korea	2000	5,020.2	20.5	79.5	53.4	14.8	3.8	3.1	24.9	**

			Percentage of GBAORD		Percentage of nondefense					
Region /country	Year	GBAORD (current PPP US$millions)	Defense	Nondefense	Economic development programs	Health and environment	Education and society	Civil space	Non-oriented research	General university funds
	2010	14,225.6	15.8	84.2	49.5	13.8	2.7	2.7	31.3	**
	2011	15,265.4	16.3	83.7	49.9	14.1	2.7	2.4	30.9	**

** = included in other categories; na = not applicable.

EU = European Union; GBAORD = government budget appropriations or outlays for R&D; PPP = purchasing power parity.

NOTES: Foreign currencies are converted to dollars through PPPs. The GBAORD statistics reported for the United States are federal budget authority data. The most recent data available for South Korea are from 2011. GBAORD data are not yet available for China or India. The socioeconomic objective categories are aggregates of the 14 categories identified by Eurostat's 2007 Nomenclature for the Analysis and Comparison of Scientific Programmes and Budgets. The data are as reported by the Organisation for Economic Co-operation and Development (OECD).

SOURCE: OECD, *Main Science and Technology Indicators* (2014/2), http://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB, accessed 3 March 2015.

Science and Engineering Indicators 2016

Defense is an objective for government funding of R&D for all the top R&D-performing countries, but the shares vary considerably (Table 4-17). Defense accounted for 53% of U.S. federal R&D support in 2013, but it was markedly lower elsewhere: a smaller but still sizable 16% in South Korea and 16% in the United Kingdom, and below 7% in France, Germany, and Japan.

Defense has received 50% or more of the federal R&D budget in the United States for many years. It was 63% in 1990 as the Cold War period drew to a close, but then dropped in subsequent years. It rose again in the first decade of the 2000s—in large part, reflecting post–9/11 security concerns—but it has been declining again over the last several years. For the other countries, the defense share of government R&D funding has generally declined or remained at a stable, low level.

The health and environment objective accounted for almost 55% of nondefense federal R&D budget support in the United States in FY 2013 and 32% in the United Kingdom. For both countries, the share has expanded markedly over the share prevailing several decades ago. The health and environment share is currently 14% in South Korea and 11% or less in France, Germany, and Japan.

The economic development objective encompasses agriculture, energy, fisheries and forestry, industry, transportation, telecommunications, and other infrastructure. In the United States, government R&D funding in this category was 13% of all nondefense federal support for R&D in 2000 but had dropped to 10% in 2013, substantially lower than most other major nations (Table 4-17).[ii] In the United Kingdom, it was 14% in 2000, declining from 2000 to 2010, but rising to 16% in 2013. France had 18% in 2000, rising to 21% by 2010, but declining back to 18% by 2013. Japan had 33% in 2000, but generally declined in the years after, to 25% in 2013. Germany had 22% in 2000, rising to 23% in 2013. South Korea, 50% in 2011, has consistently exhibited the largest share for this category in 2011 among the top R&D-performing countries.

The civil space objective accounted for about 17% of nondefense federal R&D funding in the United States in 2000 (Table 4-17). The share was 21% in 2000 and declined to 13% by 2010 but has experienced increases more recently. The share in France is about 10% for 2013, down from 13% in 2000. The space share has been well below 10% for the rest of the top R&D-performing countries.

Both the nonoriented research funding and general university fund (GUF) objectives reflect government support for R&D by academic, government, and other performers that is directed chiefly at the "general advancement of knowledge" in the natural sciences, engineering, social sciences, humanities, and related fields. For some of the countries, the sum of these two objectives currently represents by far the largest part of nondefense GBAORD: Germany (59%), Japan (59%), France (48%), the United Kingdom (44%), and South Korea (31%). The corresponding 2013 share for the United States (15%), although appearing substantially smaller, requires interpretive caution. Cross-national comparisons of these particular indicators can be difficult because some countries (notably the United States) do not use the GUF mechanism to fund R&D for general advancement of knowledge, do not separately account for GUF (e.g., South Korea), and/or more typically direct R&D funding to project-specific grants or contracts, which are then assigned to the more specific socioeconomic objectives (see sidebar, Government Funding Mechanisms for Academic Research).

Finally, the education and society objective represents a comparatively small component of nondefense government R&D funding for all of the top R&D-performing countries. However, it is notably higher in France (5%), Germany (4%), and the United Kingdom (4%) than in Japan (1%). The United States (3%) and South Korea (3%) are in between.

[ii] Some analysts argue that the relatively low nondefense GBAORD share for economic development in the United States reflects the expectation that businesses will finance industrial R&D activities with their own funds. Moreover, government R&D that may be useful to industry is often funded with other purposes in mind, such as defense and space, and then classified in these other socioeconomic objectives.

Government Funding Mechanisms for Academic Research

U.S. universities generally do not maintain data on departmental research (i.e., research that is not separately budgeted and accounted for). As such, U.S. R&D totals are understated relative to the R&D effort reported for other countries. The national totals for Europe, Canada, and Japan include the research component of general university fund (GUF) block grants provided by all levels of government to the academic sector. These funds can support departmental R&D programs that are not separately budgeted. GUF is not equivalent to basic research. The U.S. federal government does not provide research support through a GUF equivalent, preferring instead to support specific, separately budgeted R&D projects. However, some state government funding probably does support departmental research, not separately accounted for, at U.S. public universities.

The treatment of GUF is one of the major areas of difficulty in making international R&D comparisons. In many countries, governments support academic research primarily through large block grants that are used at the discretion of each higher education institution to cover administrative, teaching, and research costs. Only the R&D component of GUF is included in national R&D statistics, but problems arise in identifying the amount of the R&D component and the objective of the research. Moreover, government GUF support is in addition to support provided in the form of earmarked, directed, or project-specific grants and contracts (funds that can be assigned to specific socioeconomic categories).

In several large European countries (France, Germany, Italy, and the United Kingdom), GUF accounts for 50% or more of total government R&D funding to universities. In Canada, GUF accounts for about 38% of government academic R&D support. Thus, international data on academic R&D reflect not only the relative international funding priorities but also the funding mechanisms and philosophies regarded as the best methods for financing academic research.

Federal Programs to Promote the Transfer and Commercialization of Federal R&D

Starting in the late 1970s, concerns by domestic policymakers about the strength of U.S. industries and their ability to succeed in the increasingly competitive global economy took on greater intensity. The issues raised included whether the new knowledge and technologies arising from federally funded R&D were being fully and effectively exploited for the benefit of the national economy, whether undue barriers in the private marketplace worked to slow businesses in creating and commercializing innovations and new technologies, and whether better public-private partnerships for R&D and business innovation had the potential to significantly aid the nation's economy in responding to these emerging challenges (Tassey 2007).

Numerous national policies and related initiatives have been directed at these challenges over the last 30 years, including how to better transfer and economically exploit the results of federally funded R&D—and how to avoid unduly placing government in positions to substitute for private business decisions better left to the competitive marketplace (see sidebar, Major Federal Policies Promoting Technology Transfer and Commercialization of R&D). One major national policy thrust has been to enhance formal mechanisms for transferring knowledge arising from federally funded and performed R&D (Crow and Bozeman 1998; National Research Council [NRC] 2003). Other policies have been directed toward strengthening the prospects for the development and flow of early-stage technologies into the commercial marketplace, accelerating the commercial exploitation of academic R&D, and facilitating the conduct of R&D on ideas and technologies with commercial potential by entrepreneurial small and/or minority-owned businesses.

The sections immediately following focus on this theme of the transfer and commercial exploitation of federally funded R&D and review status indicators for several major federal policies and programs directed at these objectives. (Chapter 5 contains related information about S&E publications and the patents arising from academic research.)

Major Federal Policies Promoting Technology Transfer and Commercialization of R&D

Technology Innovation Act of 1980 (Stevenson-Wydler Act) (P.L. 96–480)—Established technology transfer as a federal government mission by directing federal laboratories to facilitate the transfer of federally owned and originated technology to nonfederal parties.

University and Small Business Patent Procedures Act of 1980 (Bayh-Dole Act) (P.L. 96–517)—Permitted small businesses, universities, and nonprofits to obtain titles to inventions developed with federal funds. Also allowed government-owned and government-operated laboratories to grant exclusive patent rights to commercial organizations.

Small Business Innovation Development Act of 1982 (P.L. 97–219)—Established the Small Business Innovation Research (SBIR) program, which required federal agencies to set aside funds for small businesses to engage in R&D connected to agency missions.

National Cooperative Research Act of 1984 (P.L. 98–462)—Encouraged U.S. firms to collaborate in generic precompetitive research by establishing a rule of reason for evaluating the antitrust implications of research joint ventures.

Patent and Trademark Clarification Act of 1984 (P.L. 98–620)—Provided further amendments to the Stevenson-Wydler Act and the Bayh-Dole Act regarding the use of patents and licenses to implement technology transfer.

Federal Technology Transfer Act of 1986 (P.L. 99–502)—Enabled federal laboratories to enter Cooperative R&D Agreements (CRADAs) with outside parties and to negotiate licenses for patented inventions made at the laboratory.

Executive Order 12591, Facilitating Access to Science and Technology (April 1987)—Issued by President Reagan, this executive order sought to ensure that the federal laboratories implemented technology transfer.

Omnibus Trade and Competitiveness Act of 1988 (P.L. 100–418)—Directed attention to public-private cooperation on R&D, technology transfer, and commercialization (in addition to measures on trade and intellectual property protection). Also established the Hollings Manufacturing Extension Partnership (MEP) program at NIST.

National Competitiveness Technology Transfer Act of 1989 (P.L. 101–189)—Amended the Federal Technology Transfer Act to expand the use of CRADAs to include government-owned, contractor-operated federal laboratories and to increase nondisclosure provisions.

Small Business Innovation Development Act of 1992 (P.L. 102–564)—Reauthorized the existing SBIR program, increasing both the percentage of an agency's budget to be devoted to SBIR and the maximum level of awards. Also established the Small Business Technology Transfer (STTR) program to enhance opportunities for collaborative R&D efforts between government-owned, contractor-operated federal laboratories and small businesses, universities, and nonprofit partners.

National Cooperative Research and Production Act of 1993 (P.L. 103–42)—Relaxed restrictions on cooperative production activities, enabling research joint venture participants to work together on jointly acquired technologies.

National Technology Transfer and Advancement Act of 1995 (P.L. 104–113)—Amended the Stevenson-Wydler Act to make CRADAs more attractive to federal laboratories, scientists, and private industry.

Technology Transfer Commercialization Act of 2000 (P.L. 106–404)—Broadened CRADA licensing authority to make such agreements more attractive to private industry and to increase the transfer of federal technology. Established technology transfer performance reporting requirements for agencies with federal laboratories.

America COMPETES Act of 2007 (America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Sciences [COMPETES] Act) (P.L. 110–69)—Authorized increased investment in R&D; strengthened educational opportunities in science, technology, engineering, and mathematics from elementary through graduate school; and further promoted the nation's innovation infrastructure. Among various provisions, the act created the Advanced Research Projects Agency–Energy (ARPA-E) to promote and fund R&D on advanced energy technologies; it also called for a President's Council on Innovation and Competitiveness.

America COMPETES Reauthorization Act of 2010 (P.L. 111–358)—Updated the America COMPETES Act of 2007 and authorized additional funding to science, technology, and education programs over the succeeding 3 years. Numerous provisions were intended to broadly strengthen the foundation of the U.S. economy, create new jobs, and increase U.S. competitiveness abroad.

Presidential Memorandum—Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Businesses (October 2011)—Issued by President Obama, this memorandum directed a variety of actions by federal departments and agencies to establish goals and measure performance, streamline administrative processes, and facilitate local and regional partnerships to accelerate technology transfer and support private-sector commercialization.

Federal Technology Transfer

Technology transfer is "the process by which technology or knowledge developed in one place or for one purpose is applied and used in another place for the same or different purpose" (Federal Laboratory Consortium for Technology Transfer [FLC] 2011:3). As applied in the federal setting, technology transfer can occur through varied channels: *commercial transfer* (the movement of knowledge or technology developed by a federal laboratory to private organizations or the commercial marketplace) *scientific dissemination* (publications, conference papers, and working papers distributed through scientific/technical channels; or other forms of data dissemination) the *export of resources* (federal laboratory personnel made available to outside organizations with R&D needs, through collaborative agreements or other service mechanisms) the *import of resources* (outside technology or expertise brought in by a federal laboratory to enhance existing internal capabilities) and *dual use* (development of technologies, products, or families of products with both commercial and federal [mainly military] applications).

The Stevenson-Wydler Act of 1980 (P.L. 96–480) directed federal agencies with laboratory operations to become active in the technology transfer process. It also required these agencies to establish technology transfer offices (termed Offices of Research and Technology Applications) to assist in identifying transfer opportunities and establishing appropriate arrangements for transfer relationships with nonfederal parties. Follow-on legislation in the 1980s through 2000 amending the Stevenson-Wydler Act has worked to extend and refine the authorities available to the agencies and their federal laboratories to identify and manage intellectual assets created by their R&D and to participate in collaborative R&D relationships with nonfederal parties, including private businesses, universities, and nonprofit organizations (FLC 2011).

The metrics on federal technology transfer continue to primarily track the number of activities—that is, invention disclosures, patent applications and awards, licenses to outside parties of patents and other intellectual property, and agreements to conduct collaborative research with outside parties (Institute for Defense Analyses Science and Technology Policy Institute 2011). Nonetheless, systematic documentation of the downstream outcomes and impacts of transfer remains a challenge.[i] Also missing for most agencies and their laboratories are comprehensive data on technology transfer through the *scientific dissemination* mode (i.e., technical articles published in professional journals, conference papers, and other kinds of scientific communications), which remains widely regarded by laboratory scientists, engineers, and managers (federal and private sector) as a key means of transfer.

Six agencies continue to account for most of the annual total of federal technology transfer activities: DOD, HHS, DOE, NASA, USDA, and DOC. Technology transfer statistics for these agencies for FY 2012 (the latest data year available) with comparisons with FYs 2006 and 2009 appear in Table 4-18. (Similar statistics for a larger set of agencies, going back to FY 2001, appear in Appendix Table 4-26.) Consistent with the agencies' statutory annual reports, these statistics span mainly the activity areas of invention disclosures and patenting, intellectual property licensing, and collaborative relationships for R&D.

[i] Data on technology transfer metrics such as these are now increasingly available. Nonetheless, the federal technology transfer community has long recognized that counts of patent applications and awards, intellectual property licenses, CRADAs, and the like do not usually of themselves provide a reasonable gauge of the downstream outcomes and impacts that eventually result from transfers––many of which involve considerable time and numerous subsequent developments to reach full fruition. Literature on federal technology transfer success stories is growing, facilitated in part by the annual agency technology transfer performance reporting mandated by the Technology Transfer Commercialization Act of 2000 and through regularly updated reports by technology transfer professional organizations such as the FLC. Even so, the documentation of these downstream outcomes and impacts remains well short of being complete.

Table 4-18 **Federal laboratory technology transfer activity indicators, total and for selected agencies: FYs 2006, 2009, and 2012**

(Number)

Technology transfer activity	All federal laboratories	DOD	HHS	DOE	NASA	USDA	DOC
	FY 2012						
Invention disclosures and patenting							
Inventions disclosed	5,149	1,037	252	1,661	1,582	160	52
Patent applications	2,346	888	222	780	139	122	21
Patents issued	1,808	667	372	483	136	70	12
Licensing							
All licenses, total active in the FY	13,405	520	1,465	5,328	4,870	384	41
Invention licenses	4,029	432	1,090	1,428	434	341	41
Other intellectual property licenses	9,376	88	375	3,900	4,436	43	0
Collaborative relationships for R&D							
CRADAs, total active in the FY	8,812	2,400	377	742	0	257	2,934
Traditional CRADAs	4,288	1,328	245	742	0	180	156
Other collaborative R&D relationships	21,677	0	0	0	4,245	14,351	2,782
	FY 2009						
Invention disclosures and patenting							
Inventions disclosed	4,452	831	389	1,439	1,412	143	41
Patent applications	1,957	690	156	775	141	123	20
Patents issued	1,319	404	397	363	93	24	7
Licensing							
All licenses, total active in the FY	12,596	432	1,584	5,742	4,181	330	40
Invention licenses	3,851	386	1,304	1,452	146	302	40

Technology transfer activity	All federal laboratories	DOD	HHS	DOE	NASA	USDA	DOC
Other intellectual property licenses	8,745	46	280	4,290	4,035	28	0
Collaborative relationships for R&D							
CRADAs, total active in the FY	7,756	2,870	457	744	1	259	2,397
Traditional CRADAs	4,296	2,247	284	744	1	207	101
Other collaborative R&D relationships	17,649	1	0	0	4,507	10,306	2,828
	FY 2006						
Invention disclosures and patenting							
Inventions disclosed	5,193	1,056	442	1,694	1,749	105	14
Patent applications	1,912	691	166	726	142	83	5
Patents issued	1,284	472	164	438	85	39	7
Licensing							
All licenses, total active in the FY	10,186	444	1,535	5,916	2,856	332	111
Invention licenses	4,163	438	1,213	1,420	308	332	111
Other intellectual property licenses	6,023	6	322	4,496	2,548	0	0
Collaborative relationships for R&D							
CRADAs, total active in the FY	7,268	2,999	164	631	1	195	3,008
Traditional CRADAs	3,666	2,424	92	631	1	163	149
Other collaborative R&D relationships	9,738	0	0	0	4,275	3,477	2,114

NOTES: CRADA = Cooperative R&D Agreement; DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; USDA = U.S. Department of Agriculture.

Other federal agencies not listed but included in the All federal laboratories totals are Department of Homeland Security, Department of the Interior, Department of Transportation, Department of Veterans Affairs, and Environmental Protection Agency. Invention licenses refer to inventions that are patented or could be patented. Other intellectual property refers to intellectual property protected through mechanisms other than a patent (e.g., copyright). Total CRADAs refers to all agreements executed under CRADA authority (15 USC 3710a). Traditional CRADAs are collaborative R&D partnerships between a federal laboratory and one or more nonfederal organizations. Federal agencies have varying authorities for other kinds of collaborative R&D relationships.

SOURCE: National Institute of Standards and Technology, U.S. Department of Commerce, *Federal Laboratory Technology Transfer, Fiscal Year 2012 Summary Report to the President and the Congress*, December 2014, http://nist.gov/tpo/publications/upload/Federal-Laboratory-TT-Report-FY2012.pdf. See appendix table 4-26.

Science and Engineering Indicators 2016

As the distribution of the statistics across the activity types in Table 4-18 shows, most agencies engage in all of the transfer activity types to some degree, but the emphases differ. Some agencies (e.g., HHS, DOE, NASA) are more intensive in patenting and licensing activities; some (e.g., DOD, USDA, DOC) place greater emphasis on transfer through collaborative R&D relationships. Some agencies have unique transfer authorities that can confer practical advantages. NASA, for example, can establish collaborative R&D relationships through special authorities it has under the National Aeronautics and Space Act of 1958; USDA has a number of special authorities for establishing R&D collaborations other than Cooperative R&D Agreements (CRADAs); DOE has contractor-operated national laboratories, with nonfederal staff, that are not constrained by the normal federal limitation on copyright by federal employees and can use copyright to protect and transfer computer software. In general, the mix of technology transfer activities pursued by each agency reflects a broad range of considerations such as agency mission priorities, the technologies principally targeted for development, the intellectual property protection tools and policies available, and the types of external parties through which transfer and collaboration are chiefly pursued.

Small Business Innovation-Related Programs

The Small Business Innovation Research (SBIR) program and Small Business Technology Transfer (STTR) program are longstanding federal programs that provide competitively awarded funding to small businesses for purposes including stimulating technological innovation, addressing federal R&D needs, increasing private-sector commercialization of innovations flowing from federal R&D, and fostering technology transfer through cooperative R&D between small businesses and research institutions. The U.S. Small Business Administration provides overall coordination for both programs, with implementation by the federal agencies that participate (SBA 2015).

The SBIR program was established by the Small Business Innovation Development Act of 1982 (P.L. 97–219) for the purpose of stimulating technological innovation by increasing the participation of small companies in federal R&D projects, increasing private-sector commercialization of innovation derived from federal R&D, and fostering participation by minority and disadvantaged persons in technological innovation. The program has subsequently received several extensions from Congress and is now authorized through 2017. Eleven federal agencies currently participate in the SBIR program: USDA, DOC, DOD, the Department of Education, DOE, HHS, DHS, DOT, EPA, NASA, and NSF.

The STTR program was established by the Small Business Technology Transfer Act of 1992 (P.L. 102–564, Title II) for the purpose of facilitating cooperative R&D by small businesses, universities, and nonprofit research organizations and encouraging the transfer of technology developed through such research by entrepreneurial small businesses. Congress has likewise provided a number of extensions since then, with the program continuing through 2017. Five federal agencies currently participate in the STTR program: DOD, DOE, HHS, NASA, and NSF.

For SBIR, federal agencies with extramural R&D budgets exceeding $100 million annually must currently (FY 2015) set aside at least 2.9% for awards to U.S.-based small businesses (defined as those with fewer than 500 employees, including any affiliates). (The set-aside minimum was 2.5% for FYs 1997–2011, rising incrementally to 2.9% in FY 2015, 3.0% in FY 2016, and 3.2% in FY 2017.) Three phases of activities are recognized. In Phase I, a small company can apply for a Phase I funding award (normally not exceeding $150,000) for up to 6 months to assess the scientific and technical feasibility of an idea with commercial potential. Based on the scientific/technical achievements in Phase I and continued expectation of commercial potential, the company can apply for Phase II funding (normally not exceeding $1 million) for 2 years of further development. Where the Phase I and II results warrant, the company pursues a course toward Phase III commercialization. The SBIR program itself does not provide funding for Phase III, but depending on the agency, Phase III may involve non-SBIR-funded R&D or production contracts for products, processes, or services intended for use by the federal government. Several agencies offer bridge funding to Phase III and other commercialization support for startups (NRC 2008:208–16).

The initial round of SBIR awards was for FY 1983. It yielded 789 Phase I awards, across the participating agencies, for a total of $38.1 million of funding (Table 4-19; Appendix Table 4-27 and Appendix Table 4-28). But the program expanded considerably in subsequent years. To date, the peak in awards was FY 2003, when the annual total of awards was 6,844 (5,100 Phase I awards and 1,744 Phase II awards), with total funding of $1.743 billion ($467 million for Phase I awards and $1.275 billion for Phase II awards). In FY 2013, the award total was 4,452 (2,999 Phase I awards and 1,453 Phase II awards), with total funding of $1.772 billion ($486 million for Phase I awards and $1.286 billion for Phase II awards). In FY 2013, the majority of the funding reflected awards by DOD (44%) and HHS (33%) (Appendix Table 4-28). DOE (8%), NSF (6%), and NASA (5%) accounted for smaller shares. The other six participating agencies were 1% or less of the total.

Table 4-19 **SBIR and STTR awards, number and funding, by type of award: Selected years, FYs 1983–2013**

	Number of awards			Funding ($millions)		
Fiscal year	Total	Phase I	Phase II	Total	Phase I	Phase II
SBIR						
1983	789	789	0	38.1	38.1	0.0
1985	1,838	1,483	355	195.3	74.5	120.8
1990	3,220	2,374	846	453.3	120.9	332.4
1995	4,367	3,092	1,275	962.2	236.5	725.8
2000	5,286	3,941	1,345	1,058.9	293.7	765.1
2005	6,085	4,216	1,869	1,862.5	452.5	1,410.0
2010	6,194	4,255	1,939	2,197.9	546.8	1,651.1
2011	5,399	3,629	1,770	2,030.5	507.7	1,522.8
2012	5,005	3,417	1,588	1,984.5	561.7	1,422.8
2013	4,452	2,999	1,453	1,771.8	485.5	1,286.3
STTR						
1983	na	na	na	na	na	na
1985	na	na	na	na	na	na
1990	na	na	na	na	na	na
1995	1	1	0	0.1	0.1	0.0
2000	410	315	95	64.0	23.7	40.3
2005	801	579	222	226.4	66.1	160.3
2010	905	625	280	298.6	77.5	221.1
2011	708	468	240	259.4	67.7	191.7
2012	636	467	169	218.0	73.1	144.9
2013	640	455	185	206.2	74.1	132.1

NOTES: na = not applicable.
SBIR = Small Business Innovation Research program; STTR = Small Business Technology Transfer program.
The first SBIR program awards were made in FY 1983. The first STTR program award was made in FY 1995.

SOURCE:	U.S. Small Business Administration, SBIR/STTR official website, http://www.sbir.gov/awards/annual-reports, accessed 26 February 2015. See appendix table 4-27, appendix table 4-28, and appendix table 4-29. *Science and Engineering Indicators 2016*

For the STTR program, federal agencies with extramural R&D budgets that exceed $1 billion annually must currently (FYs 2014 and 2015) reserve not less than 0.4% for STTR awards to small businesses. (The set-aside minimum was 0.3% for FYs 2004–11, rising incrementally to 0.4% in FYs 2014–15, and to 0.45% in FY 2016 and thereafter.) STTR operates within the same three-phase framework as SBIR. Phase I provides awards for company efforts to establish the technical merit, feasibility, and commercial potential of proposed projects; the funding in this phase normally does not exceed $100,000 over 1 year. Phase II is for continued R&D efforts, but award depends on success in Phase I and continued expectation of commercial potential. Phase II funding normally does not exceed $750,000 over 2 years. Phase III is for the small business to pursue commercialization objectives, based on the Phase I and II results. The STTR program does not provide funding for Phase III activities. Furthermore, to pursue Phase III, companies must secure non-STTR R&D funding and/or production contracts for products, processes, or services for use by the federal government.

The STTR program started with a single Phase I award for $100,000 in FY 1995 (Table 4-19; Appendix Table 4-27 and Appendix Table 4-29). This program has also expanded considerably in subsequent years. The peak years to date for number of awards were FY 2004 with a total of 903 awards (719 Phase I awards and 184 Phase II awards) and FY 2010 with 905 awards (625 Phase I awards and 280 Phase II awards). The total of funding in FY 2004 was $206 million ($82 million for Phase I awards and $123 million for Phase II awards) and $299 million in FY 2010 ($78 million for Phase I and $221 million for Phase II). In FY 2013, 640 awards were made (455 for Phase I and 185 for Phase II), with funding totaling $206 million ($74 million for Phase I and $132 million for Phase II). Fewer federal agencies participate in STTR, but those dominant in SBIR are also dominant in STTR. STTR awards from DOD accounted for 47% of the $206 million award total in FY 2013 (Appendix Table 4-29). HHS accounted for 32% of the STTR awards, and the remaining awards were from DOE (10%), NASA (7%), and NSF (4%).

Other Programs

The federal policies, authorities, and incentives established by the Stevenson-Wydler Act (and the subsequent amending legislation) and the SBIR and STTR programs are far from the whole of federal efforts to promote the transfer and commercialization of federal R&D. Numerous programs for these purposes exist in the federal agencies. Given the specifics of agency missions, they have a narrower scope and smaller pools of resources. Several examples are described subsequently.

The **Hollings Manufacturing Extension Partnership (MEP)** is a nationwide network of manufacturing extension centers located in all 50 U.S. states and Puerto Rico. MEP was created by the Omnibus Trade and Competitiveness Act of 1988 (P.L. 100–418) and is headed by DOC's NIST (NIST 2015). The MEP centers (which are nonprofit) exist as a partnership among the federal government, state and local governments, and the private sector. MEP provides technical expertise and other services to small and medium-sized U.S. manufacturers to improve their ability to develop new customers, expand into new markets, and create new products. The centers work directly with manufacturers to engage specific issues, including technology acceleration, process improvements, innovation strategies, workforce training, supply-chain development, and exporting. They also serve to connect manufacturers with universities and research laboratories, trade associations, and other relevant public and private resources. The MEP annual report for FY 2013 describes the national network of MEP centers as operating with a total budget of about $300 million annually—$123 million from the federal government (with more than three-quarters going to the centers), with the balance from state and local governments and the private sector (NIST 2014). The MEP report indicates that technical expertise and other services were provided during FY 2013 to 31,131 U.S.

manufacturing companies and attributes impacts of $8.4 billion in increased or retained sales, 62,703 increased or retained jobs, and $1.2 billion in cost savings for these businesses. (These services and impacts metrics are comparable with the reports of recent previous years.)

DOE's **Advanced Research Projects Agency–Energy (ARPA-E)** provides funding, technical assistance, and market development to advance high-potential, high-impact energy technologies that are too early stage for private-sector investment (DOE 2015). The main interest is energy technology projects with the potential to radically improve U.S. economic security, national security, and environmental quality––in particular, short-term research that can have transformational impacts, not basic or incremental research. ARPA-E was authorized by the America COMPETES Act of 2007 (P.L. 110–69), and it received $400 million of initial funding through the ARRA (P.L. 111–5). Federal funding (appropriations) for ARPA-E was $180 million in FY 2011, $275 million in FY 2012, and $250 million in FY 2013 (appropriated at $265 million that fiscal year, but received funding was reduced because of the budget sequestration applied across the board to FY 2013 appropriations). ARPA-E's annual report for FY 2013 (the most recent available) indicated 71 new project awards in FY 2013—with a total of 362 funded projects and $900 million of funding since the program's inception (DOE 2014). The program currently identifies 18 focused and 2 open project areas, with topics including advanced batteries, energy storage technologies, improved building energy efficiencies, biofuels, and solar energy.

NSF's **Industry/University Cooperative Research Centers (I/UCRC)** Program supports industry/university partnerships for the conduct of industrially relevant fundamental research, collaborative education, and the transfer of university-developed ideas, research results, and technology to industry (NSF 2015). NSF supports I/UCRC through partnership mechanisms where, according to NSF, the federal funding is typically multiplied 10 to 15 times by supplementary funding from businesses and other nonfederal sources. The I/UCRC Program reports that there are currently 60 such centers across the United States, with more than 1,000 nonacademic members: 85% are industrial firms, with the remainder consisting of state governments, national laboratories, and other federal agencies. NSF funding to I/UCRC was about $15 million in FY 2011. Research is prioritized and executed in cooperation with each center's membership organizations.

Conclusion

Worldwide R&D performance (measured as expenditures) totaled an estimated $1.671 trillion (current PPP dollars) in 2013 (latest global total available). The comparable figure for 2003 was $836 billion, which reflected a still brisk 7.2% average annual rate of growth over this 10-year period.

U.S. R&D increased to $456.1 billion in 2013 (Table 4-1), which represented 27% of the global total that year. As such, the United States remains the world's largest R&D performer. Nonetheless, investments in R&D by other countries—particularly those in Asia—continue to increase, closing the gap with the United States. China ($336.5 billion of R&D in 2013) has now moved well ahead of Japan ($160.3 billion) as the second-largest R&D-performing nation. Countries/economies of the East/Southeast and South Asian regions accounted for 27% of the global total in 2003 but rose to a striking 40% in 2013. EU countries accounted for 25% of the global total in 2003 but dropped to 20% in 2013.

In 2008, just ahead of the onset of the main economic effects of the national/international financial crisis and the Great Recession, U.S. R&D totaled $407.0 billion. The increase to $456.1 billion in 2013 is sizable. Nonetheless, inflation-adjusted growth in this R&D total over the 2008–13 period averaged only 0.8% annually, behind the 1.2% annual average for U.S. gross domestic product. By comparison, the growth of U.S. R&D averaged 3.9% annually over the 2003–08 period and similarly for 1993–2003, both well ahead of the corresponding GDP growth rates of 2.2% and 3.4%. From looking at these numbers, the longstanding vigor in the expansion of U.S. R&D has yet to return in the post-2008 era.

Glossary

Applied research: The objective of applied research is to gain knowledge or understanding to meet a specific, recognized need. In industry, applied research includes investigations to discover new scientific knowledge that has specific commercial objectives with respect to products, processes, or services.

Basic research: The objective of basic research is to gain more comprehensive knowledge or understanding of the subject under study without specific applications in mind. Although basic research may not have specific applications as its goal, it can be directed in fields of present or potential interest. This is often the case with basic research performed by industry or mission-driven federal agencies.

Development: The systematic use of the knowledge or understanding gained from research directed toward the production of useful materials, devices, systems, or methods, including the design and development of prototypes and processes.

European Union (EU): As of September 2015, the EU consists of 28 member nations: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom. Unless otherwise noted, data on the EU include all 28 member countries.

Federally funded research and development center (FFRDC): R&D-performing organizations that are exclusively or substantially financed by the federal government either to meet a particular R&D objective or, in some instances, to provide major facilities at universities for research and associated training purposes. Each FFRDC is administered by an industrial firm, a university, or a nonprofit institution.

Gross domestic product (GDP): The market value of goods and services produced within a country. It is one of the main measures in the national income and product accounts.

G20: Group of Twenty brings together finance ministers and central bank governors from Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, the Republic of Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, the United Kingdom, the United States, and the EU.

Innovation: The introduction of new or significantly improved products (goods or services), processes, organizational methods, and marketing methods in internal business practices or in the open marketplace (OECD /Eurostat 2005).

Multinational enterprise (MNE): A parent company and its foreign affiliates. An affiliate is a company or business enterprise (incorporated or unincorporated) located in one country but owned or controlled (10% or more of voting securities or the equivalent) by a parent company in another country. A majority-owned affiliate is a company owned or controlled by more than 50% of the voting securities (or equivalent) by its parent company.

National income and product accounts (NIPA): The economic accounts of a country that display the value and composition of national output and the distribution of incomes generated in this production.

Organisation for Economic Co-operation and Development (OECD): An international organization of 34 countries, headquartered in Paris, France. The member countries are Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Slovenia, South Korea, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. Among its many activities, the OECD compiles social, economic, and science and technology statistics for all member and selected nonmember countries.

R&D: Research and development, also called research and experimental development; comprises creative work undertaken on a systematic basis to increase the stock of knowledge—including knowledge of man, culture, and society—and its use to devise new applications (OECD 2002).

R&D intensity: A measure of R&D expenditures relative to size, production, financial, or other characteristics for a given R&D-performing unit (e.g., country, sector, company). Examples include R&D/GDP ratio and R&D value-added ratio.

Technology transfer: The process by which technology or knowledge developed in one place or for one purpose is applied and exploited in another place for some other purpose. In the federal setting, technology transfer is the process by which existing knowledge, facilities, or capabilities developed under federal R&D funding are used to fulfill public and private needs.

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Chapter 5.

Academic Research and Development

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Highlights

Spending for Academic R&D

In 2014, U.S. academic institutions spent $63.7 billion on research and development in all S&E fields.

- When adjusted for inflation, spending decreased by 1% between 2013 and 2014.
- As in prior years and dating back over four decades, academic R&D spending was concentrated in a relatively small number of public and private research-intensive institutions, which conduct a large share of the nation's basic research.
- Although the federal government provided well over half of academic R&D funds in 2014 (58%), its share has declined in recent years.
- By contrast, universities' share of academic R&D spending has grown in recent years and reached its highest level ever in 2014 (22%).

Six agencies provided over 92% of federal support for academic R&D in S&E in 2014.

- In declining order of funding, the major federal agencies that support academic R&D are the Department of Health and Human Services (HHS), the National Science Foundation, the Department of Defense, the Department of Energy, the National Aeronautics and Space Administration, and the Department of Agriculture.
- HHS (mainly through the National Institutes of Health) provides the bulk of total federal funds for academic R&D in S&E (55% in 2014).

Funding sources differed in importance for public and private institutions in 2014, as in prior years.

- Public universities relied more heavily on state and local government funds than their private counterparts (8% versus 2%) and more heavily on their own funds (25% versus 18%).
- Private universities relied more heavily than public universities on the federal government (66% versus 54%).
- Business funding and nonprofit funding were broadly similar for both types of institutions: 6% from business, and 8%–9% from nonprofits and other sources.

Over the last quarter century, the distribution of academic R&D expenditures has shifted in favor of life sciences and away from physical sciences. However, over the last decade, engineering R&D has grown faster than R&D in life sciences.

- Life sciences received the largest share (59%) of funding in academic S&E R&D in 2014, followed by engineering (17%).
- Over the last 20 years, life sciences was the only broad S&E field to experience a sizable increase in share—5 percentage points—of total academic R&D in S&E.
- Within life sciences, the fields of medical sciences and biological sciences have grown more rapidly than agricultural sciences.
- Within engineering, bioengineering has grown faster than the other engineering fields, although from a lower base.

- The other broad fields of science—computer sciences, environmental sciences, mathematical sciences, physical sciences, psychology, and social sciences—each received between 1% and 7% of total funding in academic S&E R&D in 2014.

Research collaboration involving multiple institutions and fields mirrors recent trends in overall academic R&D.

- Funds continue to flow among institutions in the form of pass-through arrangements made to support collaborative research activities. Although growth in pass-through funds historically has exceeded growth in overall academic R&D spending, pass-through funds in 2014 declined slightly (1%) from 2013 levels after adjusting for inflation, similar to overall academic R&D.
- With some vacillations, growth has been registered during most of the past decade in sciences that cannot be classified within one field but that instead span or integrate multiple disciplines. In 2014, approximately $1 billion was spent on such "other sciences."

Infrastructure for Academic R&D

Research space at academic institutions has continued to grow annually since the 1980s, although the pace of growth has slowed in the last few years.

- Total research space at universities and colleges was 4.7% greater at the end of 2013 than it was in 2011.
- Research space for the biological and biomedical sciences accounted for 27% of all S&E research space in 2013, making it the largest of all the major fields.
- In 2013, 81% of research space was reported as being in either superior or satisfactory condition by academic institutions, while 4% needed replacement, and the rest required renovation.
- The bulk of capital costs for laboratory and research facilities continues to be borne by the universities themselves, typically above 60% of the total. State and local governments typically support more than a quarter of the costs, while the federal government has consistently provided well below 10% of such funds.

In 2014, about $2 billion was spent for academic research equipment (i.e., movable items such as computers or microscopes), a decrease of 11% from 2013 after adjusting for inflation.

- Equipment spending as a share of total academic R&D expenditures reached a three-decade low of 3.1% in 2014.
- Three S&E fields accounted for 87% of equipment expenditures in 2014: life sciences (37%), engineering (33%), and physical sciences (17%).
- In 2014, the federal share of support for all academic research equipment funding fell below 50% for the first time since data collection began in 1981. The 2014 federal support share of 45.1% was 10 percentage points lower than the 2013 share of 55.5%.

Cyberinfrastructure

High-speed networking infrastructure, high-performance computing, and related technologies and services have become integral components of academic research.

- These resources are difficult to quantify due to rapid developments in technology.

- Valid measurements of academic R&D cyberinfrastructure are not yet available despite the central role that cyberinfrastructure now plays in many fields of S&E research.

Doctoral Scientists and Engineers in Academia

The academic workforce with research doctorates in science, engineering, and health (SEH, hereafter referred to as S&E) numbered just under 370,000 in 2013, the latest year for which data are available.

- The U.S.-trained portion of this workforce numbered about 309,000, and the foreign-trained portion numbered about 59,000.
- Growth from 2010 to 2013 in the U.S.-trained doctoral academic workforce (6%) was similar to growth in the doctoral workforce employed by businesses (4%); by contrast, the doctoral workforce employed by federal, state, or local governments remained stable from 2010 to 2013.
- The share of all U.S.-trained S&E doctorate holders employed in academia dropped from 55% in 1973 to 42% in 2013.

Full-time faculty positions for S&E doctorate holders have been in steady decline for four decades, offset by a rise in other types of full- and part-time positions.

- The percentage of S&E doctorate holders employed in academia who held full-time faculty positions declined from about 90% in the early 1970s to about 70% in 2013.
- Compared to 1997, a smaller share of the doctoral academic workforce had achieved tenure in 2013. In 1997, tenured positions accounted for an estimated 53% of doctoral academic employment; this decreased to 47% in 2013. Tenure-track positions as a share of doctoral academic employment, however, held steady.

The demographic profile of the U.S.-trained academic doctoral workforce has shifted substantially over time.

- The number of women in academia grew substantially between 1997 and 2013, from about 60,000 to 114,000. In 2013, women constituted 37% of academically employed doctorate holders, up from 25% in 1997. Women as a share of full-time senior doctoral faculty also increased substantially.
- In 2013, underrepresented minorities (blacks, Hispanics, and American Indians or Alaska Natives) constituted 8.8% of total U.S.-trained academic doctoral employment and 8.3% of full-time faculty positions, up from about 2% in 1973 and 7%–8% of these positions in 2003.
- More than one-quarter (27%) of U.S.-trained doctorate holders in academia were foreign born, contrasted with about 12% in 1973.
- About one-half of all U.S.-trained postdoctorates (postdocs) were born outside of the United States.
- The U.S.-trained doctoral academic workforce has aged substantially over the past two decades. In 2013, 24% of those in full-time faculty positions were between 60 and 75 years of age, compared with 11% in 1995.

Since 1993, there has been an increase in the share of full-time faculty who identify research as their primary work activity, and there has been a decrease in the share of full-time faculty who identify teaching as their primary activity.

- Slightly more than one-third (36%) of full-time faculty identified research as their primary work activity in 2013, up slightly from 33% in 1993.

- In 2013, 31% of recently degreed doctoral faculty identified research as their primary work activity.
- The share of full-time faculty who identified teaching as their primary activity declined from 53% in 1993 to 46% in 2013.

A substantial pool of academic researchers exists outside the ranks of tenure-track faculty.

- Approximately 43,000 S&E doctorate holders were employed in academic postdoc positions in 2013.
- In 2013, 42% of U.S.-trained doctorate holders less than 4 years beyond the doctorate held academic postdoc positions, exceeding the share (29%) employed in full-time faculty positions. Among those 4–7 years beyond their doctorates, 17% held postdoc positions.
- Almost 115,000 graduate research assistants conducted research in academia in 2013, underscoring the tight link between advanced education and direct cutting-edge research training.
- Other S&E doctorate holders engaged in academic R&D include research associates and adjunct faculty.

The share of U.S.-trained academic doctorate holders receiving federal support declined somewhat since the early 1990s.

- In 2013, about 44% of doctorate holders received federal support, compared with 49% of their peers during the late 1980s and very early 1990s.
- Among full-time faculty, recent doctorate recipients were less likely to receive federal support than their more established colleagues.
- Federal support has become less available to doctorate holders in nonfaculty positions, declining from about 60% in 1973 to about 43% in 2013.

Outputs of S&E Research: Publications and Patents

U.S. researchers accounted for just under one-fifth of the global output volume of peer-reviewed S&E articles; academic researchers contributed about three-quarters of the U.S. total. Like U.S. output, the number of EU and Japanese publications have continued to grow.

- But the developing world's growing capacity for scientific and technical activities is manifest in rapidly increasing output of peer-reviewed S&E publications. The balance of global articles—2.2 million in 2013--is shifting towards authors from the developing world. The United States and China have reached approximate parity in their respective shares of the world's total S&E publications in 2013, at 18.8% and 18.2%, respectively. Between 2003 and 2013, the U.S. share declined from 26.8%, and China's share almost tripled from 6.4%. China's growth rate was the fastest among the top 15 producers of S&E publications.
- Japan, the country with the third-largest share of S&E publications in 2013, experienced a decline from 7.8% to 4.7% over the period. Shares of Germany and the United Kingdom, fourth and fifth largest producers, declined from 6.0% to 4.6% and 6.2% to 4.4%, respectively.
- After a decade of 13.6% average annual growth, India is the sixth-largest producer of S&E articles, with a 4.2% share of world S&E publication output in 2013. South Korea reached 2.7%, Brazil 2.2%.
- Iran, a developing nation with a much smaller publication base in 2003, grew to a 1.5% global share by 2013, becoming the 16th-largest producer of S&E publications.
- When viewed as one region, the share for the EU declined, from 33.0% in 2003 to 27.5% in 2013.

Biological and medical sciences dominate research output in the United States, Japan, and the EU. Engineering dominates in China.

- Of the major producers of S&E publications, the United States has the highest concentration of publications in medical sciences.
- The United States has 46% and the EU has 40% of their publications in two fields, biological and medical sciences. Japan has 39% of its publications in those fields.
- China has 38% of its publications in engineering and 21% in biological and medical sciences.
- Of these major producers, India has the highest concentration of publications in biological sciences and the second-highest concentration in engineering.

S&E research publications are increasingly collaborative as well as increasingly international in authorship.

- More than 60% of global S&E publications had multiple authors in 2013, compared with less than half of such publications in 2000.
- Internationally coauthored publications correspondingly grew from 13.2% to 19.2% of all coauthored publications over the same period.
- International collaboration grew between 2000 and 2013 in all fields of science, with the highest percentage of international collaboration in astronomy and geosciences and the lowest percentage in engineering and social sciences.
- In the United States, 33% of publications were coauthored with institutions in other countries in 2013, compared with 19% in 2000.
- Among the major producers of S&E publications, the United Kingdom had the highest international collaboration rate in 2013, at 51%.

The impact of S&E publications has also become more global. U.S. S&E publications increasingly cite S&E publications from foreign authors and also increasingly receive citations from foreign-authored publications.

- Between 1996 and 2012, U.S. authors increased their citations to international S&E publications from 43% to 55% more than would otherwise have been expected, based on the number of U.S. S&E publications.
- The average impact of U.S. publications—a measure of citations received relative to the number of S&E articles published—was 43% higher than would otherwise have been expected in 2012.
- The average impact of S&E publications from China and India is increasing rapidly, though it is still below what would be expected, based on the number of publications.
- In 2012, publications with U.S. authors were almost twice as likely to be among the world's top 1% most-cited publications as would be expected, based on the volume of U.S. publications.
- By this measure, S&E publications from the Netherlands and Sweden are more than twice as likely to be among the top 1% of highly cited articles; S&E publications from Switzerland, almost three times as likely.
- Publications with Chinese authors are still less likely to be in the top 1% cited but are increasing their presence.

U.S. academic patents have been on a rising trend since 2008.

- Patents granted by the U.S. Patent and Trademark Office to U.S. academic institutions reached 5,990 in 2014, accounting for 4% of the patents issued to U.S. owners.
- The largest technology category for U.S. academic patents in 2014 was pharmaceuticals, which made up 16% of patents to academic institutions.

- Pharmaceutical patents exceeded biotechnology patents in 2012. Biotechnology is now the second-largest category (13%) of university patents.
- The top 201 U.S. patenting universities and university systems were granted 99% of the total patents granted to U.S. universities between 1996 and 2014.

Introduction

Chapter Overview

U.S. academic institutions play a critical role in the nation's S&E enterprise by providing advanced education and training students in research practices in the areas of science, engineering, and mathematics. The nation's universities together conduct over half of the nation's basic research, thus creating new knowledge and contributing to innovation. This model, widely admired, draws large numbers of foreign students and researchers to the U.S. research enterprise who contribute to its vitality and robustness. This chapter analyzes trends in funding sources and spending levels for academic research and development and illustrates patterns of spending. It discusses academic research facilities and equipment and examines academic research personnel. The chapter concludes with an analysis of selected results of this work in the form of journal articles and citations to these articles, along with patent-based measures.

Chapter Organization

The first section of this chapter examines trends in spending on academic R&D. It discusses funding sources and spending patterns by institution types and fields. The section highlights the continuing role of federal funding for academic R&D, even as the federal share of total spending in recent years has continued to decline, while the share paid for by universities themselves has increased.

The chapter's second section analyzes trends in infrastructure by field for academic R&D, including research facilities and research equipment. In addition, this section also comments on the role of academic research cyberinfrastructure such as high-performance computing (HPC), networking, and storage resources.

The academic workforce of scientists and engineers has changed substantially over the past decades, and the third section examines these trends, including changing demographics and types of positions held. The section further analyzes the degree of participation in academic research of full-time faculty, postdoctorates (postdocs), and graduate research assistants and focuses on recipients of federal research funds, particularly early career researchers.

The fourth and final section of this chapter analyzes trends in two types of research outputs: S&E publications, which are largely (but not exclusively) produced by the academic sector, and patents issued to U.S. universities. This section first compares the volume of S&E publications for selected regions, countries, and economies, focusing (when appropriate) on patterns and trends in publications by U.S. academic researchers. Trends in coauthored publications, both across U.S. sectors and internationally, are indicators of increasing collaboration in S&E research. Trends in production of influential publications, as measured by the frequency with which publications are cited, are examined, with emphasis on international comparisons. The analysis of U.S. academic patenting activities examines patents, licenses, and income from these as forms of academic R&D output. Patent citations to the S&E literature are also examined, with emphasis on citations in awarded patents for clean energy and related technologies.

Expenditures and Funding for Academic R&D

Academic R&D is a key component of the overall U.S. R&D enterprise.[i] Academic scientists and engineers conduct the bulk of the nation's basic research and, importantly, train young researchers in the process. (For an overview of the sources of data used, see sidebar, Data on the Financial and Infrastructure Resources for Academic R&D).

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[i] The academic R&D totals presented here exclude expenditures at the federally funded research and development centers (FFRDCs) associated with universities. Those expenditures are tallied separately and discussed in chapter 4. Nevertheless, the FFRDCs and other national laboratories (including federal intramural laboratories) play an important role in academic research and education, providing research opportunities for students and faculty at academic institutions, often by providing highly specialized, shared research facilities.

Data on the Financial and Infrastructure Resources for Academic R&D

Financial data on academic R&D are drawn from the National Science Foundation's Survey of Research and Development Expenditures at Universities and Colleges (1972–2009) and its successor, the Higher Education Research and Development Survey (HERD; 2010 onward). Trend analysis is possible because both surveys capture comparable information on R&D expenditures by sources of funds and field. HERD offers a more comprehensive treatment of R&D (including non-S&E fields), an expanded group of surveyed institutions, and greater detail about the sources of funding for R&D expenditures by field (Britt 2010). The latest survey is available at http://nsf.gov/statistics/srvyherd/surveys/srvyherd_2014.pdf.

HERD data are in current-year dollars and reported on an academic-year basis. For example, FY 2014 covers July 2013–June 2014 for most institutions and is referred to in this chapter as 2014. HERD data spanning more than 1 year are generally presented in inflation-adjusted constant 2009 dollars using gross domestic product implicit price deflators.

The data on research facility infrastructure come from the Survey of Science and Engineering Research Facilities. The facilities survey includes all universities and colleges in HERD with $1 million or more in R&D expenditures. These surveys are completed by university and college administrators under the direction of the institutional presidents. The latest survey is available at http://nsf.gov/statistics/srvyfacilities/surveys/srvyfacilities_2013.pdf.

Data on federal obligations for academic R&D are reported in chapter 4; that chapter also provides data on the academic sector's share of the nation's overall R&D.

National Academic R&D Expenditures in All Fields

Expenditures by U.S. colleges and universities on R&D in all fields totaled $67.3 billion in 2014.[i] This total includes spending by 895 degree-granting institutions that spent at least $150,000 in R&D in 2014. Furthermore, it includes spending of $3.4 billion in non-S&E fields, which constituted 5% of total academic R&D (Table 5-1). In this chapter, the discussion focuses on the highest-spending institutions, that is, 634 institutions that reported at least $1 million in R&D. Together, these schools accounted for over 99% ($67.2 billion) of academic R&D spending in

2014 (Table 5-2) . Where possible, this chapter will focus on these institutions' R&D spending in the various fields of S&E. However, certain Higher Education Research and Development Survey (HERD) data are not separated by field. Such data include institutions' estimates of spending for basic research, applied research, and development; American Recovery and Reinvestment Act of 2009 (ARRA)-funded R&D; data on R&D funds that universities and colleges pass through to other institutions (or receive from others); and detail on institutionally financed R&D.

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[i] In this chapter, the terms *universities and colleges, schools, higher education,* and *academic institutions* are used interchangeably.

Table 5-1 **R&D expenditures in non-S&E fields at universities and colleges: FY 2014**

(Millions of current dollars)

Field	Total expenditures	Federal expenditures
All non-S&E fields	3,412	1,127
Business and management	483	78
Communication, journalism, and library science	167	54
Education	1,242	661
Humanities	399	76
Law	148	24
Social work	225	106
Visual and performing arts	96	9
Other non-S&E fields	652	119

NOTE: Detail may not add to total because some respondents reporting non-S&E R&D expenditures did not break out total and federal funds by non-S&E fields.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey, 2014.

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Table 5-2 Higher education R&D expenditures, by source, character of work, and institution type: FYs 2010–14

(Thousands of dollars)

	All sources				Federal sources			
Fiscal year and institution type	Total	Basic research	Applied research	Development	Total	Basic research	Applied research	Development
2010								
All institutions	61,253,743	40,282,242	15,726,093	5,245,408	37,475,234	25,432,529	9,393,753	2,648,952
Public	41,231,333	27,065,641	10,637,171	3,528,521	23,349,370	15,829,220	5,723,934	1,796,216
Private	20,022,410	13,216,601	5,088,922	1,716,887	14,125,864	9,603,309	3,669,819	852,736
2011								
All institutions	65,276,179	42,378,148	17,217,069	5,680,962	40,767,871	27,165,672	10,666,679	2,935,520
Public	43,915,002	28,680,207	11,585,251	3,649,544	25,385,046	17,015,546	6,571,448	1,798,052
Private	21,361,177	13,697,941	5,631,818	2,031,418	15,382,825	10,150,126	4,095,231	1,137,468
2012								
All institutions	65,729,338	41,821,911	17,902,343	6,005,084	40,139,567	26,156,548	10,846,437	3,136,582
Public	44,162,988	28,454,204	11,992,691	3,716,093	25,107,091	16,565,923	6,689,969	1,851,199
Private	21,566,350	13,367,707	5,909,652	2,288,991	15,032,476	9,590,625	4,156,468	1,285,383
2013								
All institutions	67,014,807	43,108,628	17,614,033	6,292,146	39,444,861	25,831,607	10,534,555	3,078,699

Chapter 5. **Academic Research and Development**

	All sources				Federal sources			
Fiscal year and institution type	Total	Basic research	Applied research	Development	Total	Basic research	Applied research	Development
Public	44,851,358	28,855,083	11,929,504	4,066,771	24,687,550	16,194,093	6,653,441	1,840,016
Private	22,163,449	14,253,545	5,684,529	2,225,375	14,757,311	9,637,514	3,881,114	1,238,683
2014								
All institutions	67,154,642	42,952,394	17,835,521	6,366,727	37,922,314	24,813,130	10,091,346	3,017,838
Public	44,657,466	28,499,463	11,850,721	4,307,282	23,493,609	15,325,514	6,195,221	1,972,874
Private	22,497,176	14,452,931	5,984,800	2,059,445	14,428,705	9,487,616	3,896,125	1,044,964

NOTE: Data include S&E and non-S&E R&D expenditures.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey.

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Academic R&D spending is primarily for basic research—in 2014, 64% was spent on basic research, 27% was spent on applied research, and 9% was spent on development (Table 5-2),[ii] percentages largely unchanged from 2013. Of federal expenditures for academic R&D, basic research (65%), applied research (27%), and development (8%) accounted for very similar proportions. The estimated percentage of spending on basic research is somewhat less than institutions had reported throughout the late 1990s and the 2000–09 decade (Appendix Table 5-1). Improvements to the survey question in 2010 likely affected how universities reported these shares.[iii]

ARRA provided an important source of federal funds during the economic downturn and recovery. Most of these funds ($9.3 billion) were spent from 2010 to 2012. After adjusting for inflation, federal spending for academic R&D would have increased by an average annual rate of 2.3% from 2009 to 2012 if ARRA had not been enacted; with ARRA funds, these expenditures instead increased by an average annual rate of 4.5%.[iv]

By 2014, universities and colleges had spent the last of the funds provided by ARRA. In total, ARRA provided $11.3 billion over the 5-year period from 2010 to 2014 (Table 5-3).

[ii] For a more complete discussion of these concepts, see the chapter 4 “Glossary.” Chapter 4 provides further detail on federal obligations for academic R&D, by character of work.

[iii] Starting in 2010, the Higher Education Research and Development Survey asked institutions to categorize their R&D expenditures as *basic research,* as *applied research,* or as *development*; prior surveys had asked how much total S&E R&D the institution performed and requested an estimate of the percentage of their R&D expenditures devoted to basic research. By only mentioning basic research, the survey question may have caused some respondents to classify a greater proportion of their activities in this category. The 2010 question provided definitions and examples of the three R&D categories to aid institutions in making more accurate assignments. In debriefing interviews, institutional representatives cited the changes in the survey question as the most important factor affecting their somewhat lower estimates of the amount of basic research that institutions performed. The explicit inclusion of clinical trials and research training grants and the addition of non-S&E R&D may also have contributed.

[iv] From 2004 to 2008, prior to the enactment of the American Recovery and Reinvestment Act of 2009, federal academic R&D expenditures were relatively flat; they increased by an annual average rate of only 0.2% after adjusting for inflation. Because non-S&E R&D spending totals were collected only from institutions with S&E R&D and NSF did not attempt to estimate for nonresponse on the non-S&E expenditures survey question, national academic R&D spending totals for these years are lower-bound estimates.

Table 5-3 Federally financed higher education R&D expenditures funded by the American Recovery and Reinvestment Act of 2009, by Carnegie classification and institution type: FYs 2010–14

(Thousands of dollars)

	2010		2011		2012		2013		2014	
Type of institution	All federal R&D expenditures	ARRA	All federal R&D expenditures	ARRA	All federal R&D expenditures	ARRA	All federal R&D expenditures	ARRA	All federal R&D expenditures	ARRA
All institutions	37,475,234	2,684,122	40,767,871	4,173,439	40,139,567	2,435,743	39,444,861	1,468,553	37,922,314	540,590
Very high research	27,641,468	1,980,718	30,047,688	3,113,463	29,863,632	1,803,555	29,683,589	1,123,691	28,620,941	409,936
High research and doctoral research	4,167,348	235,252	4,539,476	398,189	4,487,141	286,484	4,217,978	190,238	4,034,382	69,575
Special focus	3,729,808	317,961	3,994,149	484,460	3,684,878	235,661	3,588,788	95,425	3,297,676	28,142
Other	1,936,610	150,191	2,186,558	177,327	2,103,916	110,043	1,954,506	59,199	1,969,315	32,937
Public	23,349,370	1,609,011	25,385,046	2,547,741	25,107,091	1,600,919	24,687,550	925,392	23,493,609	377,338
Private	14,125,864	1,075,111	15,382,825	1,625,698	15,032,476	834,824	14,757,311	543,161	14,428,705	163,252

NOTES: ARRA = American Recovery and Reinvestment Act of 2009.
Data include S&E and non-S&E federal expenditures. Data starting with FY 2012 include only those institutions with $1 million or more in total R&D expenditures. Institutions reporting less than $1 million in total R&D expenditures completed a shorter version of the survey form, and that form did not request information on ARRA-funded expenditures.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2015) of the Higher Education Research and Development Survey.

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National Academic R&D Spending in S&E Fields

In 2014, universities and colleges spent $63.7 billion on R&D in S&E fields, an increase of only 0.6% over the prior year (Appendix Table 5-2).[i] After adjusting for inflation, spending declined by about the same amount (0.8%), with changes ranging from a reduction of 8% in the relatively small field of computer sciences to an increase of 1% in engineering. Spending in environmental sciences and social sciences increased by less than one-half of 1% each while spending in life sciences and psychology dipped by about the same percentage. Spending in mathematical sciences and physical sciences dropped by between 2% and 3% each.

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[i] The academic R&D reported here includes separately budgeted R&D and related recovered indirect costs and also institutional estimates of unrecovered indirect costs associated with externally funded R&D projects, including committed cost sharing. *Indirect costs* are general expenses that cannot be associated with specific research projects but pay for things that are used collectively by many research projects at an academic institution. Two major components of indirect costs exist: (1) *facilities-related costs,* such as the construction, maintenance, and operation of facilities used for research; and (2) *administrative costs,* including expenses associated with financial management, institutional review boards, and environment, health, and safety management. Some indirect costs are recovered as a result of indirect-cost proposals that universities submit based on their actual costs from the previous year.

Sources of Support for Academic R&D in S&E

Academic R&D relies on funding support from a variety of sources, including the federal government, universities' and colleges' own institutional funds, state and local government, business, and other organizations (Appendix Table 5-3). The federal government has consistently provided the majority of funding for academic R&D in S&E, generally around 60% or more, although the share has been less in recent years.[i] Institutional funds contribute a sizeable share of funding (22% in 2014), while state and local governments, businesses, and nonprofit organizations each provide about 6% of R&D funds.[ii]

Federal Support

The federal government allocates R&D funding to academia primarily through competitive review processes, and overall support reflects the combined result of numerous discrete funding decisions made by the R&D-supporting federal agencies. Varying agency missions, priorities, and objectives affect the level of funds that universities and colleges receive as well as how they are spent. ARRA was an important source of federal expenditures for academic R&D during the economic downturn and recovery from 2010 through 2012 and continued to contribute to such spending, although in smaller amounts, in 2013 and 2014.

Excluding ARRA funds, there has been a gradual decline since 2005 in the proportion of R&D paid for with federal funds (from just under 64% to under 60%). Taking a longer perspective, the federal share, at 69%, was highest in 1973 (Figure 5-1). It then declined fairly steadily throughout the remainder of the 1970s and the 1980s. During the 1990s, the federal share, with some vacillations, remained at or just under 60%. However, during the first half of the 2000–09 decade, the federal share gradually increased to 64%, coinciding with rapid increases in the budget of the National Institutes of Health (NIH), a major academic R&D funding agency discussed below. The federal share fell during the latter part of the 2000–09 decade but rose in 2010 and 2011 with the infusion of ARRA funds.

In 2014, as the last of the ARRA funds were being spent, the federal government provided $36.8 billion (58%) of the $63.7 billion total, a reduction of almost $1.5 billion from 2013 (Figure 5-2).

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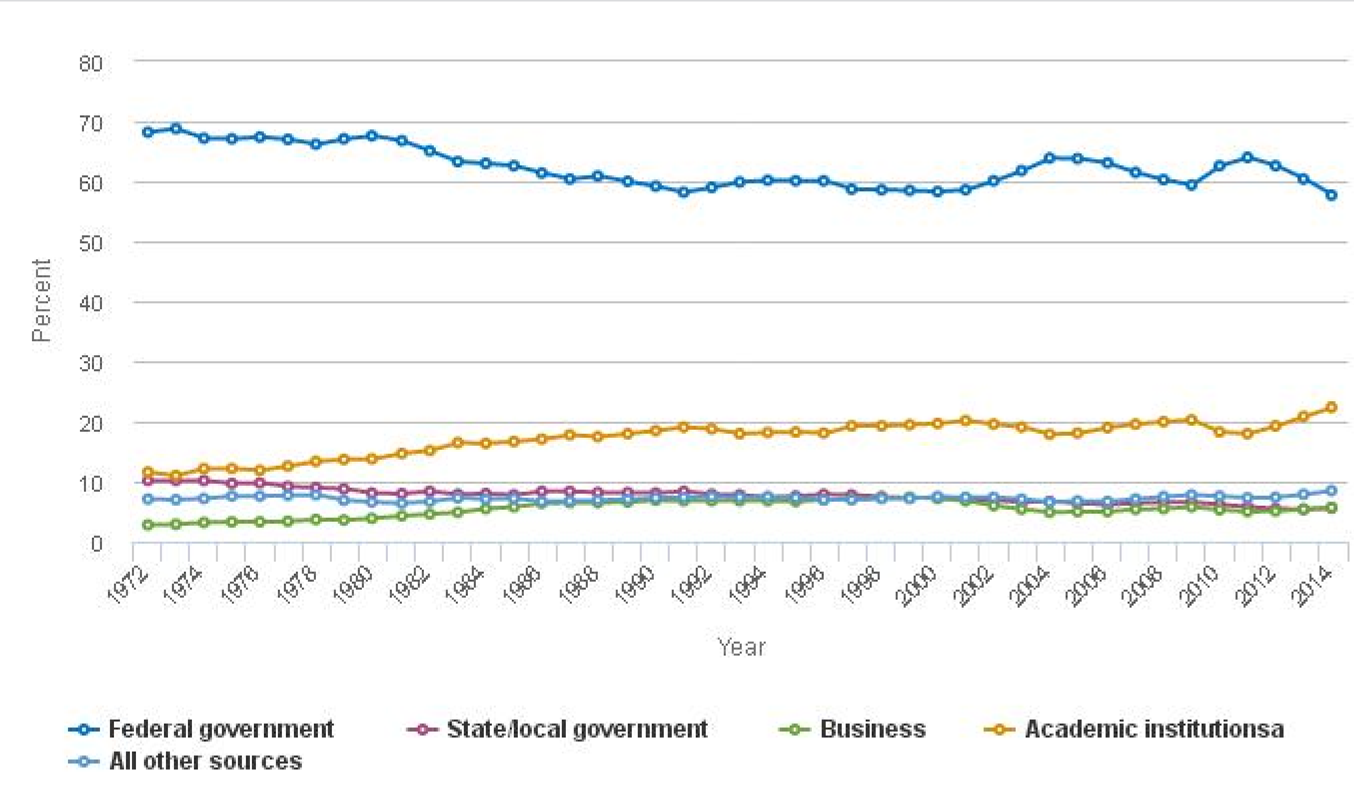
[i] The federal government funds a much smaller proportion of R&D in non-S&E fields (33% in 2014).

[ii] See (NRC 2012) for a report exploring ways to strengthen the partnership between government, universities, and industry in support of national goals.

Figure 5-1

Academic S&E R&D expenditures, by source of funding: FYs 1972–2014



[a] Academic institutions' funds exclude research funds spent from multipurpose accounts.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey.

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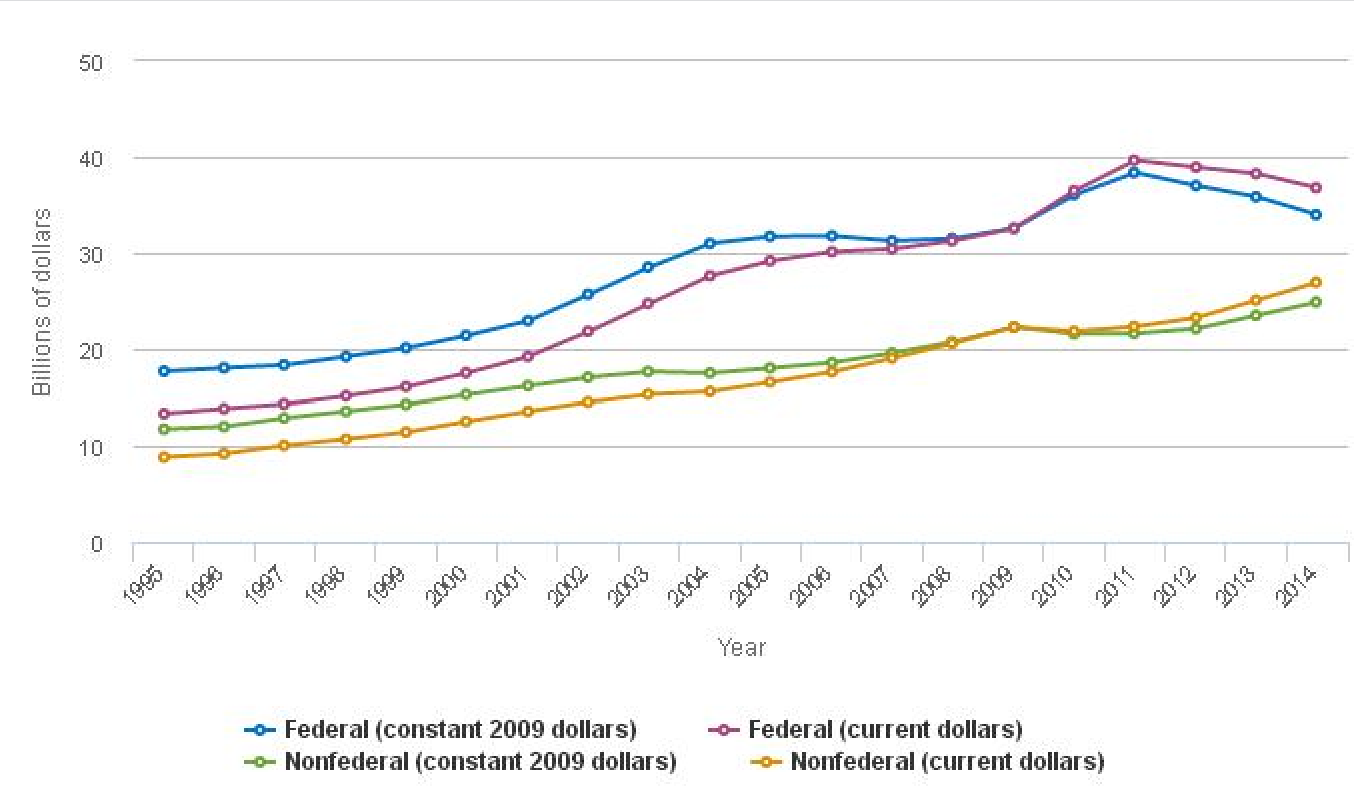
Figure 5-2

Federal and nonfederal funding of academic S&E R&D expenditures: FYs 1995–2014



NOTES: Gross domestic product deflators come from the U.S. Bureau of Economic Analysis and are available at http://www.bea.gov/national/, accessed 18 February 2015. See appendix table 4-1.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey. See appendix table 5-1.

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Top Federal Agency Supporters

Six agencies are responsible for the vast majority of annual federal expenditures for academic R&D in S&E fields: the Department of Health and Human Services (HHS), in particular, NIH; the National Science Foundation (NSF); the Department of Defense (DOD); the Department of Energy (DOE); the National Aeronautics and Space Administration (NASA); and the Department of Agriculture (USDA). In 2014, these six agencies were the source of over 92% of the estimated $36.8 billion federal expenditures (Appendix Table 5-4; Chapter 4 provides data on these agencies' obligations for academic R&D).[iii]

Among these six agencies, HHS is by far the largest funder, the source of 55% of total federal expenditures in 2014. NSF and DOD were the next-largest funders, each providing about 13%; DOE, NASA, and USDA provided smaller shares of between 3% and 5%. For at least the last decade, the relative ranking of the top six funding agencies in terms of R&D expenditures in S&E fields has remained quite stable, with DOD experiencing the greatest gains in share (from 9% in 2005 to 13% in 2014) (Table 5-4).

[iii] Statistics on R&D performance can differ depending on whether the reporting is by R&D performers—in this case, academic institutions—or R&D funders. Reasons for this difference are discussed in the chapter 4 sidebar, “Tracking R&D Expenditures: Disparities in the Data Reported by Performers and Sources of Funding.”

Table 5-4 **Top six federal agencies' shares of federally funded academic S&E R&D expenditures: FYs 2005–14**

(Percent)

Agency	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Department of Health and Human Services	55.8	56.7	56.1	56.0	55.4	57.3	57.4	55.6	54.8	54.5
National Science Foundation	12.1	11.9	11.7	12.1	12.1	12.5	12.5	13.0	13.5	13.3
Department of Defense	8.9	9.2	9.1	9.8	10.4	12.1	12.0	12.4	13.0	13.2
Department of Energy	3.6	3.7	3.7	3.6	3.8	4.2	4.7	5.0	4.9	4.9
National Aeronautics and Space Administration	3.9	3.5	3.5	3.4	3.4	4.0	3.6	3.4	3.4	3.6
Department of Agriculture	2.8	2.9	3.0	2.9	2.8	2.6	2.5	2.8	2.8	2.8

NOTE: The Department of Health and Human Services includes primarily the National Institutes of Health.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2015) of the Higher Education Research and Development Survey.

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Federal support for academic R&D historically has been concentrated at the nation’s most research-intensive higher education institutions. Recognizing that human talent is widespread, federal government agencies have long supported a program to develop academic research capability in states that are less competitive in obtaining federal research grants. An overview of the program and recent statistics on its activities are presented in the sidebar, Experimental Program to Stimulate Competitive Research.

Experimental Program to Stimulate Competitive Research

The Experimental Program to Stimulate Competitive Research (EPSCoR) is a long-standing multiagency federal program that seeks to increase the geographical dispersion of federal support for academic R&D. It is based on the premise that universities and their S&E faculty and students are resources that can influence a state’s development in the 21st century just as agricultural, industrial, and natural resources did in the 20th century.

EPSCoR is rooted in the history of the National Science Foundation (NSF) and of federal support for R&D. In 1978, Congress, concerned about undue concentration of federal R&D funds, authorized NSF to initiate EPSCoR, which was targeted at states that received lesser amounts of federal R&D funds but demonstrated a commitment to develop sustainable, competitive research capabilities anchored in their research universities. The ultimate aim was to move EPSCoR researchers and institutions into the mainstream of federal and private-sector R&D support.

The experience of the NSF EPSCoR program during the 1980s prompted Congress to authorize the creation of EPSCoR and EPSCoR-like programs in six other federal agencies: the Departments of Energy, Defense

(DOD), and Agriculture; the National Aeronautics and Space Administration; the National Institutes of Health; and the Environmental Protection Agency (EPA). Two of these, EPA and DOD, discontinued issuing EPSCoR program solicitations in FY 2006 and FY 2010, respectively.

In FY 2014, the five remaining agencies spent a total of $488.6 million on EPSCoR and EPSCoR-like programs, up from $288.9 million in 2002 (Table 5-A).

Table 5-A **EPSCoR and EPSCoR-like program budgets, by agency: FYs 2002–14**

(Millions of dollars)

Agency	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
All agencies	288.9	358.0	353.3	367.4	367.1	363.1	418.9	437.2	460.1	436.0	483.4	461.0	488.6
DOD	15.7	15.7	8.4	11.4	11.5	9.5	17.0	14.1	0.0	0.0	0.0	0.0	0.0
DOE	7.7	11.7	7.7	7.6	7.3	7.3	14.7	16.8	21.6	8.5	8.5	8.4	10.0
EPA	2.5	2.5	2.5	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NASA	10.0	10.0	10.0	12.0	12.5	12.8	15.5	20.0	25.0	25.0	18.0	18.0	18.0
NIH	160.0	210.0	214.0	222.0	220.0	218.0	223.6	224.3	228.8	226.5	276.5	261.6	273.3
NSF	79.3	88.8	93.7	93.4	97.8	101.5	120.0	133.0	147.1	146.8	150.9	147.6	158.2
USDA	13.7	19.3	17.0	18.6	18.0	14.0	28.1	29.0	37.6	29.2	29.5	25.4	29.1

DOD = Department of Defense; DOE = Department of Energy; EPA = Environmental Protection Agency; EPSCoR = Experimental Program to Stimulate Competitive Research; NASA = National Aeronautics and Space Administration; NIH = National Institutes of Health; NSF = National Science Foundation; USDA = U.S. Department of Agriculture.

NOTES: EPA and DOD discontinued issuing separate EPSCoR program solicitations in FY 2006 and FY 2010, respectively. USDA's reported budget in FY 2012 includes $6.8 million in unobligated funds. NASA made minor revisions to prior-year data in 2014.

SOURCE: Data are provided by agency EPSCoR representatives and are collected by the NSF Office of Integrative Activities, Office of EPSCoR, January 2015.

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Institutional Support for Academic R&D

Notwithstanding the continuing dominant federal role in academic R&D funding in S&E fields, nonfederal funding sources have grown steadily over the past 20 years (Figure 5-2). Adjusted for inflation, annual growth in nonfederal funding for academic R&D averaged 4% from 1995 to 2014. The largest source of this funding comes from higher education institutions themselves. In 2014, institutional funds combined to be the second-largest source of funding for academic R&D, accounting for 22% of the total ($14.3 billion) (Appendix Table 5-3). This share grew rapidly from only 11% in 1973 to around 18% by 1990 (Figure 5-1). With some vacillations, universities' and colleges' share of R&D spending increased more slowly during the decades of 1990–99 and 2000–09. With the infusion of federal ARRA funds, the institutional share dipped slightly in 2010 and 2011 but has since climbed to 22%, its highest-ever share (Figure 5-1; Appendix Table 5-3).

In addition to internal funding from general revenues, institutionally financed R&D includes unrecovered indirect costs and committed cost sharing (discussed in greater detail below, where differences between public and private research institutions are highlighted).[iv]

Institutionally financed research includes both organized research projects fully supported with internal funding and all other separately accounted-for institutional funds for research. This category does not include funds spent on research that are not separately accounted for, such as estimates of faculty time budgeted for instruction that is spent on research. Funds for institutionally financed R&D may also derive from general-purpose state or local government appropriations; general-purpose awards from industry, foundations, or other outside sources; endowment income; and gifts. Universities may also use income from patents and licenses or revenue from patient care to support R&D.[v] (See this chapter's section Academic Patenting, Commercialization of U.S. Academic Patents, for a discussion of patent and licensing income.)

Other Sources of Funding

- **State and local government funds.** State and local governments provided 5.6% ($3.6 billion) of academic R&D funding in S&E fields in 2014, with public institutions receiving a higher share and their private counterparts a lower share (Figure 5-1; Appendix Table 5-3). The state and local government funding share has declined from a peak of 10% in the early 1970s to below 6% in recent years. However, these figures are likely to understate the actual contribution of state and local governments, particularly for public institutions, because they reflect only funds that these governments directly target to academic R&D activities.[vi] They exclude any general-purpose, state government, or local government appropriations that academic institutions designate and use to fund separately accounted-for research or to pay for unrecovered indirect costs; such funds are categorized as institutional funds. (See the State Data Tool for some indicators of academic R&D by state, and see chapter 2 section Trends in Higher Education Expenditures and Revenues for a discussion of trends in higher education spending and revenues.)
- **Nonprofit funds.** Nonprofit organizations provided 5.7% ($3.6 billion) of academic R&D funding in S&E fields in 2014, about the same share as that provided by state and local governments (Appendix Table 5-5). A large share of nonprofit funding (over 70%) is directed toward R&D in life sciences—in particular, medical sciences. Nonprofit organizations provided approximately $2.5 billion in each year from 2010 to 2014 for R&D in life sciences, with about $1.5 billion in each year directed toward medical sciences.
- **Business funds.** Businesses provided 5.7% ($3.6 billion) of academic R&D funding in S&E fields in 2014, about the same amount as provided by nonprofit organizations and by state and local governments (Figure 5-1; Appendix Table 5-5).
- **Other funds.** In 2014, all other sources of support, such as foreign-government funding or gifts designated for research, accounted for 2.8% ($1.8 billion) of academic R&D funding in S&E fields (Appendix Table 5-5).

[iv] *Unrecovered indirect costs* are calculated as the difference between an institution's negotiated indirect cost rate on a sponsored project and the amount that it recovers from the sponsor. *Committed cost sharing* is the sum of the institutional contributions required by the sponsor for specific projects (*mandatory cost sharing*) and the institutional resources made available to a specific project at the discretion of the grantee institution (*voluntary cost sharing*).

[v] Various challenges exist with measuring institutionally financed research. For numerous universities, including some with very high research activity, their accounting systems or administrative practices do not enable them to separate the R&D component of multipurpose accounts. Because HERD measures only spending that is fully budgeted as R&D, for these institutions, reported institutional funds are less than the full amount of academic R&D their schools fund.

[vi] Federal grants, contracts, and awards from other sources that are passed through state and local governments to academic institutions are credited to the original provider of the funds.

Academic R&D Expenditures, by S&E Field

Academic R&D spending has long been concentrated in the life sciences, which have received more than half of all academic R&D expenditures for more than three decades. The remainder is distributed across seven broad fields, including computer sciences, environmental sciences, mathematical sciences, physical sciences, psychology, social sciences, and engineering (Appendix Table 5-5). Over the past decade, engineering grew fastest, at an annual average rate of about 4%, after adjusting for inflation, followed by life sciences, computer sciences, and psychology, each at about 2% annually. The mathematical, environmental, physical, and social sciences grew more slowly, at about 1% annually. In one indication that research spanning more than one field of S&E remains vital, there has also been notable growth in sciences that are not classified within a particular field. For all fields of S&E, constant average annual growth rates were lower in recent years (from 2005 to 2014) than earlier (from 1995 to 2004) (Table 5-5).

Table 5-5 **Growth of academic R&D expenditures, by S&E field: FYs 1995–2014**

(Percent)

	Constant average growth rate		
S&E field	1995–2004	2005–14	
Computer sciences	6.3	1.7	
Environmental sciences	3.7	0.9	
Life sciences	6.7	1.7	
Mathematical sciences	3.5	1.4	
Physical sciences	3.2	0.6	
Psychology	6.6	1.8	
Social sciences	3.7	1.2	
Engineering	4.7	3.7	

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2015) of the Higher Education Research and Development Survey.

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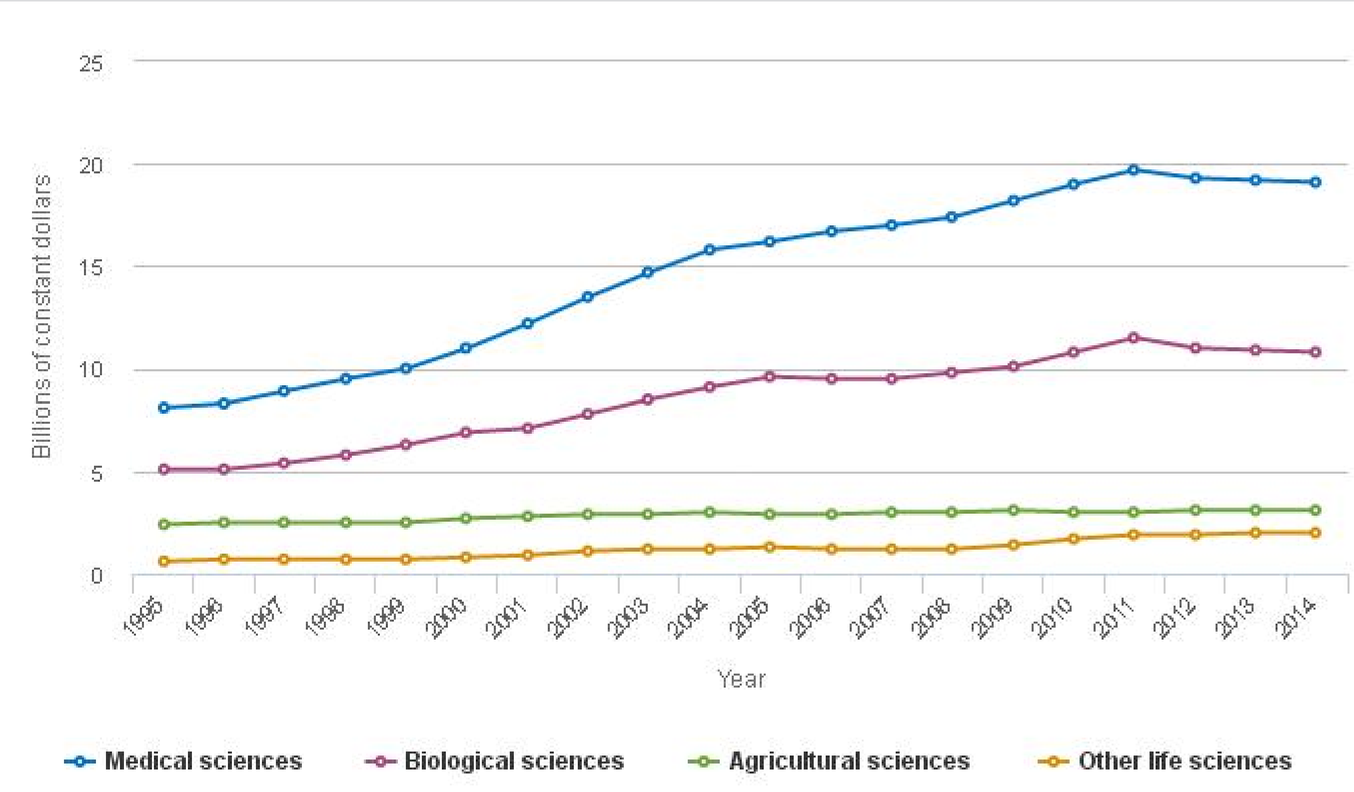
In 2014, academic R&D in life sciences accounted for 59% of total academic spending in all fields of S&E and a slightly smaller share (56%) of federally supported academic R&D that year. Within life sciences, medical sciences accounted for over one-half of this field's spending (and 32% of total academic R&D), while biological sciences constituted just under one-third of spending in the life sciences (and 18% of total academic R&D). The remainder was spread between agricultural sciences (5% of total academic R&D) and other life sciences—life sciences R&D that could not be classified into one of the subfields. Academic R&D expenditures in medical sciences almost doubled from 1995 to 2004 and then grew more slowly from 2005 to 2013, declining slightly from 2011 to 2014. The sizeable increase from 1995 to 2004 resulted, in part, from a near-doubling of NIH's budget from 1998 to 2003. Similarly, academic R&D expenditures in biological sciences increased by about 80% from 1995 to 2004 and by much less (13%) from 2005 to 2014 after adjusting for inflation; there was also a decline in spending from 2011 to 2014. Spending changes over the two decades were somewhat less dramatic within the smaller life sciences field of agricultural sciences (Figure 5-3).

Figure 5-3

Academic R&D expenditures, by life sciences field: FYs 1995–2014



NOTES: Gross domestic product deflators come from the U.S. Bureau of Economic Analysis and are available at http://www.bea.gov/national/, accessed 18 February 2015. See appendix table 4-1.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey.

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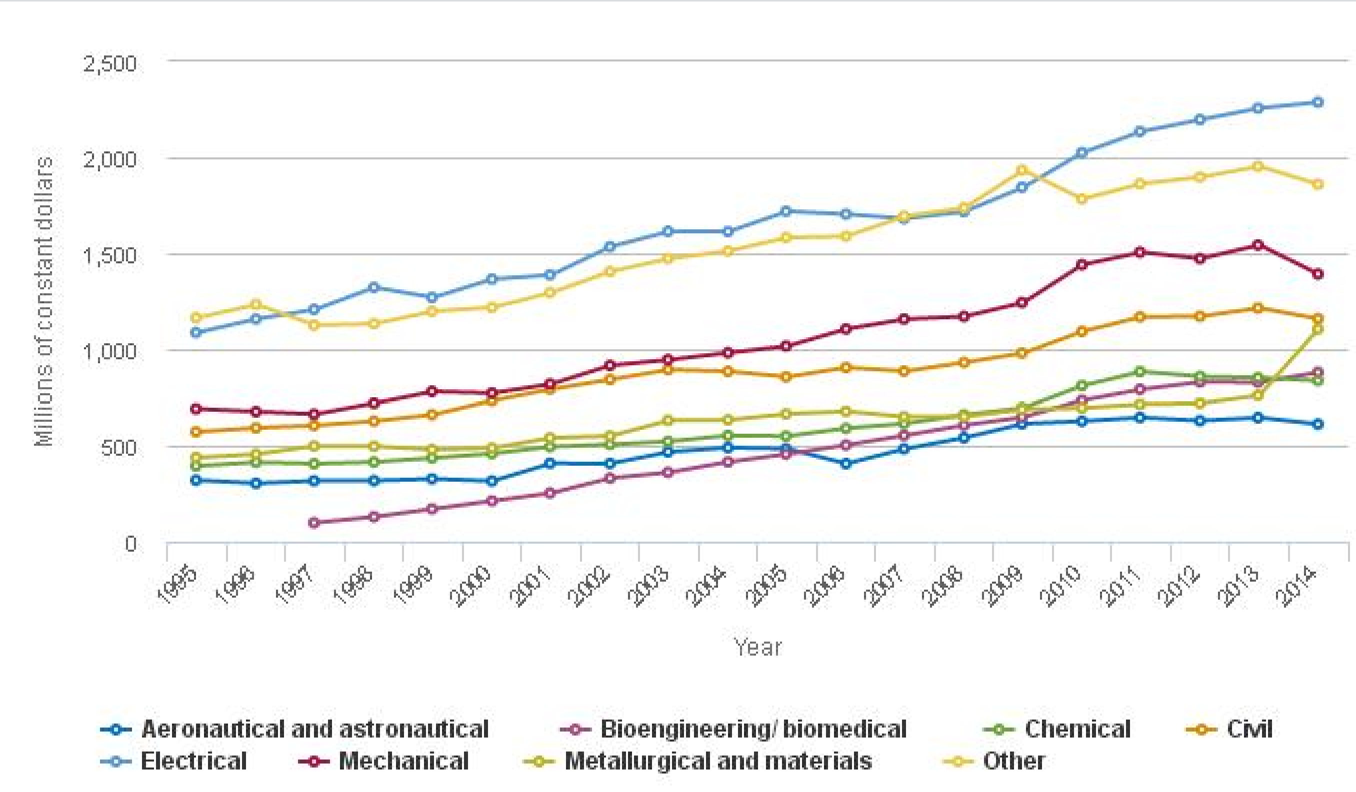
Engineering R&D—constituting 17% of academic R&D spending in S&E fields in 2014—has generally seen robust growth over the past decade, particularly over the period from 2008 to 2011. Bioengineering/biomedical engineering exceeded the rapid growth of the medical sciences, increasing by almost 800% from a small base in 1997—the first year for which spending data are available. Spending essentially doubled from 1995 to 2014 in each of the other subfields of engineering after adjusting for inflation (Figure 5-4).

Figure 5-4

Academic R&D expenditures, by engineering field: FYs 1995–2014



NA = not available.

NOTES: Data were not available for all fields for all years. Gross domestic product deflators come from the U.S. Bureau of Economic Analysis and are available at http://www.bea.gov/national/, accessed 18 February 2015. See appendix table 4-1.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey.

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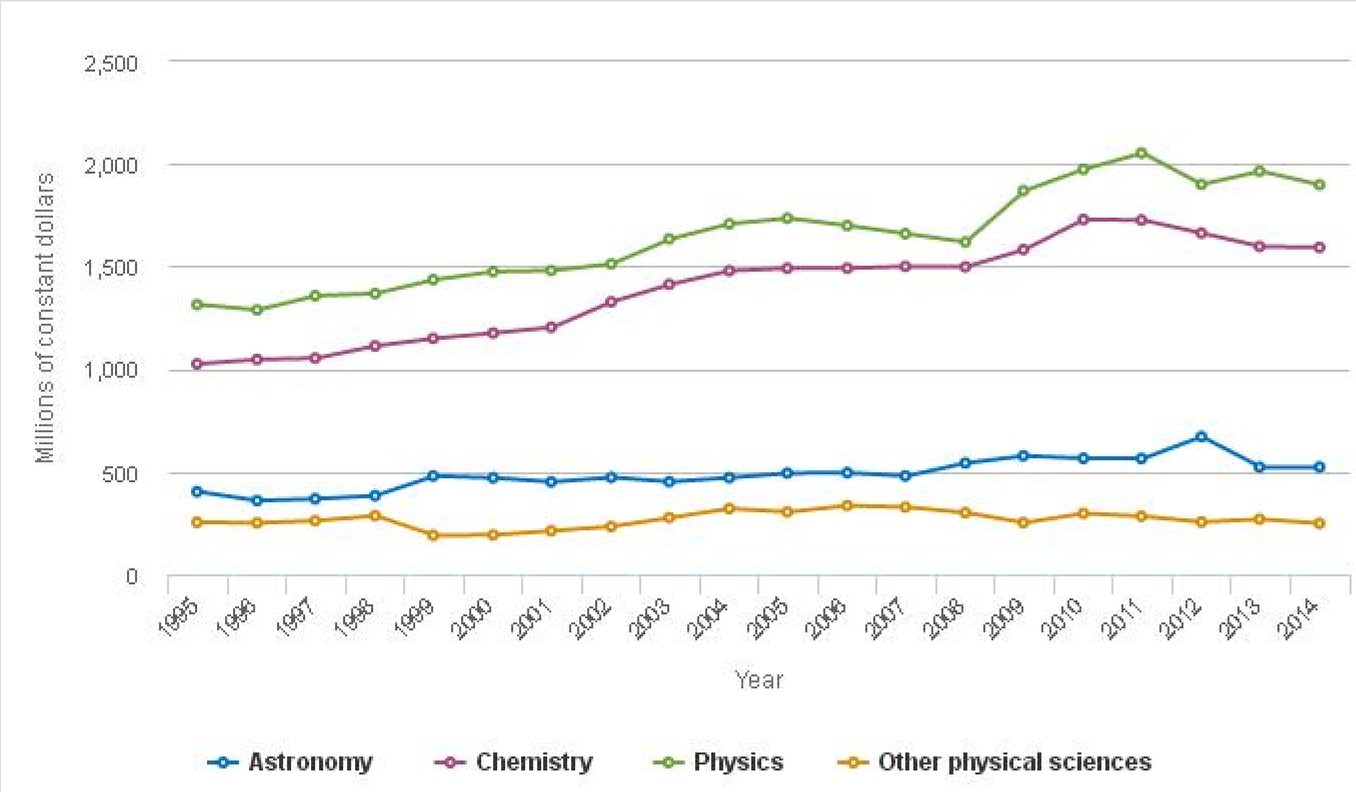
Physical sciences—consisting primarily of astronomy, chemistry, and physics—experienced slower-than-average growth in recent decades in academic R&D spending. In 2014, academic R&D spending in physical sciences accounted for 7% of total spending in S&E fields. In 1995, by contrast, inflation-adjusted spending in physical sciences, at $3 billion, constituted over 10% of total academic R&D spending in S&E fields that year. As with life sciences, constant average growth was quite a bit lower from 2005 to 2014 (1%) than it was over the decade prior to 2004 (3%) (Figure 5-5).

Figure 5-5

Academic R&D expenditures, by physical sciences field: FYs 1995–2014



NOTES: Gross domestic product deflators come from the U.S. Bureau of Economic Analysis and are available at http://www.bea.gov/national/, accessed 18 February 2015. See appendix table 4-1.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey.

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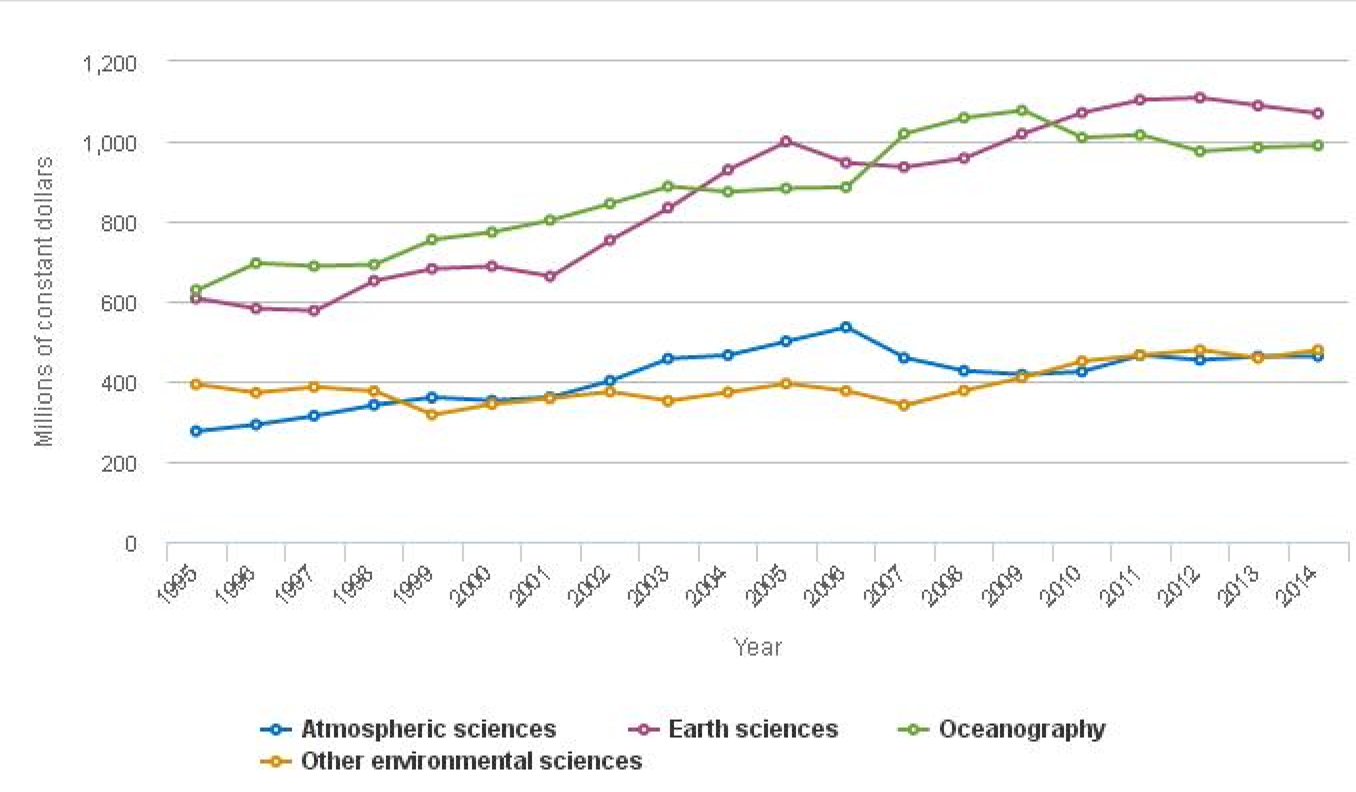
Environmental sciences, which include atmospheric and earth sciences as well as oceanography and other environmental sciences, showed the same dual-growth pattern as the other fields: about 4% from 1995 to 2004 and 1% thereafter (Figure 5-6). In 2014, environmental sciences constituted about 5% of academic R&D in S&E fields.

Figure 5-6

Academic R&D expenditures, by environmental sciences field: FYs 1995–2014



NOTES: Gross domestic product deflators come from the U.S. Bureau of Economic Analysis and are available at http://www.bea.gov/national/, accessed 18 February 2015. See appendix table 4-1.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey.

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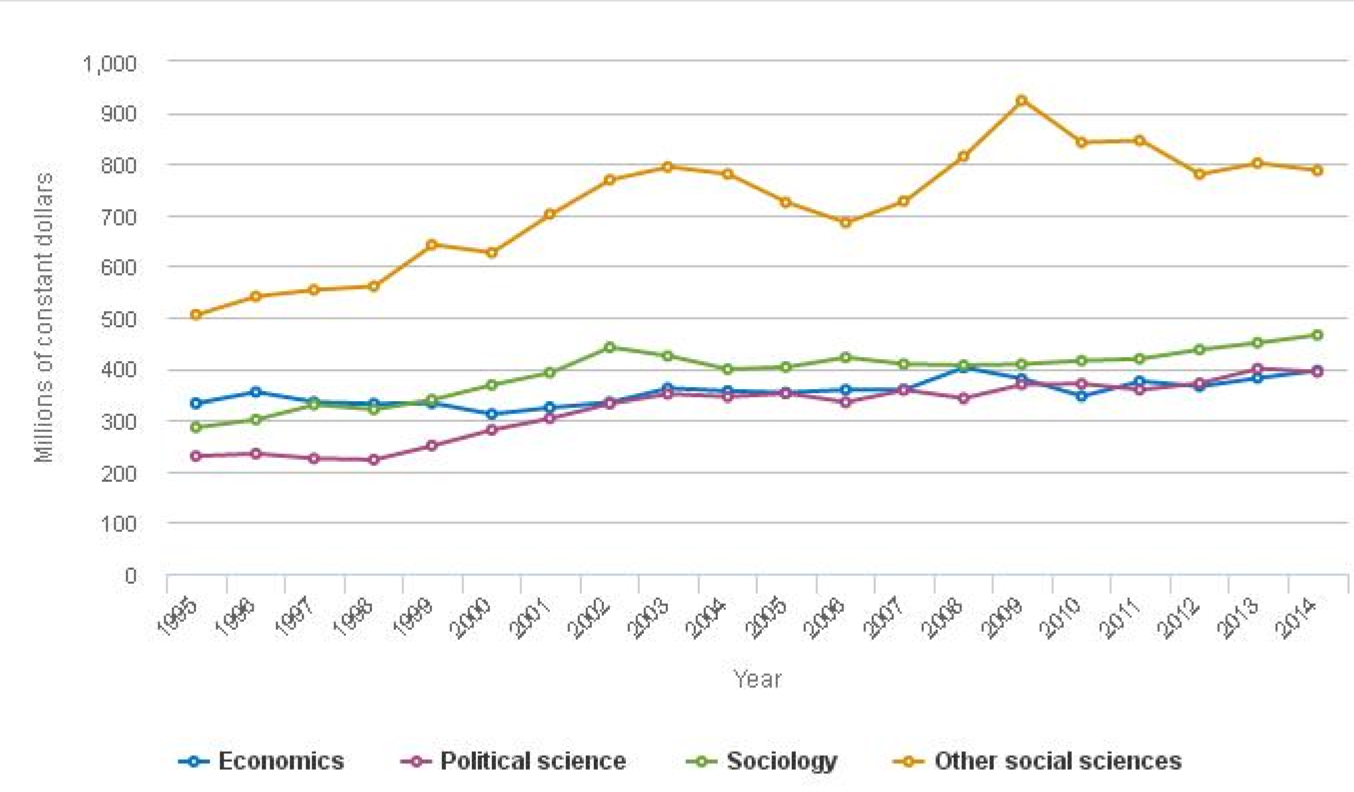
In 2014, academic R&D spending in social sciences constituted 3.5% of total spending in S&E fields and a lesser share (2.5%) of federal spending. Spending trends in the social sciences differed somewhat from spending trends in other fields (Figure 5-7). Economics grew by a fairly steady annual average of 1% over the entire two-decade period, with somewhat greater growth in the most recent decade. Political science, by contrast, saw 5% growth from 1995 to 2004 before dropping to 1% annual average growth. Sociology followed a similar pattern, with greater growth from 1995 to 2004 than from 2005 to 2014. The largest share of social sciences spending (just under 40% in 2014) occurred in fields not classified within economics, political science, or sociology. These social sciences include archaeology, city and community studies, criminal justice, history of science, linguistics, and urban studies, among other disciplines. They do not include the humanities, which is classified as a non-S&E field (Table 5-1).

Figure 5-7

Academic R&D expenditures, by social sciences field: FYs 1995–2014



NOTES: Gross domestic product deflators come from the U.S. Bureau of Economic Analysis and are available at http://www.bea.gov/national/, accessed 18 February 2015. See appendix table 4-1.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey.

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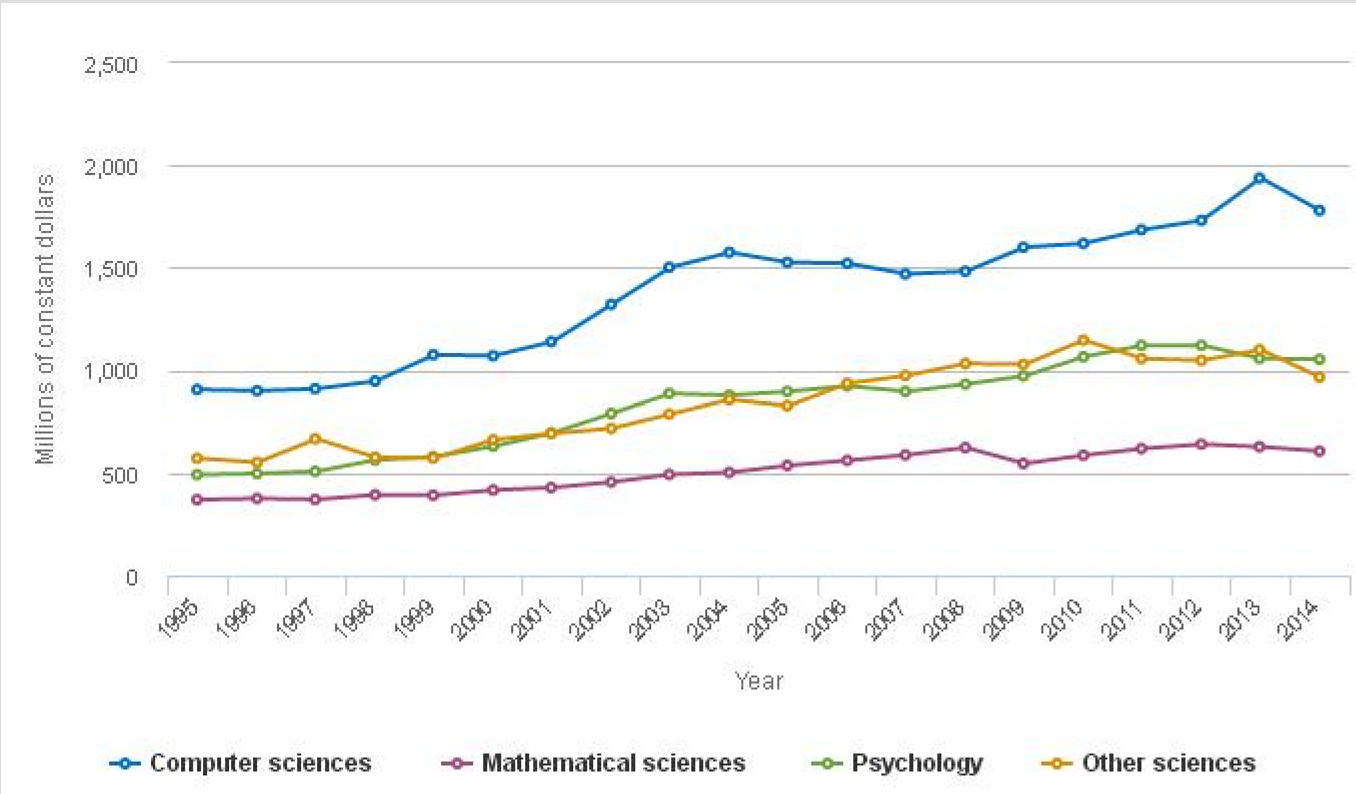
Growth trajectories of two dissimilar fields stand out. Spending in computer sciences grew by a 6% annual average from 1995 to 2004, followed by 2% thereafter. Psychology had a 7% annual average growth rate from 1995 to 2004 and 2% thereafter. The mathematical sciences grew by about 1% from 2005 to 2014 after a faster growth rate in the preceding decade (4%) (Figure 5-8).

Figure 5-8

Academic R&D expenditures, by selected fields: FYs 1995–2014



NOTES: Gross domestic product deflators come from the U.S. Bureau of Economic Analysis and are available at http://www.bea.gov/national/, accessed 18 February 2015. See appendix table 4-1.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey.

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In 2014 as in prior years over the past decade, around 2% of total and federal spending for academic R&D in S&E has been devoted to interdisciplinary or multidisciplinary work that cannot readily be assigned to a specific field (see sidebar, Interdisciplinary Research: Strategic Implications and Measurement Challenges).

Interdisciplinary Research: Strategic Implications and Measurement Challenges

The National Academy of Sciences defines *interdisciplinary research* (*IDR*) as "a mode of research by teams or individuals that integrates information and techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice" (NAS/NAE/IOM 2005). By engaging experts from different disciplines, IDR has the potential to provide a comprehensive approach for understanding and solving problems.

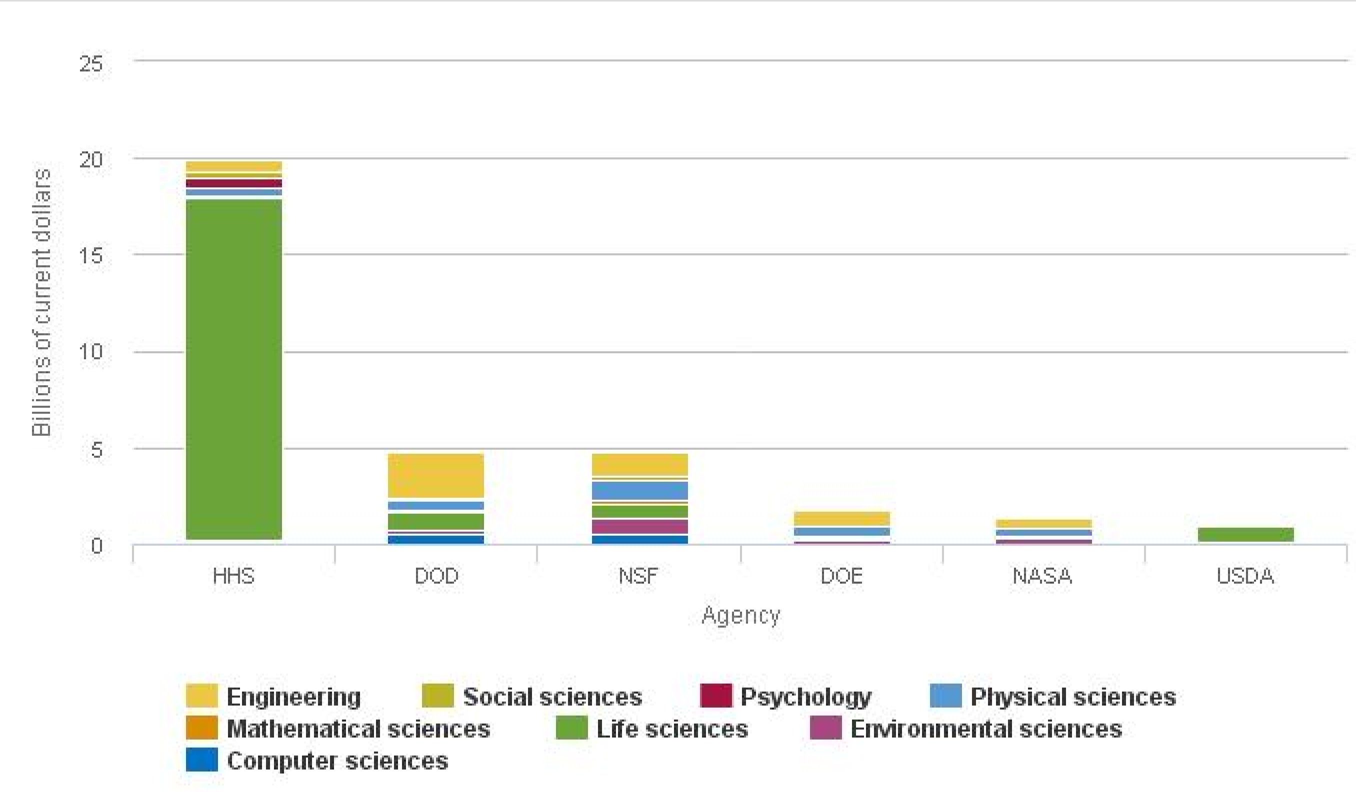
Because of the variety of forms, contexts, and outcomes of IDR, national quantitative data to measure IDR do not exist. Typically, the efforts to measure IDR have relied on bibliometric data. Other efforts to measure IDR have focused on proposal review, for example, by counting the stated disciplines of research proposals as well as enumerating the various disciplines represented by co–principal investigators. Recently, more sophisticated techniques for tracking IDR are also being attempted via text mining and mapping clusters of research interest. Surveys, interviews, and site visits can also shed light on interactions and collaborations of researchers from various academic disciplines.

Within U.S. higher education, national survey data indicate an increasing tendency of knowledge integration from multiple disciplines. Specifically, over the last decade, universities responding to the National Science Foundation's (NSF's) annual Higher Education Research and Development Survey have reported steady growth on R&D that spans more than one field of S&E. Additionally, in 2013, 40% of respondents to NSF's 2013 Survey of Earned Doctorates reported two or more dissertation research fields, up from 24% in 2001.

The federal government's role in funding R&D in the various fields of S&E hinges on each agency's mission focus (Figure 5-9). HHS—primarily NIH—supports the vast majority of federal funding in life sciences (84%) and is also the lead funding agency in psychology and the social sciences (Appendix Table 5-4). By contrast, with smaller shares of total academic R&D funding, DOD, DOE, NASA, and NSF have more diversified funding patterns. In 2014, as in previous years, NSF was the lead federal funding agency for academic research in physical sciences, mathematics, computer sciences, and environmental sciences. In 2014, DOD was the lead funding agency in engineering and spent almost as much as NSF in computer sciences.

Figure 5-9

Federally financed academic R&D expenditures, by agency and S&E field: FY 2014



DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; USDA = U.S. Department of Agriculture.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey, 2014. See appendix table 5-4.

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Federal funding has played a larger role in overall support for some fields than for others (Appendix Table 5-5). The federal government is the dominant funder in fields such as atmospheric sciences (78% in 2014), physics (73%), computer sciences (72%), and aeronautical and astronautical engineering (72%). It plays a smaller role in other fields, such as agricultural sciences (32%), economics (32%), and political sciences (34%).

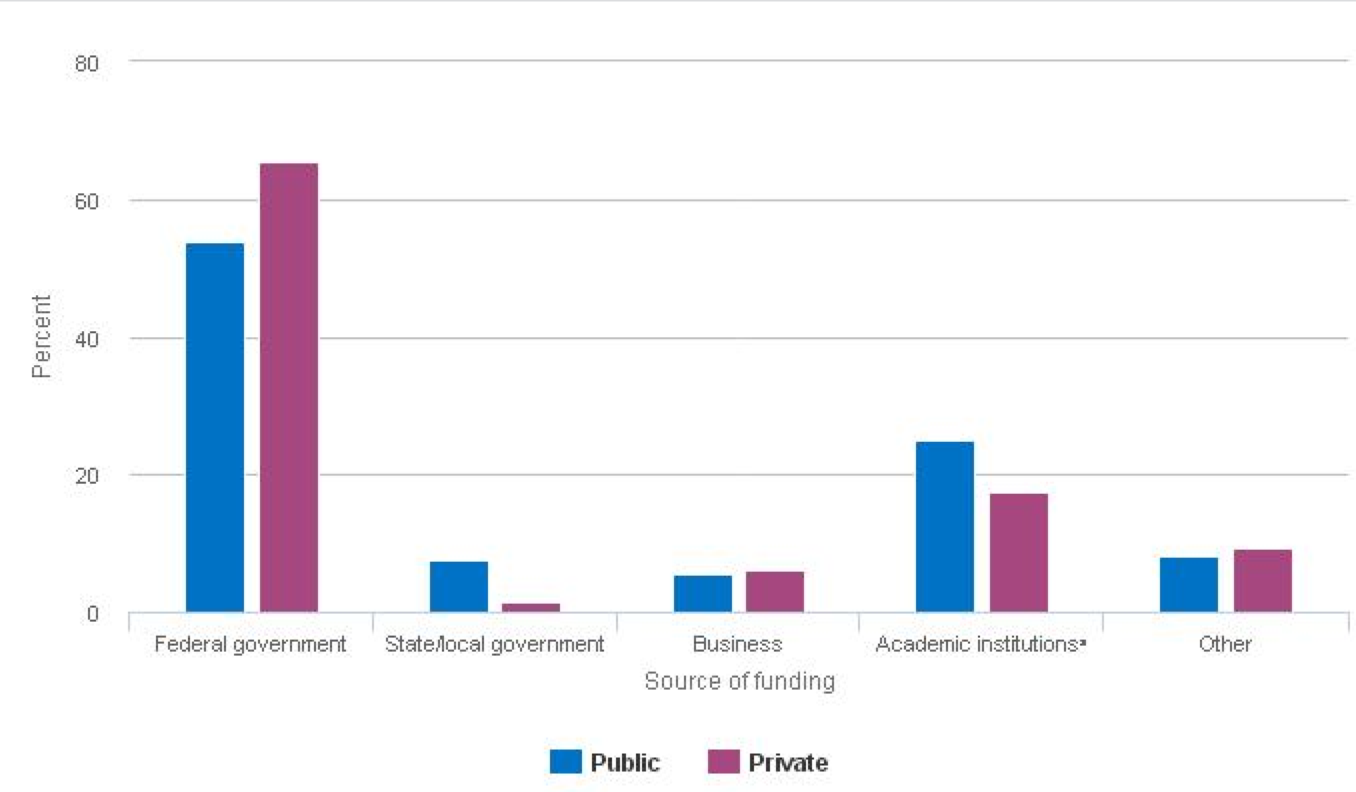
Academic R&D, by Public and Private Institutions

The federal government is the primary source of financing for academic R&D in S&E fields, but it accounts for a substantially greater share of private institutions' R&D spending (66%) than that of their public counterparts (54%) (Figure 5-10).[i] Conversely, public institutions derive about 8% of their R&D funds from state government sources versus 2% for private ones.

[i] See also the chapter 2 section on "Trends in Higher Education Expenditures and Revenues" for a discussion of average per-student financial flows at public and private institutions.

Figure 5-10

Sources of S&E R&D funding for public and private academic institutions: FY 2014



[a] Academic institutions' funds exclude research funds spent from multipurpose accounts.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey, 2013. See appendix table 5-3.

Science and Engineering Indicators 2016

Public universities pay for about 25% of their R&D from their own institutional funds, while private universities pay for a smaller share (18%) (Table 5-6). This larger proportion of institutional R&D funds in public institutions may reflect general-purpose government funds that public institutions direct toward R&D. Private institutions also reported a larger proportion of unrecovered indirect costs in their institutional total in 2014 (35% versus 28% for public institutions) (Table 5-7).[ii], [iii]

[ii] These data are available for academic R&D spending across all fields, including S&E and non-S&E funds. HERD does not provide breakouts for S&E only.

[iii] In 1991, the Office of Management and Budget capped reimbursement of administrative costs at 26% of total direct costs. As a result, actual unrecovered indirect costs at both public and private universities may be somewhat higher than the amounts reported on the HERD Survey.

Table 5-6 **Total and institutionally funded R&D expenditures at universities and colleges, by year, institution type, and Carnegie classification: FYs 2010–14**

(Thousands of dollars)

Year, institution type, and Carnegie classification	All R&D expenditures[a]		S&E R&D expenditures	
	Total	Institutional funds[b]	Total	Institutional funds[b]
2010	61,253,743	11,940,472	58,356,805	10,673,732
Public	41,231,333	9,330,065	39,079,435	8,393,767
Research universities–very high research activity	28,389,670	6,537,430	27,070,983	5,961,451
Private	20,022,410	2,610,407	19,277,370	2,279,965
Research universities–very high research activity	16,251,746	2,099,604	15,747,784	1,865,536
2011	65,276,179	12,610,368	61,992,171	11,130,017
Public	43,915,002	9,897,596	41,508,388	8,812,273
Research universities–very high research activity	30,013,886	6,909,899	28,530,915	6,248,587
Private	21,361,177	2,712,772	20,483,783	2,317,744
Research universities–very high research activity	17,227,320	2,090,861	16,646,487	1,818,092
2012	65,729,338	13,633,435	62,201,879	12,031,470
Public	44,162,988	10,455,853	41,612,532	9,300,101
Research universities–very high research activity	30,386,473	7,359,656	28,830,163	6,663,763
Private	21,566,350	3,177,582	20,589,347	2,731,369
Research universities–very high research activity	17,523,071	2,492,532	16,832,136	2,159,238
2013	67,014,807	14,984,948	63,360,571	13,264,458
Public	44,851,358	11,193,056	42,297,456	9,987,420
Research universities–very high research activity	31,192,547	7,876,152	29,571,921	7,123,842
Private	22,163,449	3,791,892	21,063,115	3,277,038
Research universities–very high research activity	18,085,899	3,013,479	17,280,423	2,618,997
2014	67,154,642	15,753,517	63,742,539	14,279,085
Public	44,657,466	11,649,654	42,154,026	10,493,742

Year, institution type, and Carnegie classification	All R&D expenditures[a]		S&E R&D expenditures	
	Total	Institutional funds[b]	Total	Institutional funds[b]
Research universities–very high research activity	31,176,923	8,335,437	29,514,304	7,544,998
Private	22,497,176	4,103,863	21,588,513	3,785,343
Research universities–very high research activity	18,379,538	3,249,291	17,744,487	3,041,937

[a] All R&D expenditures include S&E and non-S&E R&D expenditures.

[b] Institutional funds exclude research funds spent from multipurpose accounts.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey.

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Table 5-7 **Higher education R&D expenditures at all universities and colleges financed by institutional funds, by source, year, institution type, and Carnegie classification: FYs 2010–14**

(Thousands of dollars)

Year, institution type, and Carnegie classification	All R&D expenditures b	Institutional funds[a]			
		Total	Institutionally financed research	Cost sharing	Unrecovered indirect costs
2010	61,253,743	11,940,472	6,194,288	1,085,116	4,661,068
Public	41,231,333	9,330,065	5,202,327	742,848	3,384,890
Research universities – very high research activity	28,389,670	6,537,430	3,624,936	479,886	2,432,608
Private	20,022,410	2,610,407	991,961	342,268	1,276,178
Research universities – very high research activity	16,251,746	2,099,604	668,713	292,051	1,138,840
2011	65,276,179	12,610,368	6,844,738	1,159,675	4,605,955
Public	43,915,002	9,897,596	5,704,522	790,084	3,402,990
Research universities – very high research activity	30,013,886	6,909,899	3,958,178	520,785	2,430,936
Private	21,361,177	2,712,772	1,140,216	369,591	1,202,965
Research universities – very high research activity	17,227,320	2,090,861	736,403	304,676	1,049,782
2012	65,729,338	13,633,435	7,735,781	1,292,462	4,605,192

		Institutional funds[a]			
Year, institution type, and Carnegie classification	All R&D expenditures b	Total	Institutionally financed research	Cost sharing	Unrecovered indirect costs
Public	44,162,988	10,455,853	6,340,188	851,547	3,264,118
Research universities – very high research activity	30,386,473	7,359,656	4,441,962	586,974	2,330,720
Private	21,566,350	3,177,582	1,395,593	440,915	1,341,074
Research universities – very high research activity	17,523,071	2,492,532	918,236	385,897	1,188,399
2013	67,014,807	14,984,948	8,922,398	1,364,685	4,697,865
Public	44,851,358	11,193,056	7,008,443	886,125	3,298,488
Research universities – very high research activity	31,192,547	7,876,152	4,911,547	608,879	2,355,726
Private	22,163,449	3,791,892	1,913,955	478,560	1,399,377
Research universities – very high research activity	18,085,899	3,013,479	1,359,326	416,674	1,237,479
2014	67,154,642	15,753,517	9,605,160	1,394,088	4,754,269
Public	44,657,466	11,649,654	7,438,364	899,795	3,311,495
Research universities – very high research activity	31,176,923	8,335,437	5,324,197	621,904	2,389,336
Private	22,497,176	4,103,863	2,166,796	494,293	1,442,774
Research universities – very high research activity	18,379,538	3,249,291	1,532,708	433,587	1,282,996

[a] Institutional funds exclude research funds spent from multipurpose accounts.

[b] All R&D expenditures include S&E and non-S&E R&D expenditures.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey.

Science and Engineering Indicators 2016

In 2014, nonprofit organizations funded about 5% of total R&D expenditures in public institutions and 7% in private institutions. Among the nation's 73 most research-intensive public universities according to Carnegie classification, nonprofit funds were the source of an average of 4% of these schools' total R&D spending in S&E. Percentages ranged from less than 1% to over 17%, with most schools (46) receiving less than 5% from nonprofit funds and only 3 schools receiving over 10% of their total academic R&D monies from nonprofit funds. The story is somewhat different at the nation's 35 most research-intensive private institutions, where nonprofit funds were the source of an average of 7% of these institutions' total R&D spending in S&E. Percentages ranged from 2% to 14%, with most schools (22) receiving at least 6% from nonprofit organizations and 7 schools receiving 10% or more of total R&D funds from nonprofit organizations.

Universities and colleges received about 6% of their R&D support from business in 2014. Business funding was slightly higher as a share at the nation's most research-intensive private institutions (6%) than at their public counterparts (5%). Funding from all other sources was around 3% in both institution types.

Distribution of R&D Funds across Academic Institutions

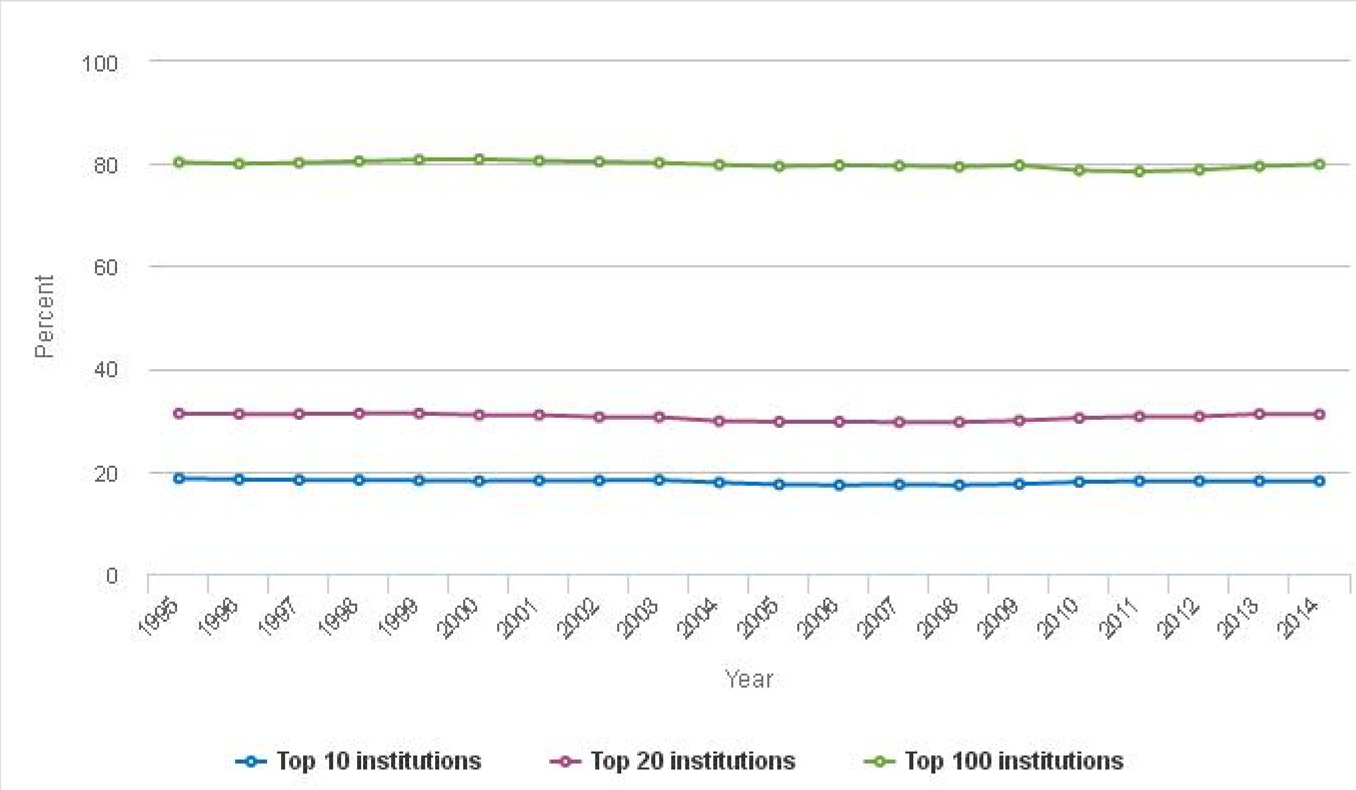
In 2014, a total of 395 public institutions spent $42.2 billion on R&D in S&E fields, and a total of 239 private institutions spent $21.6 billion (Appendix Table 5-3). Among the top 100 universities in academic R&D expenditures in 2014, two-thirds were public universities and colleges, and one-third were private schools (Appendix Table 5-6).

Academic R&D expenditures are highly concentrated in a relatively small number of institutions. In 2014, out of approximately 3,000 baccalaureate-, master's-, and doctorate-granting institutions, 634 reported spending at least $1 million on R&D.[iv] The top-spending 20 institutions accounted for over 30% of total academic R&D spending in S&E fields in 2014, and the top-spending 100 institutions accounted for 80%. The relative shares of the large research universities have been remarkably stable over the past two decades (Figure 5-11), although the identities of the top 20 or top 100 institutions have varied over time.

[iv] An additional 261 institutions reported spending less than $1 million on academic R&D in FY 2013. These institutions received a shorter version of the survey questionnaire and are not represented in this chapter.

Figure 5-11

Share of academic S&E R&D, by institution rank in R&D expenditures: FYs 1995–2014



SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey. See appendix table 5-6.

Science and Engineering Indicators 2016

R&D Collaboration between Academic Institutions

Research collaboration involving multiple institutions is a growing trend. Federal initiatives encourage it, interdisciplinary research areas invite it, and technological advances facilitate communication and provide opportunities to mobilize specialized skills beyond the capacity of individual institutions. Opportunities to share risk and increase research credibility contribute to R&D collaboration's growth (Cummings and Kiesler 2007). The rise of academic R&D collaboration across different organizations is also evident in the growth of research articles with authors at different institutions (see Outputs of S&E Research: Publications and Patents in this chapter).

The trend is also evident in the growing flow of funds among institutions to support collaborative research activities—that is, the amount of their total expenditures for R&D that universities pass through to other organizations, including academic institutions and others. Available data on pass-through funding encompass S&E R&D from 2000 to 2009 and total R&D (including non-S&E as well as S&E funds) from 2010 to 2014. From a low base in 2000, academic pass-through funds increased more rapidly than R&D expenditures through 2009, doubling in amount over this period in constant dollars, while total academic R&D grew by about 50% (Hale 2012).[v] As with overall academic R&D funding, pass-through funding arrangements are heavily concentrated in the most research-intensive institutions.

Funds that universities passed through to other higher education institutions increased substantially from 2010 to 2011, coinciding with the highest levels of ARRA spending, and then remained relatively flat from 2011 to 2014. As with overall academic R&D funding, the federal share of funds that universities passed through to other higher education institutions declined somewhat from 2013 to 2014 (Figure 5-12). However, the federal government continues to be the major provider of pass-through funds; in 2014 (as in prior years), it was the source for about 90% of all pass-through funds that universities and colleges provided to or received from other higher education institutions (Appendix Table 5-7). Both public and private universities engage actively in pass-through funding arrangements (Table 5-8 and Table 5-9).

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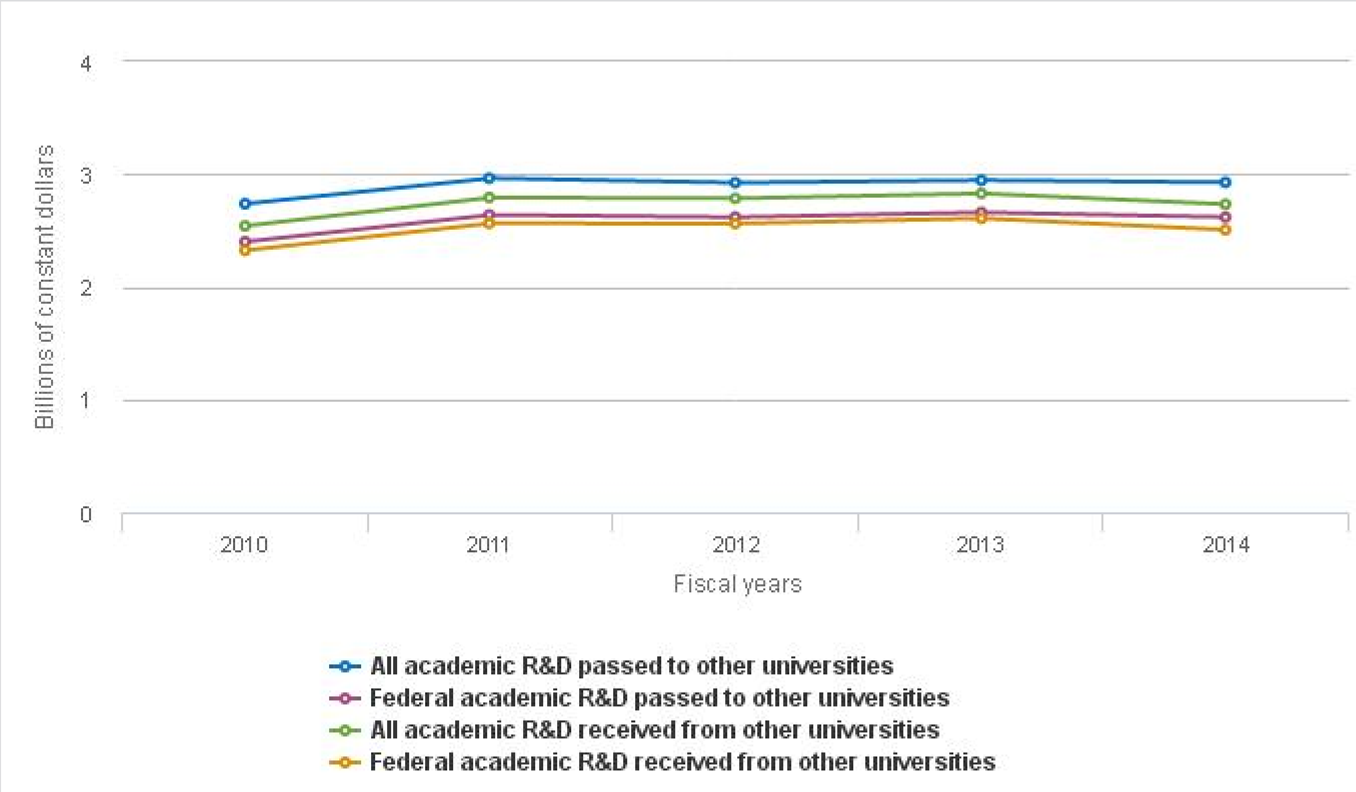
[v] During the early years of the 2000–09 decade, survey questions on pass-through funding were voluntary, with relatively high nonresponse (11% in 2000 versus 4% in 2009).

Figure 5-12

Total and federally funded academic R&D pass-throughs: FYs 2010–14



SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey.

Science and Engineering Indicators 2016

Table 5-8 Total and federally financed higher education R&D expenditures passed through to subrecipients, by institution type: FY 2014

(Thousands of dollars)

		R&D expenditures passed through to subrecipients				
R&D expenditures and type of institution	All R&D expenditures	Total	Higher education subrecipients	Businesses	Nonprofit organizations	Other subrecipients
Total R&D, all institutions	67,154,642	5,715,966	3,168,555	1,071,503	948,947	526,961
Public	44,657,466	3,566,961	2,020,333	707,107	534,275	305,246
Private	22,497,176	2,149,005	1,148,222	364,396	414,672	221,715
Federally financed R&D, all institutions	37,922,314	4,899,188	2,834,727	833,508	815,462	415,491
Public	23,493,609	3,086,201	1,785,680	601,383	459,493	239,645

		R&D expenditures passed through to subrecipients				
R&D expenditures and type of institution	All R&D expenditures	Total	Higher education subrecipients	Businesses	Nonprofit organizations	Other subrecipients
Private	14,428,705	1,812,987	1,049,047	232,125	355,969	175,846

NOTE: Data include S&E and non-S&E R&D expenditures.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey, 2014.

Science and Engineering Indicators 2016

Table 5-9 **Total and federally financed higher education R&D expenditures received as a subrecipient, by institution type: FY 2014**

(Thousands of dollars)

		R&D expenditures received as a subrecipient				
R&D expenditures and type of institution	All R&D expenditures	Total	Higher education pass-through entities	Businesses	Nonprofit organizations	Other pass-through entities
Total R&D, all institutions	67,154,642	6,526,751	2,958,040	1,068,695	1,420,380	1,079,636
Public	44,657,466	4,535,620	1,907,434	765,042	958,764	904,380
Private	22,497,176	1,991,131	1,050,606	303,653	461,616	175,256
Federally financed R&D, all institutions	37,922,314	5,556,238	2,712,063	825,726	1,125,912	892,537
Public	23,493,609	3,792,648	1,753,883	561,311	731,263	746,191
Private	14,428,705	1,763,590	958,180	264,415	394,649	146,346

NOTE: Data include S&E and non-S&E R&D expenditures.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey, 2014.

Science and Engineering Indicators 2016

The growth in pass-through funding has been accompanied by changing research practices, seen particularly in the growth of larger research teams, including many that span or integrate multiple disciplines (see sidebar, Interdisciplinary Research: Strategic Implications and Measurement Challenges).

Infrastructure for Academic R&D

Physical infrastructure is an essential resource for the conduct of R&D. Traditionally, the capital infrastructure for R&D consisted primarily of research space (e.g., laboratories and computer rooms) and instrumentation. Accordingly, the square footage of a designated research space and counts of instruments have been the principal indicators of the status of research infrastructure.

Advances in information technology (IT) have brought significant changes to both the methods of scientific research and the infrastructure necessary to conduct R&D. The technologies, human interfaces, and associated processing capabilities resulting from these innovations are often called *cyberinfrastructure.* The value of research facilities, research equipment, and cyberinfrastructure to the academic R&D infrastructure is highlighted below.

Research Facilities

Research Space

The nation's colleges and universities had 211.8 million net assignable square feet (NASF) of research space available at the end of 2013 (Appendix Table 5-8).[i] This was 4.7% above the NASF at the end of 2011, continuing more than two decades of expansion. The average rate of increase for all biennial periods measured from 1988 to 2013 was 5.2% (Figure 5-13).

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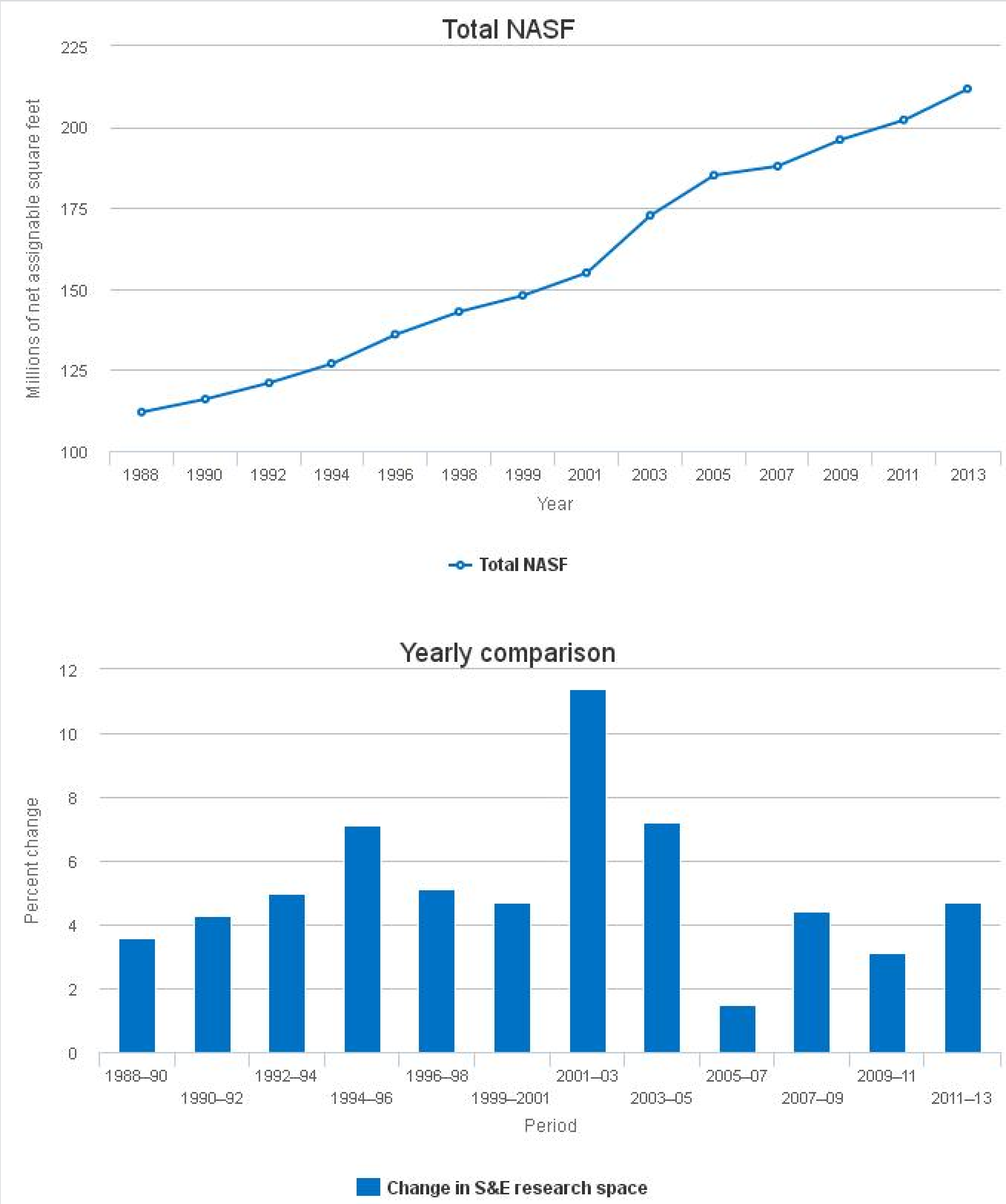
[i] Research space here is defined as the space used for sponsored R&D activities at academic institutions and for which there is separate budgeting and accounting. Research space is measured in net assignable square feet (NASF). This is the sum of all areas on all floors of a building assigned to, or available to be assigned to, an occupant for a specific use, such as research or instruction. NASF is measured from the inside faces of walls. Multipurpose space that is partially used for research is prorated to reflect the proportion of time and use devoted to research.

Figure 5-13

Change in S&E research space in academic institutions, by 2-year period: FYs 1988–2013



NASF = net assignable square feet.

NOTE: The biennial survey cycle ran on even years from 1988 to 1998 and on odd years from 1999 to 2013.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Science and Engineering Research Facilities.

Science and Engineering Indicators 2016

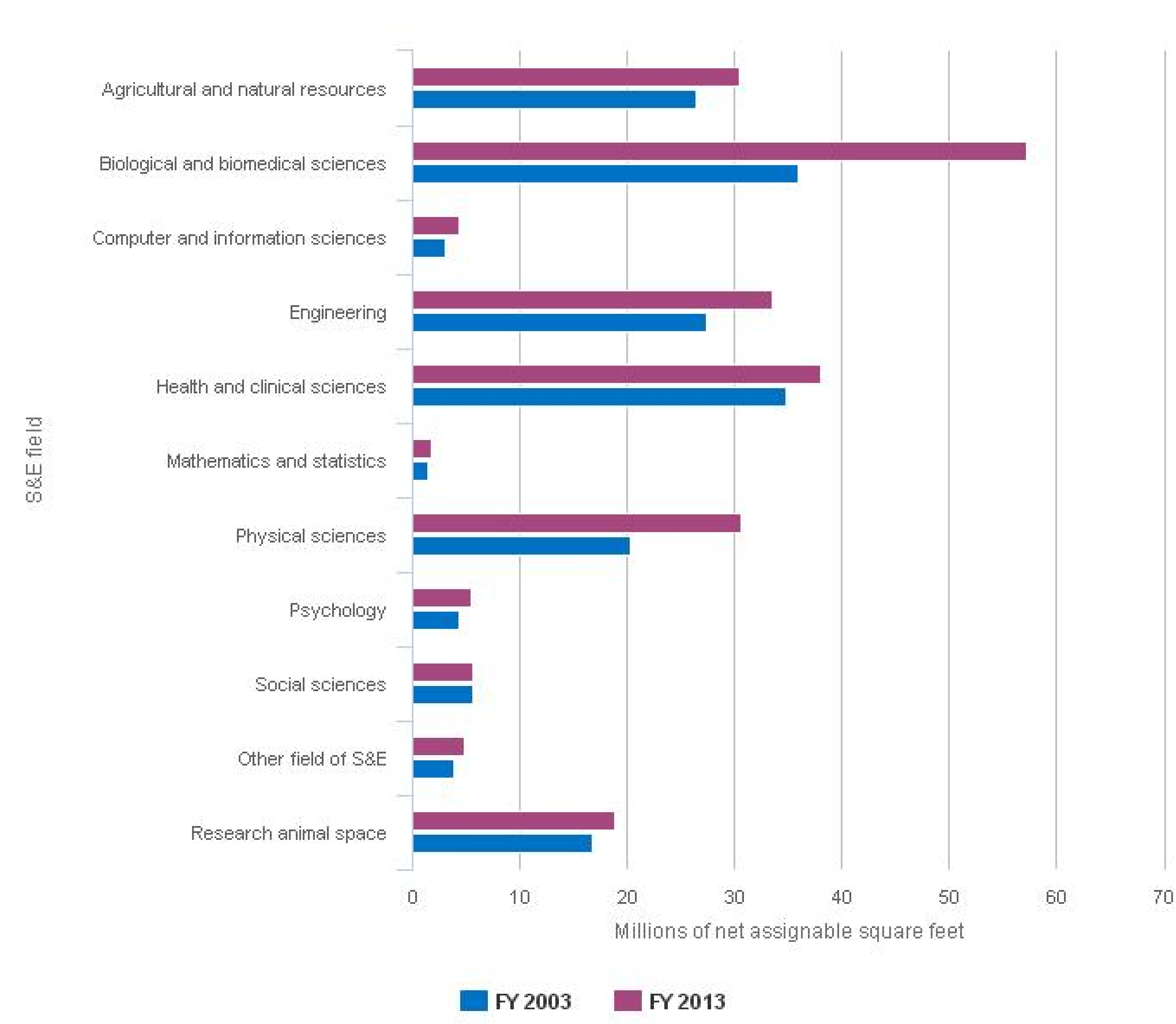
The biological and biomedical sciences constituted the largest share (27.0%, or 57.2 million NASF) of all academic research space in 2013, which is slightly more than the share it held in 2011 (26.6%) (Appendix Table 5-8). This field, along with the agricultural and natural resources sciences, accounted for two-thirds of the 9.6 million in NASF growth from 2011. Research space in the biological and biomedical sciences increased 6.5% (3.5 million NASF) during the 2011–13 period. Space in the agricultural and natural resources sciences increased 10.5% (2.9 million NASF).[ii] From 2003 to 2013, research space in biological and biomedical sciences grew 58.9% (Figure 5-14); this is the only field that increased space in each of the five biennial periods since 2003. The related field of health and clinical sciences was the second largest in 2013, accounting for 17.9% of the total, or 38.0 million NASF. However, this total is slightly lower than the 39.7 million NASF of health and clinical sciences research space in use in 2005 after the near-doubling of the NIH budget from 1998 to 2003. The remaining large fields in 2013 were engineering (15.8%, or 33.5 million NASF); physical sciences (14.5%, or 30.7 million NASF); and agricultural and natural resources (14.4%, or 30.5 million NASF).[iii]

[ii] The S&E fields used in the National Science Foundation Survey of Science and Engineering Research Facilities are based on the National Center for Education Statistics Classification of Instructional Programs (CIP)—which is updated every 10 years (the current version is dated 2010). The S&E fields used in the FY 2011 and FY 2013 Survey of Science and Engineering Research Facilities reflect the 2010 CIP update. Both the FY 2007 and FY 2009 surveys reflect the 2000 CIP standard. For a comparison of the subfields in the FY 2005 and FY 2007 surveys, see the detailed statistical tables for S&E Research Facilities: FY 2007 (NSF/NCSES 2011). No major impacts on these data resulted from the CIP 2010 update.

[iii] The science and technology field and subfield definitions were updated to the 2000 Classification of Instructional Programs starting with the FY 2007 Survey of Science and Engineering Research Facilities. Some of the observed declines in research space for health and clinical sciences and for physical sciences between FY 2005 and FY 2007 could reflect definition changes.

Figure 5-14

Research space at academic institutions, by S&E field: FYs 2003 and 2013



NOTES: S&E fields are those used in the National Center for Education Statistics (NCES) Classification of Instructional Programs (CIP). NCES updates the CIP every 10 years. S&E fields here reflect the NCES 2010 CIP update.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Science and Engineering Research Facilities. See appendix table 5-8.

Science and Engineering Indicators 2016

In 2013, 81% of research space was reported by academic institutions as being in superior or satisfactory condition (Table 5-10).[iv] Fifteen percent of space required renovations, while the remaining 4% required replacement. These percentages changed very little over the past decade. In 2003, 79% of academic research space was reported as being in superior or satisfactory condition, 16% required renovations, and 5% required replacement. Between 79% and 85% of research space was rated as either superior or satisfactory across all but two major fields in 2013. Ninety-one percent of research space in the computer and information sciences (4.3 million NASF) was rated as superior or satisfactory, while 77% of space in the agricultural and natural resources sciences (30.5 million NASF) was similarly rated.

[iv] For the FY 2013 Survey of Science and Engineering Research Facilities, 588 academic institutions were asked to identify the percentage of research NASF (including research animal space) that fell into each of the four following condition categories: *superior condition*—suitable for the most scientifically competitive research in this field over the next 2 years (FY 2014 and FY 2015); *satisfactory condition*—suitable for continued use over the next 2 years (FY 2014 and FY 2015) for most levels of research in this field but may require minor repairs or renovation; *requires renovation*—will no longer be suitable for current research without undergoing major renovation within the next 2 years (FY 2014 and FY 2015); *requires replacement*—should stop using space for current research within the next 2 years (FY 2014 and FY 2015).

Table 5-10 **Condition of S&E research space in academic institutions, by field: FY 2013**

		Condition (% NASF)			
Field	NASF (millions)[a]	Superior	Satisfactory	Requires renovations	Requires replacement
All research space	211.2	35	46	15	4
Agricultural and natural resources sciences	30.5	24	53	19	4
Biological and biomedical sciences	57.0	39	43	14	4
Computer and information sciences	4.3	48	43	7	2
Engineering	33.4	35	46	16	3
Health and clinical sciences	37.9	41	44	12	3
Mathematics and statistics	1.7	29	53	15	3
Physical sciences	30.5	31	48	18	4
Earth, atmospheric, and ocean sciences	7.8	31	47	18	4
Astronomy, chemistry, and physics	22.7	31	48	17	4
Psychology	5.5	35	45	15	4
Social sciences	5.6	28	56	14	2
Other	4.8	42	43	8	6

NASF = net assignable square feet.

[a] NASF is the amount of NASF located at only those institutions that also rated the condition of their space. Consequently, this table accounts for approximately 0.6 million fewer NASF than other tables.

NOTES:	Detail may not add to total due to rounding. Condition was assessed relative to the usage of the current research program.
SOURCE:	National Science Foundation, National Center for Science and Engineering Statistics, Survey of Science and Engineering Research Facilities, FY 2013.
	Science and Engineering Indicators 2016

New Construction

New research space is added each year through new construction projects and the repurposing of existing space. Similarly, some space is withdrawn from use through decommissioning and repurposing. The net result has been an increase in research space for more than two decades. As part of this process, academic institutions broke ground on 6.7 million NASF of new S&E research space construction projects in 2012–13, the lowest total in a decade. This total is 17.3% lower than the new research space construction that began in 2010–11 and 56.8% lower than the NASF of new building that began in 2002–03 (Table 5-11). Public institutions accounted for 73.4% of new construction space, which is within the typical range of 73%–78%.

Table 5-11 **New construction of S&E research space in academic institutions, by field and time of construction: FYs 2002–13**

Field	Started in FY 2002 or FY 2003	Started in FY 2004 or FY 2005	Started in FY 2006 or FY 2007	Started in FY 2008 or FY 2009	Started in FY 2010 or FY 2011	Started in FY 2012 or FY 2013	Planned to start in FY 2014 or FY 2015
	Net assignable square feet (millions)						
All fields	15.5	10.1	8.8	9.9	8.1	6.7	8.8
Agricultural and natural resources	0.8	0.4	0.5	0.4	0.4	0.4	0.5
Biological and biomedical sciences	3.7	3.2	2.9	3.5	2.0	2.0	2.0
Computer and information sciences	0.9	0.3	0.6	0.3	0.1	0.2	0.5
Engineering	2.2	1.5	1.3	2.1	1.3	1.4	1.6
Health and clinical sciences	4.9	3.3	1.7	1.9	2.8	1.6	1.9
Mathematics and statistics	*	*	*	*	*	*	*
Physical sciences	2.0	0.8	1.0	1.0	0.9	0.8	1.7
Earth, atmospheric, and ocean sciences	0.5	0.3	0.3	0.1	0.3	0.2	0.8
Astronomy, chemistry, and physics	1.5	0.5	0.7	0.9	0.6	0.6	0.9

Field	Started in FY 2002 or FY 2003	Started in FY 2004 or FY 2005	Started in FY 2006 or FY 2007	Started in FY 2008 or FY 2009	Started in FY 2010 or FY 2011	Started in FY 2012 or FY 2013	Planned to start in FY 2014 or FY 2015
Psychology	0.2	0.2	0.1	0.3	0.1	*	0.1
Social sciences	0.2	0.1	0.1	0.2	0.1	0.1	0.1
Other sciences	0.7	0.3	0.7	0.3	0.3	0.1	0.3
Research animal space[a]	1.4	1.2	1.0	0.8	0.6	0.7	na
	Share of total new construction square feet (%)						
All fields	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Agricultural and natural resources	5.1	3.9	5.7	4.0	4.9	6.0	5.7
Biological and biomedical sciences	23.6	31.4	33.0	35.4	24.7	29.9	22.7
Computer and information sciences	5.9	2.9	6.8	3.0	1.2	3.0	5.7
Engineering	14.2	14.7	14.8	21.2	16.0	20.9	18.2
Health and clinical sciences	31.4	32.4	19.3	19.2	34.6	23.9	21.6
Mathematics and statistics	*	*	*	*	*	*	*
Physical sciences	12.5	7.8	11.4	10.1	11.1	11.9	19.3
Earth, atmospheric, and ocean sciences	3.1	2.9	3.4	1.0	3.7	3.0	9.1
Astronomy, chemistry, and physics	9.4	4.9	8.0	9.1	7.4	9.0	10.2
Psychology	1.1	2.0	1.1	3.0	1.2	*	1.1
Social sciences	1.3	1.0	1.1	2.0	1.2	1.5	1.1
Other sciences	4.6	2.9	8.0	3.0	3.7	1.5	3.4
Research animal space[a]	9.0	11.8	11.4	8.1	7.4	10.4	na

* = > 0 but < 50,000 net assignable square feet; na = not applicable.

	[a] Figures for research animal space are listed separately and are also included in individual field totals.
NOTES:	Detail may not add to total because of rounding. S&E fields are those used in the National Center for Education Statistics (NCES) Classification of Instructional Programs (CIP). NCES updates the CIP every 10 years; S&E fields here reflect the NCES 2010 CIP update. For comparison of subfields in the FY 2005 and FY 2007 surveys, see S&E Research Facilities: FY 2007, detailed statistical tables.
SOURCE:	National Science Foundation, National Center for Science and Engineering Statistics, Survey of Science and Engineering Research Facilities.
	Science and Engineering Indicators 2016

Although the growth rate of new construction projects has declined over the past decade, institutions initiated new construction in all fields in this latest period. Construction projects for the biological and biomedical sciences accounted for 2.0 million NASF in 2012–13, the largest amount of space initiated for any field. While the amount of new construction in the field has remained the same since 2010–11, it is lower than each of the four data collection periods from 2002 to 2009. Health and clinical sciences combined with engineering to add 3.0 million NASF, resulting in these S&E fields (biological and biomedical sciences, health and clinical sciences, and engineering) accounting for 74.6% of new research space construction in 2012–13. Overall, an estimated 8.8 million NASF of new research space construction are planned for 2014–15, and these three fields are projected to account for nearly two-thirds (62.5%) of this new construction.

Academic institutions draw on various sources to fund their capital projects, including the institutions' own funds, state or local governments, and the federal government (Appendix Table 5-9). Institutions provide the majority of funds for construction of new research space, typically accounting for over 60.0% of the cost.[v] For the construction of new research space initiated in 2012–13, 67.5% of the funding came from institutions' internal sources, 26.9% from state and local governments, and the remaining 5.7% from the federal government, which was never a major funder of academic research facilities. Three-quarters of federal funding ($235.8 million) went to public doctorate-granting institutions. The total estimated cost of $5.5 billion reported for new construction started in 2012–13 was the lowest total reported in over a decade.

Repair and Renovation

Academic institutions expended $3.7 billion on major repairs and renovations of S&E research space in 2012–13 (Appendix Table 5-10).[vi] They anticipated $3.4 billion in costs for planned repair and renovation of research space with start dates in 2014–15. Over $901 million were planned to improve space in biological and biomedical sciences as well as more than $817 million for improvements to health and clinical sciences space. In addition to these slated improvements, academic institutions reported $5.4 billion in repair and renovation projects from their institutional plans that were not yet funded or scheduled to start in 2014–15. An additional $2.9 billion in needed improvements were identified that lay beyond institutional plans. Public institutions spent 51.6% of the total $3.7 billion, which is below the average share of 56.1% for the 2004–11 period.

The total backlog of deferred improvements was greater than all projects started or planned for the 2012–15 period. The costs for deferred repairs and renovations have consistently been greater than those started or planned for similar cycles in the past. This is due in part to the longer time frames of institutional plans that often run to 5 years or more.

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[v] *Institutional sources* include universities' operating funds, endowments, private donations, tax-exempt bonds and other debt financing, and indirect costs recovered from federal and nonfederal sources.

[vi] Only projects whose prorated cost was estimated to be $250,000 or more for at least one field of S&E were included.

Research Equipment

In 2014, about $2 billion in current funds were spent for movable equipment necessary for the conduct of academic S&E research projects (Appendix Table 5-11).[i] This spending accounted for 3.1% of the $63.7 billion of total academic S&E R&D expenditures. Spending decreased 11.3% from 2013 to 2014 when adjusted for inflation. Expenditures for academic research equipment reached the highest mark in several decades in 2004. Research equipment expenditures reached this level again in 2011 due in part to ARRA funding. After this temporary increase, the 2012 expenditures fell to the lowest constant-dollar level since 2007 before rising almost 10% in 2013. The recent fluctuations continued in 2014, with the lowest total in constant dollars since 2001.

Research equipment expenditures continue to be concentrated in just three fields, which accounted for 87.1% of the 2014 total: life sciences (36.9%), engineering (32.9%), and physical sciences (17.3%). The shares for these three fields have consistently accounted for about 80% or more of total equipment expenditures, although the 2014 combined shares are the highest on record (Appendix Table 5-11).

When adjusted for inflation, the 2014 level of equipment spending in engineering was slightly below its decades-high level reached in 2013 and also 36.7% greater than the 2004 spending level (Figure 5-15). This is notable because all science equipment spending in constant dollars decreased 26.7% from 2004 to 2014 (Appendix Table 5-11). Computer science equipment spending saw a 1-year jump in 2013 due in large part to federal funding of the Blue Waters and Stampede supercomputers that were formally launched in 2013 (NSF 2013a, 2013b).

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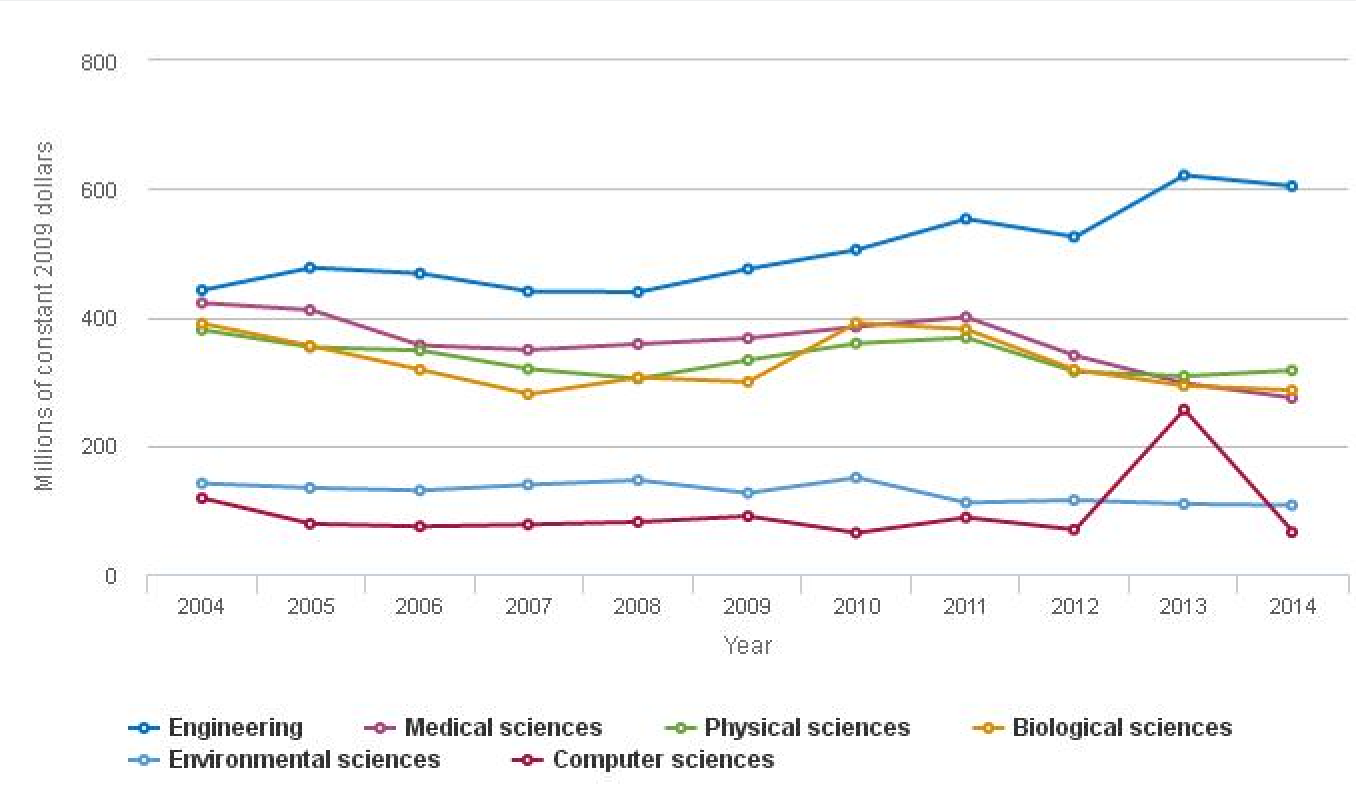
[i] Because of rising capitalization thresholds, the dollar threshold for inclusion in the equipment category has changed over time. Generally, university equipment that costs less than $5,000 would be classified under the cost category of “supplies.”

Figure 5-15

Current fund expenditures for S&E research equipment at academic institutions, by selected fields: FYs 2004–14



NOTES: Gross domestic product deflators come from the U.S. Bureau of Economic Analysis and are available at http://www.bea.gov/national, accessed 18 February 2015. See appendix table 4-1.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Research and Development Expenditures at Universities and Colleges, and Higher Education Research and Development Survey. See appendix table 5-11.

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Most academic research equipment funding typically comes from the federal government. These federal funds are generally received as part of research grants or as separate equipment grants. In 2014, the federal government supported 45.1% of total academic S&E research equipment funding, which marked the first time federal support fell below 50% since data were initially collected in 1981 (Appendix Table 5-12). Seventy-two percent of equipment funding went to public institutions in 2014. Public institutions also garnered 65% of federal funding and 77.7% of nonfederal funding support for research equipment.

The federal share of funding varies significantly by S&E field. Only physics (79.8%) and atmospheric sciences (79.6%) received greater than 70% federal funding for R&D equipment, while four fields (agricultural sciences, economics, metallurgical/materials engineering, and sociology) received less than 30%.

Cyberinfrastructure

Advances in computing technology and IT have changed the nature of scientific research and the infrastructure for conducting it over the past three decades. Cyberinfrastructure includes resources such as high-capacity networks, which are used to transfer information, and data storage systems, which are used for short-term access or long-term curation. It may also involve HPC systems used to analyze data, create visualization environments, or facilitate remote use of scientific instrumentation (NSF 2012). Cyberinfrastructure helps researchers process, transfer, manage, analyze, and store large quantities of data.

Quantifying these resources has proven difficult. The 2004–14 editions of *Science and Engineering Indicators* included analyses of data collected through NSF's Survey of Science and Engineering Research Facilities on various computing and networking capacity metrics. After a comprehensive review, NSF determined that the computing and networking infrastructure data did not provide adequate coverage of the academic research cyberinfrastructure because of rapid changes in the field, the survey's focus on capacity as opposed to usage, and the challenges that institutions have in accounting for these resources. Many researchers access computing, storage, software, and networking resources on their own rather than through the resources provided by their university. Increasingly, academic institutions are centralizing their cyberinfrastructure resources to increase efficiency. Providing metrics on these trends creates an incomplete and possibly misleading picture, although the centrality of cyberinfrastructure to S&E research is clear (CASC 2015).

Doctoral Scientists and Engineers in Academia

Academically employed research doctorate holders in science, engineering, and health (S&E) hold a central role in the nation's academic R&D enterprise.[i] Through the R&D they undertake, S&E doctorate holders produce new knowledge and contribute to marketplace innovation. They also teach and provide training opportunities for young people who may then go on to earn S&E doctorates; some of these will then train the next generation of scientists and engineers, while others will contribute through their employment in business or in government.

This section examines trends in the demographic composition of the doctoral S&E academic workforce and its deployment across institutions, positions, and fields. Particular attention is paid to the component of this workforce that is more focused on research, including graduate assistants; those employed in postdoc positions; and researchers receiving federal support. A central message of this section is that, whether looked at across 15–20 years or across four decades, the demographic composition of the academically employed S&E workforce, like the S&E workforce throughout the economy, has changed substantially. There also have been noteworthy changes in the types of positions or job titles held by S&E doctorates employed at academic institutions. Changes in academic doctoral employment across institution types and fields of S&E have been more modest.

Longer-term comparisons from 1973 to 2013 are made to illustrate fluctuations over multiple decades and trends that continue to unfold. Shorter-term comparisons (from the early to mid-1990s to 2013) are made to illustrate what the past two decades have brought forth.[ii] Since individuals in faculty and nonfaculty positions both conduct R&D, much of the discussion addresses the overall academic employment of U.S.-trained S&E doctorate holders, regardless of position or rank. However, at various points, full-time faculty and those who work outside of the full-time faculty population are discussed separately. (For an overview of the sources of data used, see sidebar, Data on Doctoral Scientists and Engineers in Academia and sidebar, Foreign-Trained Academic S&E Doctoral Workforce)

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[i] For purposes of this discussion, health sciences are combined with biological, agricultural, and environmental life sciences to create the broad field of life sciences.

[ii] In the discussion covering the age composition of the academic doctoral workforce, comparisons are made between 1995 and 2013 because the Age Discrimination in Employment Act of 1967 applied to the professoriate starting in 1994. Comparisons over the 10-year period from 2003 to 2013 are used in the discussion of minorities in the academically employed workforce because data prior to this time are not directly comparable to data from 2003 forward. In the section on federal support of doctoral researchers, comparisons are made between 1973, the very early 1990s, and 2013 because of the availability of relatively comparable data for these years. In most discussions of full-time faculty, comparisons are made between 1997 and 2013 because comparable data on senior and junior faculty groupings are available for these years.

Data on Doctoral Scientists and Engineers in Academia

Data on academically employed research doctorate holders are drawn primarily from the Survey of Doctorate Recipients (SDR), a biennial National Science Foundation (NSF) survey of individuals, including foreign-born individuals, who received their research doctorate in a science, engineering, or health field from a U.S. institution. This survey provides the most comprehensive data available on these individuals. Data are provided on educational background, employment status, occupation, and demographic characteristics. Unless specifically stated, estimates of S&E doctorates come from the SDR. The latest survey is available at http://www.nsf.gov/statistics/srvydoctoratework/surveys/srvydoctoratework_nat2013.pdf.

Because the SDR covers only U.S.-trained individuals, it substantially undercounts postdoctoral researchers (postdocs), many of whom were trained outside the United States, and provides no estimates of foreign-trained doctoral holders in other positions in academia, such as full-time faculty. Two other surveys referenced in this section supplement SDR data to provide coverage of the foreign-trained doctorate recipients. To obtain more complete counts of postdocs, this section supplements SDR's estimated counts with counts provided in the Survey of Graduate Students and Postdoctorates in Science and Engineering, an annual survey cosponsored by NSF and the National Institutes of Health. Data on graduate assistants are also provided from this survey. The latest survey is provided here: http://nsf.gov/statistics/srvygradpostdoc/surveys/srvygradpostdoc-2013.pdf.

To provide more data on the role of foreign-trained doctorate holders in academic R&D, this section draws from NSF's National Survey of College Graduates (NSCG). Although the NSCG provides less detail on academic employment, it provides estimates of the foreign-trained component. See the sidebar "Foreign-Trained Academic S&E Doctoral Workforce" for data on foreign-trained individuals' presence in academic employment. The latest NSCG forms are available at http://www.nsf.gov/statistics/srvygrads/surveys/srvygrads-newrespond2013.pdf and http://www.nsf.gov/statistics/srvygrads/surveys/srvygrads-returnrespond2013.pdf.

Foreign-Trained Academic S&E Doctoral Workforce

U.S. universities and colleges have long employed S&E doctorate holders from foreign countries; most received their doctorate from a U.S. institution, but many earned it overseas. In 2013, approximately 59,000 foreign-trained S&E doctorate holders worked in U.S. higher education institutions. Approximately two-thirds of the foreign-trained doctorate holders were men and one-third were women, similar to the gender distribution of their U.S.-trained counterparts.

Because the Survey of Doctorate Recipients (SDR) uses a more restrictive definition of the research doctorate, some complications exist in comparing National Survey of College Graduates S&E fields with those from the SDR, particularly with regard to the life sciences and psychology. Taking these complications into consideration, the field distribution of the foreign-trained doctorate holders nonetheless varies from the U.S.-trained doctorate holders. The majority (about 60%) of the foreign-trained individuals hold doctorates in the life sciences, while the majority of their U.S.-trained counterparts hold doctorates in either the life sciences (36%) or the social sciences (18%) (Appendix Table 5-13). In 2013, female foreign-trained S&E doctorate holders were largely concentrated in the life sciences (Table 5-B).

Table 5-B **Foreign-trained S&E doctorate holders employed in academia, by degree field and sex: 2013**

Field	Total	Male	Female
Full-time positions			

Field	Total	Male	Female
All fields	55,000	38,000	17,000
Physical sciences	11,000	10,000	1,000
Computer and mathematical sciences	4,000	3,000	S
Life sciences	34,000	20,000	14,000
Social sciences and psychology	3,000	2,000	D
Engineering	3,000	3,000	D
Part-time positions			
All fields	4,000	2,000	1,000

D = suppressed for reasons of confidentiality; S = suppressed for reasons of data reliability.

NOTE: Detail may not add to total due to suppression.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2015) of the 2013 National Survey of College Graduates.

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The foreign-trained doctorate holders have a substantial presence in conducting academic R&D, with about 90% reporting that research was their primary or secondary work activity in 2013 and almost two-thirds reporting support from federal grants and contracts. A smaller percentage of foreign-trained S&E doctorate holders are heavily engaged in teaching. In 2013, about 35% reported that teaching was their primary or secondary work activity (Table 5-C).

Table 5-C **Foreign-trained S&E doctorate holders employed in academia, by research and teaching focus: 2013**

(Percent)

Field	Federal support	R&D	Teaching
Full-time positions			
All fields	63.6	89.1	34.5
Physical sciences	54.5	90.9	45.5
Computer and mathematical sciences	50.0	75.0	75.0
Life sciences	67.6	88.2	23.5
Social sciences and psychology	D	66.7	66.7
Engineering	66.7	100.0	33.3

Field	Federal support	R&D	Teaching
Part-time positions			
All fields	25.0	50.0	75.0

NOTES: D = suppressed for reasons of confidentiality.

The percentage of R&D is the percentage of SEH doctorate holders reporting that their primary or secondary work activity is R&D. The percentage teaching is the percentage of SEH doctorate holders reporting that their primary or secondary work activity is teaching.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2015) of the 2013 National Survey of College Graduates.

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Trends in Academic Employment of S&E Doctorate Holders

Academic employment of S&E doctorate holders grew over the past three decades and reached an estimated 368,000 in 2013. Of this total, the large majority—almost 309,000—were U.S. trained. There was an increase of about 14,000 over the employment numbers estimated in 2010 (Appendix Table 5-13).

The U.S. employment pattern of S&E doctorate holders is distinctive from that of other countries: relatively fewer than elsewhere in academia, more in business and industry, and fewer in government. A 2009 comparison of doctorate holders from 18 countries in all fields, including S&E and other fields, found that, in most of these countries, more than half and up to 90% of the doctorate holders were employed in academia, compared with about 40% for those in the United States. In the United States, along with Belgium, Denmark, and the Netherlands, a fairly large share (roughly one-third) of doctorate holders worked in business, contrasting with fewer than 15% in other jurisdictions including Lithuania, the Russian Federation, Romania (2008), Malta, Turkey, Taiwan, Portugal, and Poland (2008). The United States also had one of the smallest fractions employed in government (less than 10%) (Auriol 2010; Auriol, Misu, and Freeman 2013). In recent decades, growth in the number of doctoral scientists and engineers in the academic sector has been slower than the rate of growth in the business and government sectors, resulting in a decline in the academic sector's share of all S&E doctorates, from 55% in the early 1970s to just under 50% in the early 1990s to about 40% in 2013.

Trends in Types of Academic Positions Held

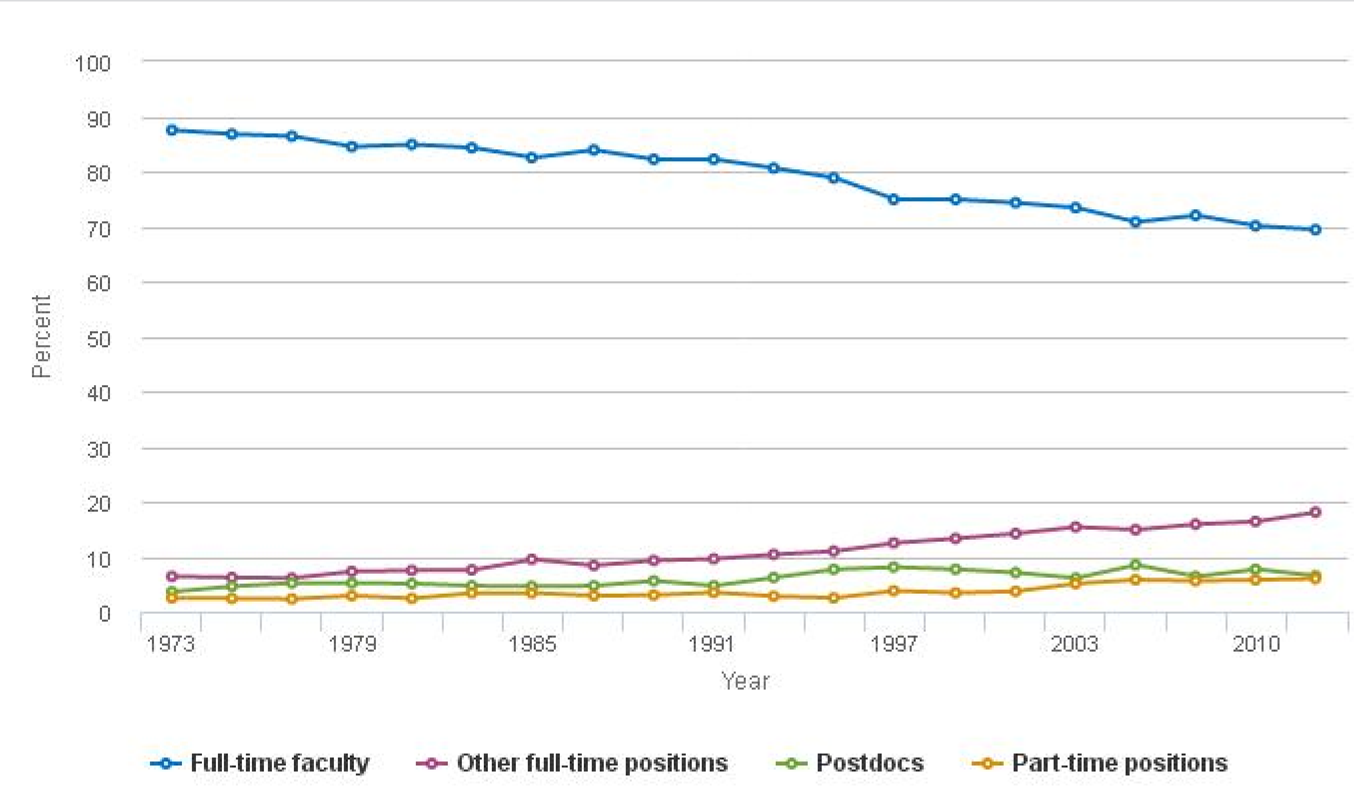
The doctoral academic workforce discussed in this section includes doctorate holders in S&E who are employed at 2-year and 4-year colleges and universities, including medical schools and university research institutes. This workforce includes full and associate professors (senior faculty); assistant professors (junior faculty); postdocs; persons in other full-time positions, such as instructors, lecturers, adjunct faculty, research associates, and administrators; and those employed in part-time positions of all kinds.

Taking a look at broad trends by position title over the past 40 years, very different patterns emerge. The total number of academically employed doctorate holders in S&E almost tripled over the period from 1973 to 2013, rising from 118,000 to 309,000, while the number of full-time faculty more than doubled (from 103,000 to 214,000) (Appendix Table 5-13). By contrast, the number of other full-time positions increased by over 600% from 1973 to 2013, rising rapidly from a low base of 7,600 (6% of the total) to 55,800 (18% of the total). Greatest growth was registered over the period from 2006 to 2013 in these nonfaculty positions. Finally, the period from 1989 to 2006 was a slow one in terms of growth in employment as full professors. Almost the same number of people held these positions in 1989 (83,000) as in 2006 (85,000).

Full-time faculty positions as either senior or junior faculty continue to be the norm in academic employment, but S&E doctorate holders are increasingly employed in other full-time positions, in postdoctoral positions, and in part-time positions (Figure 5-16). The share of full-time faculty among all U.S.-trained, academically employed S&E doctorate holders fell from almost 90% (103,000 of 118,000 total) in the early 1970s to about 80% by the mid-1990s and then dropped further, to about 70% in 2013 (214,000 of 309,000 total) (Appendix Table 5-13). The decline in the proportion of full-time faculty was evident among doctorate holders in all S&E fields (Appendix Table 5-13).

Figure 5-16

S&E doctorate holders employed in academia, by type of position: 1973–2013



NOTES: Academic employment is limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities, medical schools, and university research institutes. Full-time faculty includes full, associate, assistant professors, and instructors (from 1973 to 1995), and full, associate, and assistant professors from 1997 to 2013. Other full-time positions includes positions such as research associates, adjunct appointments, instructors (from 1997 to 2013), lecturers, and administrative positions. Part-time positions excludes those held by students or retired persons.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the 1973–2013 Survey of Doctorate Recipients.

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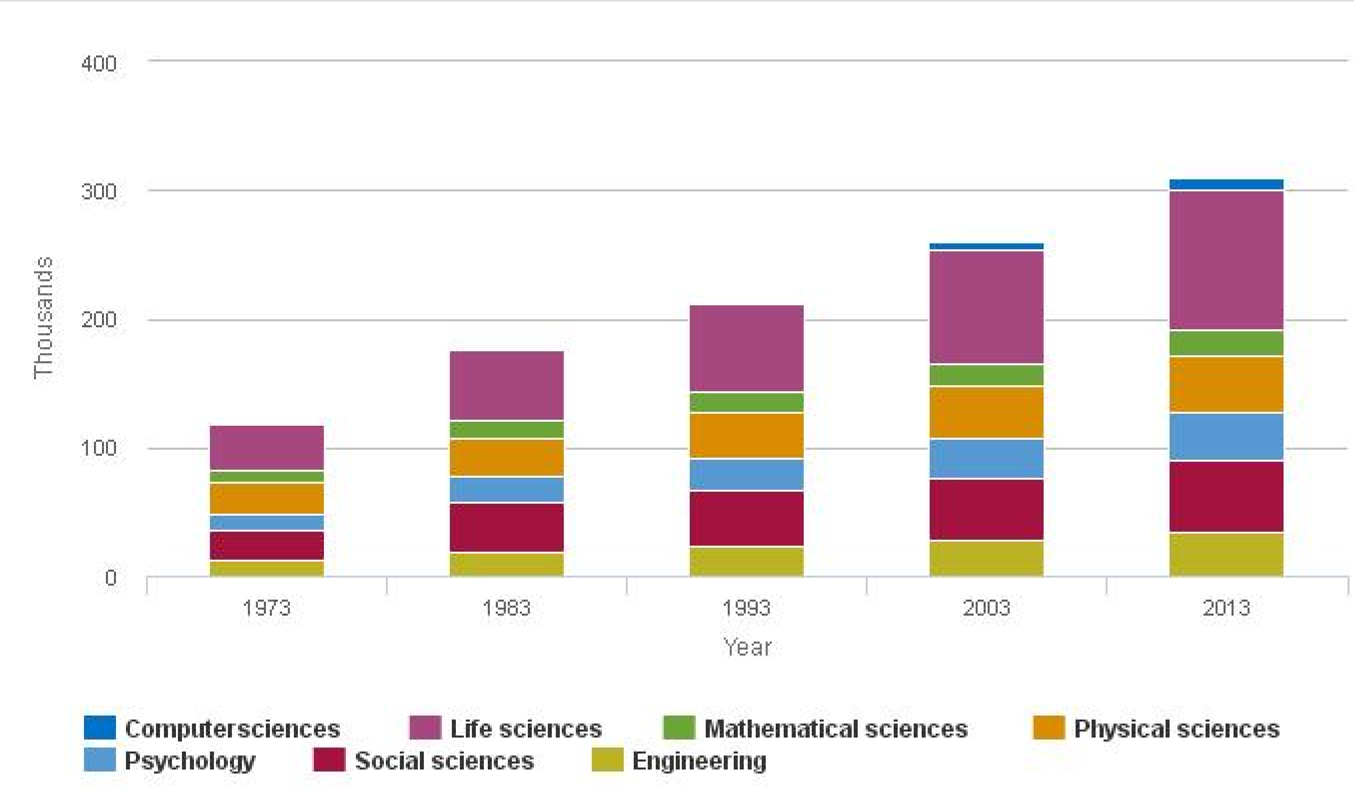
Additionally, from the early 1970s to 2013, the share of U.S.-trained postdocs increased from 4% in 1973 (4,200) to 7% in 2013 (20,200), and the share of part-time positions increased from 2% in 1973 (2,900) to 6% of all academic S&E doctorate holders in 2013 (18,500). There has also been a decrease in the percentage of U.S.-trained doctorate holders in tenured positions (discussed below).

From the early 1970s through 2013, growth in the academic employment of life scientists, psychologists, and engineers was greater than for doctorate holders in other S&E fields (Figure 5-17). Starting from a very small base around 1980, there was also consistent, rapid growth in computer scientists. Growth in academic employment slowed in the early to mid-1990s for social sciences, physical sciences, and mathematics. It has increased since then in social sciences and mathematics and, very recently, in the physical sciences (Appendix Table 5-13). Similar to spending patterns discussed in the expenditures section of this chapter, the most recent decade saw greater growth in the number of engineers in academic employment than their peers in most fields of science, while hiring of computer scientists continued to grow rapidly in numbers from a continuing small base (Figure 5-17).

Figure 5-17

S&E doctorate holders employed in academia, by S&E field: Selected years, 1973–2013



na = not applicable.

NOTES: Data for computer sciences are not available for 1973. Academic employment is limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities, excluding those employed part time who are students or retired. Physical sciences include earth, atmospheric, and ocean sciences; life sciences include biological, agricultural, environmental, and health sciences.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the 1973–2013 Survey of Doctorate Recipients.

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Trends in Tenure Status

Among U.S.-trained S&E doctorate holders working full-time in academia, the proportion that has achieved tenure has diminished since 1997, although the proportion in tenure-track positions has not. In 1997, about 53% (123,000) of U.S.-trained S&E doctorate holders in academic employment held tenured positions; this decreased to 47% in 2013 (144,600) as nontenured positions grew as a share of overall doctoral academic employment.[i] About the same percentage of individuals in 1997 (16%, 37,800 individuals) as in 2013 (15%, 47,600 individuals) was untenured but on a tenure track. Drawing on different data sources (U.S. Department of Education data on overall academic employment without regard to field or degree level), the American Association of University Presidents (AAUP) found larger decreases of about 10 percentage points over the past 15–20 years in tenured positions' share of academic employment (AAUP 2013). Broadening the scope of analysis to both tenured and tenure-track positions, AAUP reports that a 13% decline in the share of tenured and tenure-track positions (as a group) was matched with a 13% increase in the share of contingent positions.

In both 1997 and 2013, the distribution of tenured status varied by S&E field (Table 5-12). For those with doctoral degrees in psychology, engineering, or mathematical sciences, the percentage of tenured positions decreased from 1997 to 2013 by about 8–10 percentage points. For those with doctoral degrees in life sciences, physical sciences, or social sciences, there was a somewhat smaller decrease in the percentage of tenured positions of about 4–5 percentage points over this period of time. For those with a degree in computer and information sciences, the percentage in tenured positions was higher in 2013 (57%, 8,400 individuals) than in 1997 (46%, 3,300 individuals).

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[i] These other positions included positions at universities and colleges where no tenure system exists and where there are various nontenured-track positions.

Table 5-12 Tenured status, by field of doctorate: 1997 and 2013

(Percent)

Field of doctorate	1997	2013
Mathematical sciences	70.3	61.6
Social sciences	63.0	58.1
Computer and information sciences	45.5	57.1
Engineering	58.6	49.0
Physical and related sciences	50.7	47.0
Psychology	50.4	42.1
Life sciences	43.6	38.3

NOTE: Academic employment is limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities, including medical schools and university research institutes.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the Survey of Doctorate Recipients.

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Tenure status varied by age (Table 5-13). In 2013, lower percentages of S&E doctorate holders at each age group were tenured, compared with 1997.[ii] For example, 39% of those 40–44 years of age held tenured positions in 2013, compared with 47% in 1997. For older cohorts, there were also large differences between 1997 and 2013 in tenure status by age. For example, 67% of those 60–64 years of age held tenured positions in 2013, while 85% of those in this age range held tenured positions in 1997. In a reflection of the lifting of age restrictions on university faculty discussed below, there was a much larger presence in the doctoral academic workforce of those ages 65–75 years in 2013 (30,300, just under 10%) than in 1997 (8,500, 4%), making it difficult to compare changes in tenure status in this age range over time.

[ii] In addition, individuals aged 70–75 years grew as a share of the total doctoral academic workforce from 1995 to 2013. In 1995, less than 1% of the doctoral academic workforce was between 70 years of age and 75 years of age; this increased to 3% in 2013.

Table 5-13 **Tenured S&E doctorate holders employed in academia, by age: 1997 and 2013**

(Percent)

Age	1997	2013
All ages	52.6	46.8
< 30	D	D
30–34	4.9	2.4
35–39	24.9	19.6
40–44	46.9	38.5
45–49	63.0	54.1
50–54	72.0	61.1
55–59	78.3	66.4
60–64	84.6	66.8
65–75	80.0	73.6

D = suppressed to avoid disclosure of confidential information.

NOTE: Academic employment is limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities, medical schools, and university research institutes.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the Survey of Doctorate Recipients.

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The reduction from 1997 to 2013 in tenured positions' share of total positions occurred across most (but not all) Carnegie classifications (see the chapter 2 sidebar, "Carnegie Classification of Academic Institutions" for a discussion of Carnegie classifications). In 1997, an estimated 47% of academically employed S&E doctorate holders at the most research-intensive institutions (research I institutions) held tenured positions (44,400 individuals); this percentage decreased to just over 40% in 2013 (47,900 individuals). Similar reductions occurred at less research-intensive doctorate-granting institutions and at master's-granting institutions. At medical schools and medical centers, a slightly higher percentage of academically employed doctorate holders occupied tenured positions in 1997 (30%, or 12,600 individuals) than in 2013 (27%, or 14,000 individuals).[iii] At baccalaureate institutions, a similar share of academically employed doctorate holders filled tenured positions in 2013 (62%) as in 1997 (58%).

Differences have emerged over the past couple of decades in the tenure status of S&E doctorate holders 7–10 years after having received their degree. In 1997, approximately 232,500 individuals with U.S. S&E doctorates worked in academia. Of these, about 30,300 (13%) had earned their doctorate 7–10 years earlier. In 2013, when about 309,000 U.S.-trained S&E doctorate holders worked in academia, about 45,300 individuals (15%) had earned their doctorate 7–10 years earlier. Greater shares of such S&E doctorate holders held tenured positions in 1997 (37%, or 11,300 individuals) than in 2013 (27%, or 12,000 individuals). Somewhat smaller shares were not on tenure track in 1997 (12%, or 3,500 individuals) than in 2013 (17%). On the other hand, similar shares (around 32%) held tenure-track positions in 1997 as in 2013; similar shares (5%) reported that their institution did not offer tenure-track positions.

[iii] Gaining tenured status has posed particular challenges for doctorate holders employed at medical schools and centers. In 1997, 26% of S&E doctorate holders employed at medical schools and centers (10,900) reported that no tenure system existed for their position; this percentage had increased to 35% by 2013 (18,400). Furthermore, Stephan (2012) notes in *How Economics Shapes Science* that at many medical schools, tenured faculty do not have a commitment for their salary if they do not get grant support; see also (AAMC 2010).

Women in the Academic S&E Workforce

The past 40 years have seen 10-fold growth in the participation of women in the academic doctoral S&E workforce. In 1973, only about 11,000 U.S.-trained female S&E doctorates were employed in academia, contrasting sharply with about 114,000 in 2013.[iv] Over the past two decades alone, academic employment of women with S&E doctorates rose from about 47,000 in 1993 to 114,000 in 2013. Over the four decades, the number of their male counterparts grew by about 80%, from 110,000 to about 200,000 (Appendix Table 5-14).

These differential rates of increase are reflected in the steadily rising share of women with S&E doctorates in the academic workforce. Women constituted 37% of all U.S.-trained, academic S&E doctoral employment and 30% of full-time senior faculty in 2013, up from 9% and 6%, respectively, in 1973 (Appendix Table 5-14). Women's share of academic S&E employment increased markedly over time in all position categories, though to a lesser degree in part-time positions (Table 5-14). Women have held a larger share of junior faculty positions than positions at either the associate or full professor rank, reflecting a decades-long trend in the rising proportion of doctoral degrees earned by women, coupled with their slightly greater propensity to enter academic employment. The share of women in all faculty ranks rose substantially between 1973 and 2013, reaching 24% of full professors, 38% of associate professors, and 45% of assistant professors (Figure 5-18).

[iv] Despite these gains, the number of academically employed, U.S.-trained female S&E doctorate holders in 2013 (114,000) was very similar to the number of their male counterparts four decades earlier (107,000).

Table 5-14 **Women as a percentage of S&E doctorate holders employed in academia, by position: Selected years, 1973–2013**

(Percent)

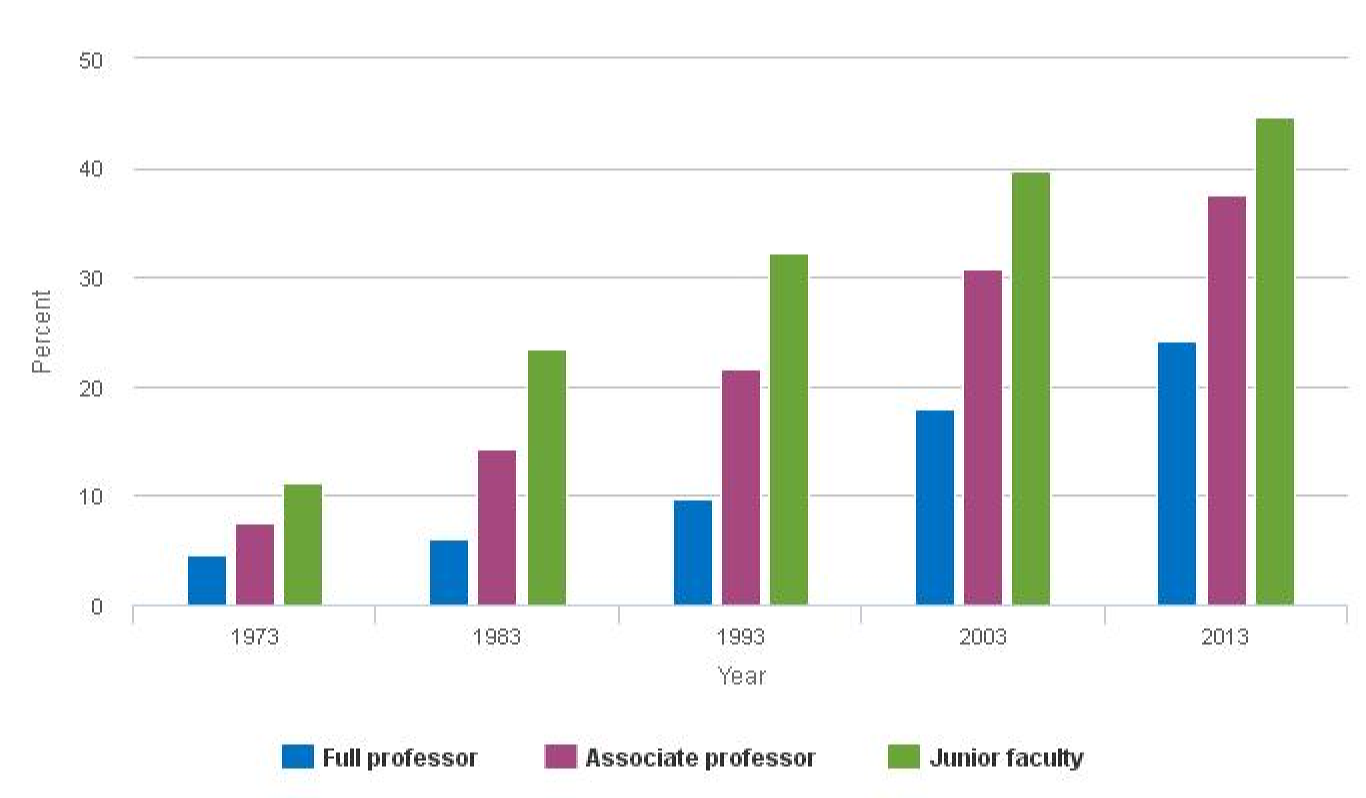
Position	1973	1983	1993	2003	2013
All positions	9.1	15.0	21.9	30.3	36.9
Full-time senior faculty	5.8	9.3	14.2	22.8	29.5
Full-time junior faculty	11.3	23.5	32.2	39.7	44.9
Other full-time positions	14.5	23.1	30.2	34.8	42.1
Postdocs	14.3	30.1	30.8	38.0	40.6
Part-time positions	48.3	41.7	61.0	54.5	56.8

NOTES: Academic employment is limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities, medical schools, and university research institutes. Senior faculty includes full and associate professors; junior faculty includes assistant professors and instructors in 1973, 1983, and 1993; in 2003 and 2013, junior faculty includes assistant professors. Other full-time positions include positions such as research associates, adjunct appointments, instructors (in 2003 and 2013), lecturers, and administrative positions. Part-time positions exclude those employed part time who are students or retired.

SOURCE:	National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the 2003 and 2013 Survey of Doctorate Recipients. *Science and Engineering Indicators 2016*

Figure 5-18

Women as a percentage of S&E doctorate holders employed full time in academia, by academic rank: Selected years, 1973–2013



NOTES: Academic employment is limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities, medical schools, and university research institutes, excluding those employed part time who are students or retired. Junior faculty includes assistant professors and instructors in 1973, 1983, and 1993; in 2003 and 2013, junior faculty includes assistant professors.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the 2003 and 2013 Survey of Doctorate Recipients.

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Women are relatively more concentrated in the life sciences, social sciences, and psychology, with correspondingly lower shares in engineering, physical sciences, mathematics, and computer sciences. Women's share of doctorate holders in each of these fields, however, grew during the 1973–2013 period (Appendix Table 5-14).[v] Although, as noted above, there has been an overall reduction over the past 15–20 years in the proportion of U.S.-trained S&E doctorate holders that have achieved tenure, the experiences of men and women have differed (Table 5-15). Although smaller shares of women than men held tenured positions in both 1997 and 2013, there were greater reductions over this period in the proportion of men in tenured positions across most S&E fields.

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[v] According to 2010 survey data from the American Institute of Physics, despite the economic downturn, women continued to be hired as assistant professors, as well as instructors and adjuncts, at well above their availability rate among doctoral recipients during the latter half of the 2000–09 decade.

Table 5-15 **Tenured S&E doctorate holders employed in academia, by sex and field: 1997 and 2013**

(Percent)

	Total		Female		Male	
Tenured	1997	2013	1997	2013	1997	2013
All fields	52.8	46.8	34.9	36.2	58.9	52.9
Physical sciences	50.7	47.0	30.0	37.5	54.0	50.1
Mathematics and statistics	70.3	61.6	42.9	42.2	74.5	67.1
Computer and information sciences	45.5	57.1	42.9	50.0	42.3	58.2
Life sciences	43.6	38.3	27.8	29.0	50.9	45.6
Psychology	50.4	42.1	34.5	35.5	62.6	52.0
Social sciences	63.0	58.1	49.2	50.9	68.7	63.1
Engineering	58.6	49.0	29.4	31.6	60.6	52.6

NOTE: Academic employment is limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities, medical schools, and university research institutes.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the Survey of Doctorate Recipients.

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Minorities in the Academic S&E Workforce

Similar to women, members of underrepresented minority groups (i.e., blacks, Hispanics, and American Indians or Alaska Natives) have increased their presence in academic employment over time, but unlike women, they continue to hold a small percentage of S&E doctorate positions (Appendix Table 5-15).[vi] These groups combined constituted 8.8% of total doctoral academic S&E employment in 2013, up from about 7.9% in 2003 and 2.0% in 1973. Underrepresented minorities held 8.3% of full-time faculty positions in 2013, up from 7.0% in 2003 and 1.9% in 1973 (Table 5-16). In 2013, underrepresented minority groups held lower shares of full-time faculty positions than they did of other positions. Compared to white and Asian or Pacific Islander S&E doctorate holders employed in academia, underrepresented minorities in 2013 were somewhat more concentrated in the social sciences and somewhat less in the physical sciences and life sciences (Appendix Table 5-15).

[vi] Analysis of trends in minority and underrepresented minority representation in the U.S.-trained academic doctoral workforce is complicated by changes in the Survey of Doctorate Recipients question about race and ethnicity starting in 2001. Specifically, since 2001, respondents have been allowed to report more than one race. Because of this change, data from 2001 to 2013 are not directly comparable to earlier years' data (Milan 2012).

Table 5-16 **Underrepresented minorities as a percentage of S&E doctorate holders employed in academia, by position: Selected years, 1973–2013**

(Percent)

Position	1973	1983	1993	2003	2013
All positions	2.0	3.7	5.0	7.9	8.8
Full-time faculty	1.9	3.6	5.0	7.0	8.3
Postdocs	2.4	4.8	4.5	7.0	10.4
Other positions	2.9	4.1	5.3	7.3	9.7

NOTES: Underrepresented minorities include blacks, Hispanics, and American Indians or Alaska Natives. Academic employment is limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities, medical schools, and university research institutes. Faculty includes full, associate, and assistant professors plus instructors in 1973, 1983, and 1993. In 2003 and 2013, faculty includes full, associate, and assistant professors. Other positions include part-time positions and full-time positions such as research associates, adjunct appointments, instructors (in 2003 and 2013), lecturers, and administrative positions. Other positions exclude those employed part time who are students or retired.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2015) of the 2003 and 2013 Survey of Doctorate Recipients.

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In both 2003 and 2013, a slightly higher percentage of women than men who are underrepresented minorities held faculty positions.[vii] Female blacks held about 4.7% of full-time faculty positions held by women in 2003 and about 4.6% of these positions in 2013. Male blacks were in about 2.9% of full-time faculty positions held by men in 2003 and about 3.3% in 2013. Similarly, female Hispanics occupied about 4.0% of full-time faculty positions held by women in 2003 and about 4.8% in 2013. Male Hispanics were in about 3.2% of full-time faculty positions occupied by men in 2003 and about 4.1% in 2013. Male and female American Indians or Alaska Natives held about the same percentage of full-time faculty positions in 2003 and 2013 (less than 1%).

The share of Asians or Pacific Islanders employed in the S&E academic doctoral workforce grew dramatically over the past three decades, rising from 4% in 1973 to 17% in 2013.[viii] Asians or Pacific Islanders were heavily represented among those with degrees in engineering and computer sciences, where they constituted 31% and 36%, respectively, of these segments of the doctoral workforce in 2013. They constituted far smaller employment proportions among social scientists (11%) and psychologists (6%) (Appendix Table 5-15).

In both 2003 and 2013, a higher percentage of male Asians or Pacific Islanders held full-time faculty positions than their female counterparts. Male Asians or Pacific Islanders were in about 12.0% of full-time faculty positions occupied by men in 2003 and about 16.3% of these positions in 2013. Female Asians or Pacific Islanders held about 9.3% of faculty positions occupied by women in 2003 and about 13.1% in 2013. Both male and female Asians or Pacific Islanders increased their share of faculty positions from 2003 to 2013.

For those within 7–10 years of having received their S&E doctorate, greater shares were white in 1997 (roughly 79%) than in 2013 (66%), while Asians or Pacific Islanders had larger shares in 2013 (23%) than in 1997 (about 13%). Shares for black or Hispanic doctorates varied little (roughly 4%–5% in 1997 and in 2013).[ix]

Foreign-Born S&E Doctorate Holders in the Academic Workforce

Academia has long employed foreign-born doctorate holders, many with doctorates from U.S. universities, as faculty and other staff. The following discussion focuses on foreign-born individuals who earned their S&E doctorate in the United States.

Academic employment of these foreign-born, U.S.-trained individuals has increased continuously since the 1970s, at a rate faster than that of their native-born counterparts, increasing the foreign-born share of academic S&E

employment from 12% in 1973 to about 27% in 2013 (Figure 5-19). Particularly high proportions are found in engineering (49%) and computer sciences (50%) (Appendix Table 5-16). Nearly half (48%) of all postdoc positions were held by foreign-born doctorate holders in 2013, compared to 26% of full-time faculty positions.

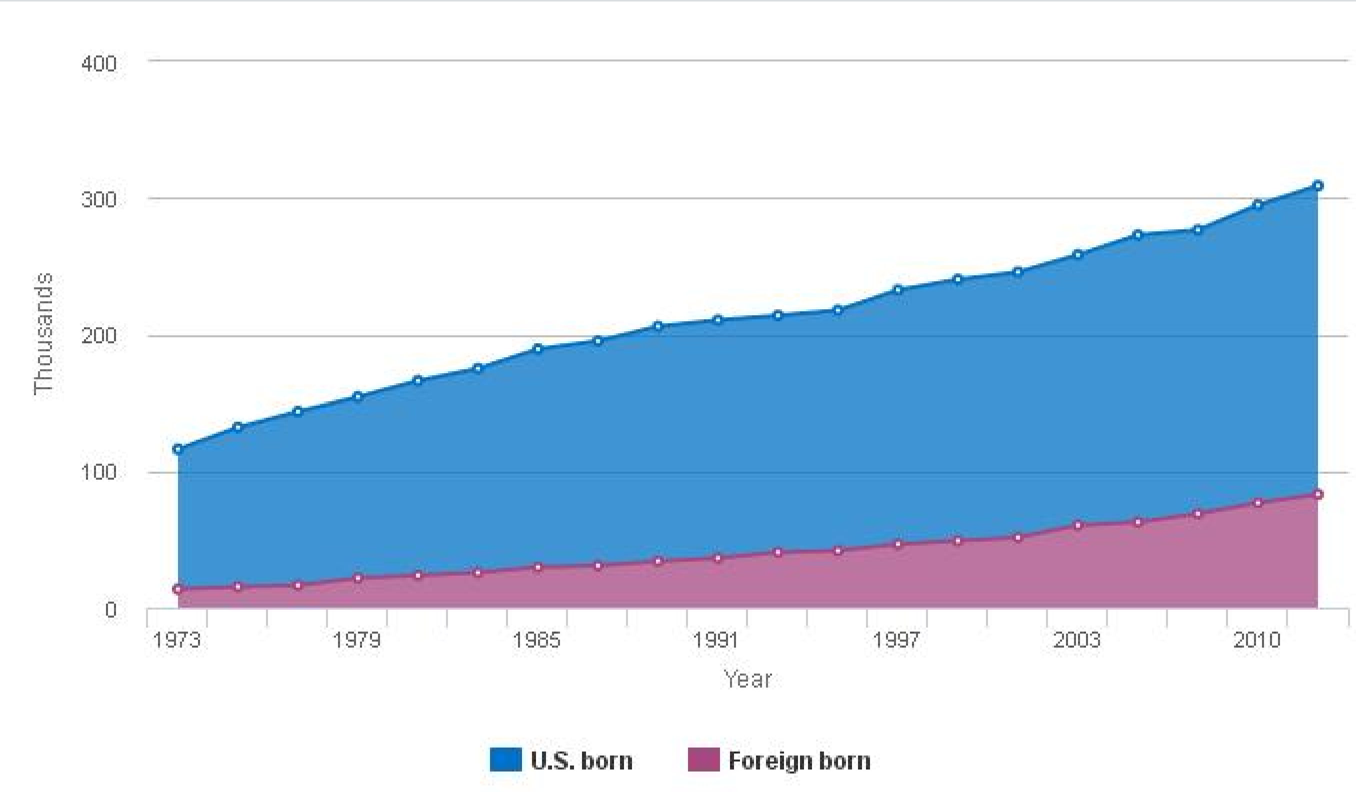
[vii] Estimates of the percentage of underrepresented minorities by sex in the U.S.-trained academic doctoral workforce are based on small samples and are particularly sensitive to sampling error.

[viii] Asians or Pacific Islanders include Native Hawaiians and Other Pacific Islanders.

[ix] Because data on race and ethnicity collected prior to 2001 are not directly comparable to data collected after this year, these estimates are somewhat less precise than if data had been compared from 2001 onward.

Figure 5-19

S&E doctorate holders employed in academia, by birthplace: 1973–2013



NOTE: Academic employment is limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities, medical schools, and university research centers, excluding those employed part time who are students or retired.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2015) of the 2013 Survey of Doctorate Recipients.

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In 2013, about 52,000 U.S.-trained Asian or Pacific Islanders were employed in universities and colleges. Of these, 11% were native-born U.S. citizens, 38% were naturalized U.S. citizens, and 51% were noncitizens. In 2013, Asians or Pacific Islanders represented 51% of the foreign-born, U.S.-trained S&E faculty employed full-time in the United States and nearly 70% of the foreign-born S&E doctorate holders with postdoc appointments.

Age Composition of the Academic Doctoral Workforce

The trend toward relatively fewer full-time faculty positions and relatively more postdoc and other full-time and part-time positions is especially noteworthy because of the steady increase over the past 20 years in the share of full-time faculty positions that are held by those over 60 years of age.

In 1995, individuals ages 60–75 years constituted about 11% of full-time faculty that year; this percentage increased to 24% in 2013.[x] In 1994, the Age Discrimination in Employment Act of 1967 (ADEA) became fully applicable to universities and colleges, prohibiting the forced retirement of faculty at any age. From this point through 2013, as more individuals born during the period of high birth rates from 1946 to 1964 (the “Baby Boomers”) began to move through middle age into their 50s and 60s, the proportion of academically employed doctorate holders in the oldest age groups increased (Table 5-17). (See Age and Retirement of the S&E

Workforce within Chapter 3 for a discussion of the age profile and retirement patterns of the broader S&E workforce.)

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[x] Some academically employed S&E doctorate holders were older than 75 years of age in 1995 and in 2013, but the Survey of Doctorate Recipients does not report on this because it drops respondents from the survey sample after they have reached 75 years of age. It is generally believed that individuals over age 75 years hold a small but growing share of academic doctoral employment.

Table 5-17 **Academically employed S&E doctorate holders, by age: 1995 and 2013**

(Percent)

Age	1995	2013
39 and under	29.0	25.9
40–59	61.0	52.7
60–75	10.0	21.4

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the Survey of Doctorate Recipients.

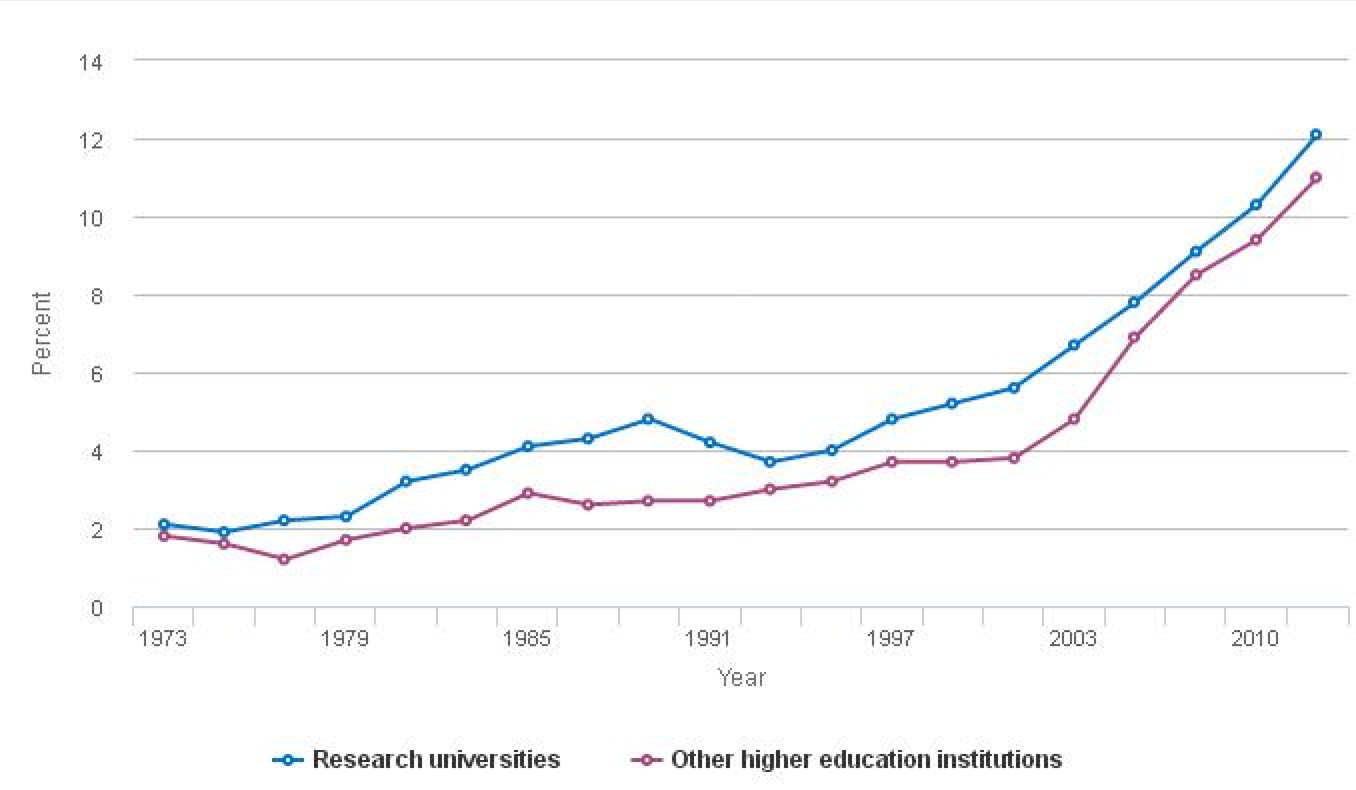
Science and Engineering Indicators 2016

Many of the oldest doctorate full-time faculty work at research-intensive universities, where those ages 60–75 years constituted about 11% of the total in 1995 and about 25% by 2013. Over the same period of time, there was a decline in the proportion of much younger doctorate holders (ages 30–44 years) employed as full-time faculty at research-intensive universities (from about 43% to about 34%).

A comparison of the age distribution of full-time faculty positions at research universities and other universities and colleges shows that there has been a relatively sharp increase since the mid-1990s—when ADEA became applicable to the professoriate—in the percentage of these positions held by those ages 65–75 years. The data show that the share of those ages 65–75 years was gradually rising before the act became mandatory, dipped in the early 1990s at research universities (and leveled off at other institutions), and then rose steeply in most years from 1995 to 2013, particularly at the most research-intensive universities (Figure 5-20; Appendix Table 5-17). By contrast, the percentage of full-time faculty under age 45 years dropped at research universities from 60% in 1973 to 34% in 2013. The trend was broadly similar at other universities and colleges, with those under age 45 years dropping from 65% in 1973 to 34% in 2013.

Figure 5-20

Full-time faculty ages 65–75 at research universities and other higher education institutions: 1973–2013



NOTE: Faculty positions include full, associate, and assistant professors and instructors from 1973 to 1995; from 1997 to 2013, faculty positions include full, associate, and assistant professors.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients, 1973–95, and special tabulations (2013, 2015) of the Survey of Doctorate Recipients, 1997–2013. See appendix table 5-17.

Science and Engineering Indicators 2016

Academic Researchers

The interconnectedness of research, teaching, and public service activities in academia makes it difficult to assess the precise size and characteristics of the academic research workforce by examining the employment trends in academic positions. Individuals with the same academic job titles may be involved in research activities to differing degrees or not be involved in research. Therefore, self-reported research involvement is a somewhat better measure than position title for gauging research activity.[i] This section limits the analysis to two groups of academic S&E doctorate holders, including those who reported that research is their primary work activity (i.e., the activity that occupies the most hours of their work time during a typical workweek) and those who reported that research is their primary or secondary work activity (i.e., the activity that occupies the most or second-most hours of their work time during a typical workweek). Separate breakouts are provided for all doctorate holders and for full-time faculty.

Doctoral S&E Researchers

Since 1973, the number of academic researchers (based on primary or secondary work activity) grew from just over 80,000 to over 200,000 (Appendix Table 5-18). In 2013, of those identified as such researchers, over 140,000 were employed in full-time faculty positions.[ii]

Looking across all doctoral academic positions and across the past four decades, the proportion of researchers has fluctuated between about 60% and 75%. A similar pattern of fluctuation occurred among full-time faculty. In 2013, 65% of S&E doctorate holders in academia and 67% of full-time faculty classified research as their primary or secondary activity.

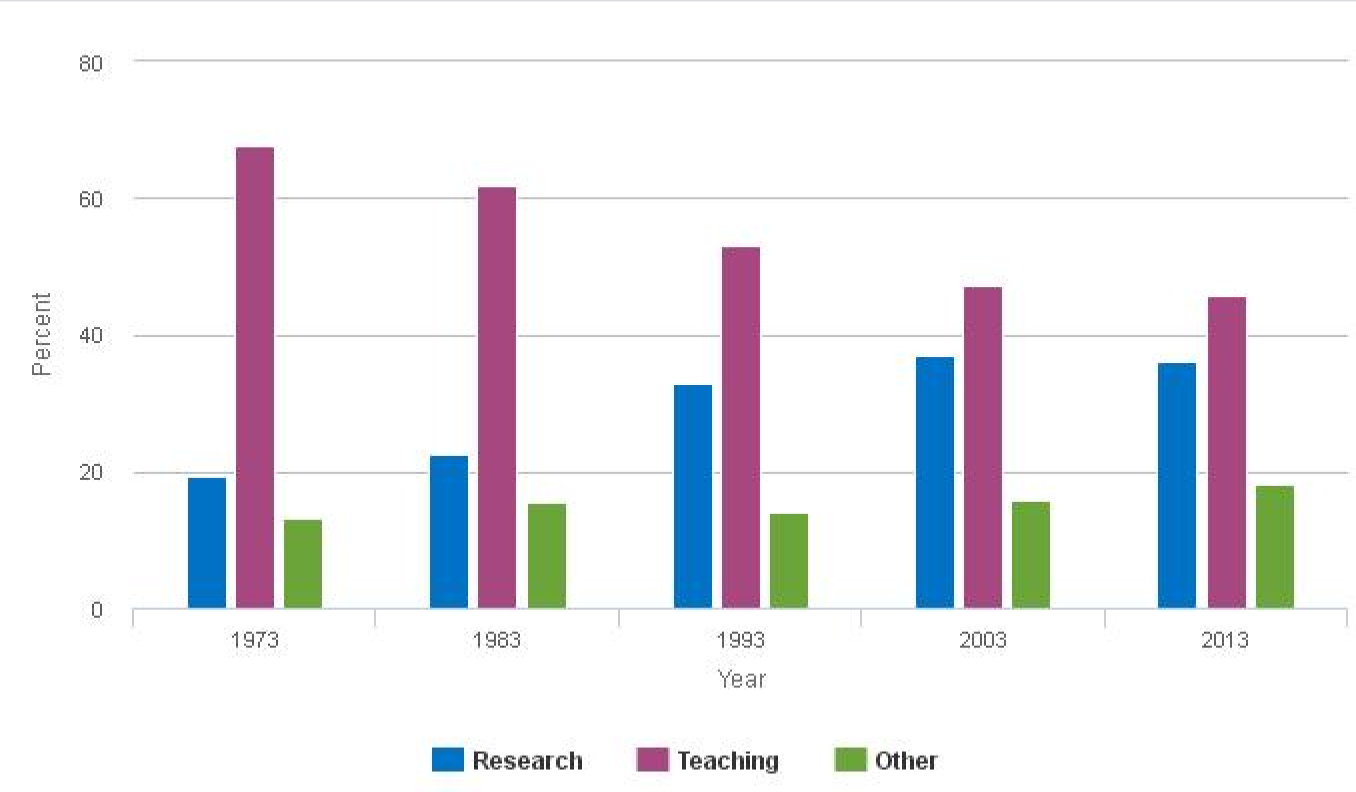
In 2013, the proportions of researchers among the academic doctoral workforce were higher in engineering than in other fields (Appendix Table 5-18). In most fields, the share of researchers declined slightly between 1993 and 2013. Turning to the subset who identify research as their primary work activity, although similar shares of doctorate holders reported this in 2013 as in 1993 (39% versus 38%), somewhat larger shares of full-time faculty did so (36% versus 33%). Looking across the past four decades, the proportion of academically employed S&E doctorate holders who identified research as their primary activity has fluctuated from just below 25% to about 40%. For full-time faculty, this proportion ranged from just under 20% to about 37%. Among full-time doctoral S&E faculty, there was a shift in priority from teaching to research from 1973 to 2003, with the proportion of full-time faculty identifying research as their primary work activity climbing from 19% to 37% and the share of faculty with teaching as their primary activity falling from 68% to 47%. But in the last decade, from 2003 to 2013, the shares of faculty who primarily teach and the shares of faculty who primarily conduct research remained more stable (Figure 5-21).

[i] The Survey of Doctorate Recipients presents respondents with a list of work activities and asks them to identify the activities that occupied the most hours and second-most hours during their typical workweek. This measure was constructed slightly differently prior to 1993, and the data are not strictly comparable across the two periods. Prior to 1993, the survey question asked respondents to select their primary and secondary work activity from a list of activities. Beginning in 1993, respondents were given the same list and asked on which activity they spent the most hours and on which they spent the second-most hours.

[ii] University-reported data from the Higher Education Research and Development Survey indicate that approximately 155,000 people paid from R&D salaries and wages were designated as principal investigators in academic FY 2013 and that an additional 757,000 people, including students paid from R&D accounts, were in positions other than principal investigators. Universities reported salaries, wages, and fringe benefits totaling $28.8 billion in FY 2013 for these research personnel.

Figure 5-21

Primary work activity of full-time doctoral S&E faculty: Selected years, 1973–2013



NOTES: Academic employment is limited to U.S. doctorate holders employed full-time at 2- or 4-year colleges or universities, excluding adjuncts and postdocs. Full-time faculty includes full, associate, and assistant professors and instructors for 1973, 1983, and 1993; for 2003 and 2013, full-time faculty includes full, associate, and assistant professors. Research includes basic or applied research, development, or design. Other activities include a wide range of activities.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2015) of the 2013 Survey of Doctorate Recipients. See appendix table 5-18.

Science and Engineering Indicators 2016

The balance of emphasis between teaching and research varied across the disciplines. A higher share of faculty with doctorate degrees in life sciences and engineering identified research as their primary work activity, and a higher share of faculty with doctorate degrees in mathematics and social sciences reported teaching as their primary activity. Since 1991, the proportion of doctorate holders who reported research as a primary work activity declined among computer scientists and life scientists but grew among mathematicians, psychologists, engineers, and social scientists (Appendix Table 5-18).

Stage of career plays a role in the reported primacy of research, teaching, or other activities. In 2013, 31% of the S&E doctoral faculty who had earned their degree since 2010 identified research as their primary work activity, a lower share than that reported by faculty who had earned S&E doctorate degrees 4–7 years earlier (41%) or 8–11 years earlier (40%) (Table 5-18). The comparable percentage for faculty 12 years or more from receipt of their degree is 35%. A similar pattern across career stages prevailed in most degree fields.

Table 5-18	Full-time S&E faculty reporting research as primary work activity, by years since doctorate and degree field: 2013

(Percent)

Years since doctorate	All fields	Computer and information sciences	Life sciences	Mathematics and statistics	Physical sciences	Psychology	Social sciences	Engineering
All years since doctorate	36.1	37.5	41.3	29.2	35.3	32.8	29.8	40.6
1–3	30.8	50.0	33.3	16.7	25.0	28.6	27.3	37.5
4–7	41.3	33.3	37.3	39.1	37.5	36.7	40.3	58.8
8–11	39.9	33.3	44.4	42.1	35.9	30.2	32.1	52.6
≥ 12	34.5	36.1	41.6	25.2	34.5	32.7	27.0	33.3

NOTES: Academic employment is limited to U.S. doctorate holders employed full-time at 2- or 4-year colleges or universities, medical schools, and university research institutes, excluding adjuncts and post docs. Faculty includes full, associate, and assistant professors. Research includes basic or applied research, development, and design. Physical sciences include earth, atmospheric, and ocean sciences; life sciences include biological, agricultural, environmental, and health sciences.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2015) of the 2013 Survey of Doctorate Recipients. See appendix table 5-18.

Science and Engineering Indicators 2016

Graduate Research Assistants

The close coupling of advanced training with hands-on research experience is a key feature of U.S. graduate education. Many of the nearly one-half million full-time S&E graduate students in 2013 conducted research as part of their academic studies (Table 5-19).

Table 5-19 **Full-time S&E graduate students and graduate research assistants at universities and colleges, by degree field: Selected years, 1973–2013**

	1973		1983		1993		2003		2013[a]	
Group and degree field	Thousands	Percent	Thousands	Percent	Thousands	Percent	Thousands	Percent	Thousands	Percent
Graduate students	161.6	100	252.0	100	329.6	100	397.4	100	457.4	100
Computer sciences	2.9	2	10.6	4	17.4	5	30.7	8	39.3	9
Earth, atmospheric, and ocean sciences	7.8	5	12.0	5	11.3	3	11.5	3	12.3	3
Life sciences	40.6	25	69.2	27	91.6	28	122.7	31	124.3	27
Mathematical sciences	10.3	6	11.0	4	14.5	4	14.6	4	19.5	4
Multidisciplinary and interdisciplinary studies[b]	na	na	na	na	na	na	na	na	3.9	1
Physical sciences	21.1	13	25.2	10	30.6	9	30.4	8	36.0	8
Psychology	15.2	9	26.6	11	34.8	11	35.8	9	38.2	8
Social sciences	32.4	20	43.5	17	55.6	17	61.4	15	71.1	16
Engineering	31.3	19	53.9	21	73.8	22	90.2	23	112.8	25
Graduate research assistants	35.9	100	54.9	100	90.2	100	114.3	100	114.9	100
Computer sciences	0.7	2	1.4	3	3.8	4	7.5	7	7.7	7

	1973		1983		1993		2003		2013[a]	
Group and degree field	Thousands	Percent	Thousands	Percent	Thousands	Percent	Thousands	Percent	Thousands	Percent
Earth, atmospheric, and ocean sciences	2.6	7	3.5	6	4.7	5	4.6	4	4.5	4
Life sciences	9.4	26	16.5	30	28.0	31	35.5	31	35.8	31
Mathematical sciences	0.7	2	0.8	1	1.4	2	1.8	2	2.0	2
Multidisciplinary and interdisciplinary studies[b]	na	na	na	na	na	na	na	na	1.0	1
Physical sciences	6.3	18	9.1	17	12.3	14	13.5	12	13.3	12
Psychology	1.9	5	3.0	5	4.6	5	5.6	5	4.9	4
Social sciences	4.0	11	5.0	9	7.4	8	8.4	7	7.2	6
Engineering	10.4	29	15.6	28	28.0	31	37.3	33	38.6	34

na = not available.

[a] Totals exclude fields that were added or reclassified in the 2007 survey (communication, family and consumer sciences, and architecture).

[b] Includes study fields with a science or engineering component.

NOTES: Graduate research assistants are full-time graduate students with research assistantships as their primary mechanism of support. Physical sciences include astronomy, chemistry, and physics; in prior *Science and Engineering Indicators*, physical sciences also included earth, atmospheric, and ocean sciences in this table. Life sciences include biological, agricultural, and health sciences and, in 2013, the field of neurosciences, which was reclassified as a separate field in the 2007 survey. Detail may not add to total due to rounding.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2015) of the 2013 Survey of Graduate Students and Postdoctorates in Science and Engineering.

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Looking across the period from 1973 to 2013, the number of research assistants—full-time graduate students whose primary mechanism of financial support is a research assistantship—grew faster during most years than graduate enrollment, both overall and in most fields. However, from 2003 to 2013, there was less overall growth in graduate research assistants (0.5%) than there was in the total number of graduate students (15%). Graduate research assistantships were the primary means of support for 25% of graduate students in 2013 and for a similar percentage (22%) of graduate students in the early 1970s.

Academic Employment in Postdoc Positions

About 43,000 S&E doctorate holders were employed in academic postdoc positions in 2013 (see sidebar, Postdoctoral Researchers). The estimate comes from NSF's Survey of Graduate Students and Postdoctorates in Science and Engineering, which reported a total of about 62,000 postdocs in 2013, with about two-thirds (over 43,000) holding positions in S&E and almost one-third (just under 19,000) holding positions in clinical medicine or other health-related fields (Kang 2015).[i] [ii] (See U.S. S&E Workforce: Definition, Size, and Growth within Chapter 3 for more information on biomedical sciences doctorates.) The U.S.-trained component of academically employed postdocs with S&E degrees climbed from 4,200 in the early 1970s to 20,200 in 2013 (Appendix Table 5-13). During that time period, the share of postdocs varied, gradually increasing to just under 9% of all U.S.-trained, academically employed S&E doctorate holders in 2006 and then dipping somewhat to just under 7% in 2013. Postdocs were more prevalent in life sciences, physical sciences, and engineering than in social sciences, psychology, mathematics, and computer sciences. Looking over the decade from 2003 to 2013, there was growth in the proportion of U.S.-trained postdocs in physical sciences and engineering but not in other fields (Figure 5-22; Appendix Table 5-13). The demographic profile of U.S.-trained individuals employed in academic postdoc positions has changed dramatically over the past 40 years. In particular, the proportions of postdocs held by women, racial and ethnic minorities, and foreign-born individuals have climbed (Table 5-20).

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[i] The Survey of Graduate Students and Postdoctorates in Science and Engineering does not include estimates of postdocs employed outside of the academic sector, and comprehensive data are not available on postdocs employed by businesses. See NSF's Survey of Postdocs at Federally Funded Research Development Centers for data on postdocs at FFRDCs (http://www.nsf.gov/statistics/srvyffrdcpd/).

[ii] HERD data report an estimated 66,000 postdocs in 2013 across all fields.

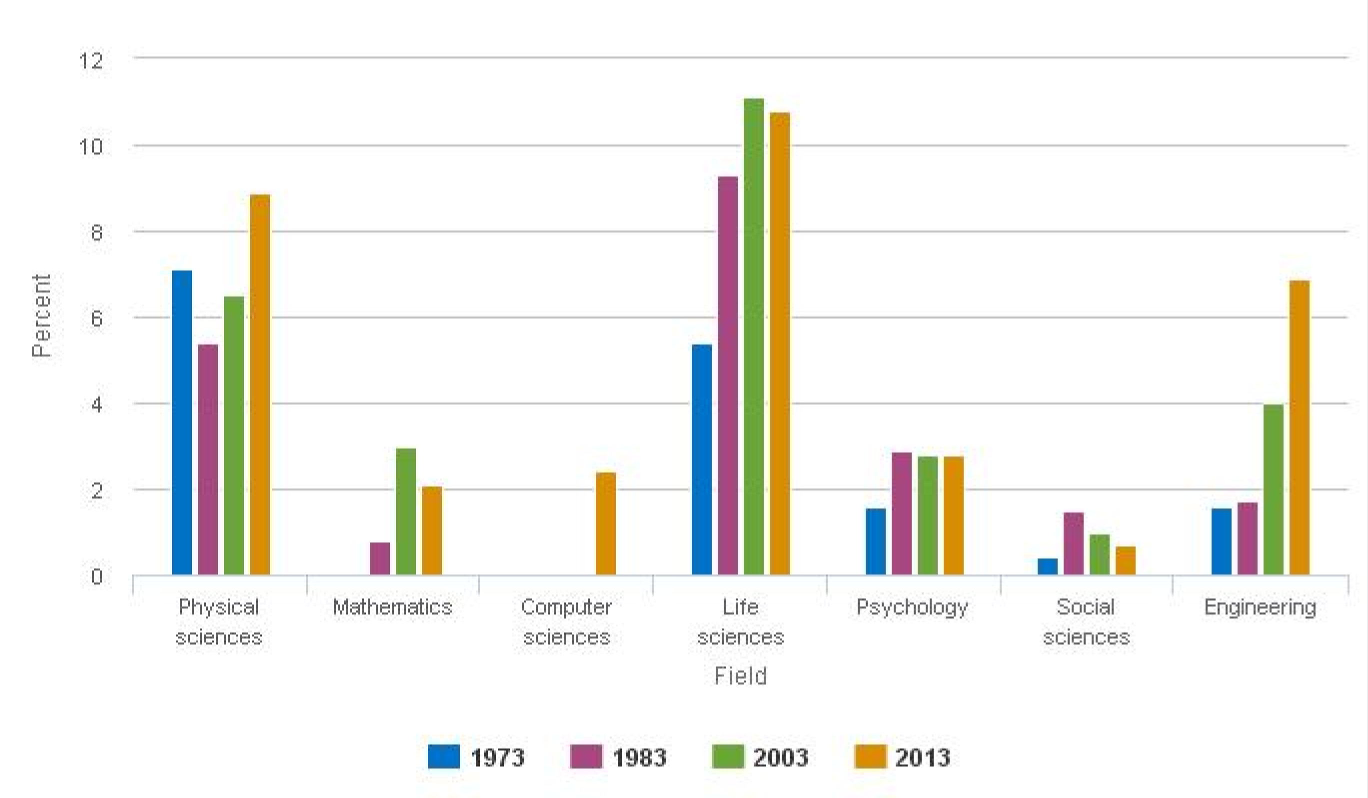
Postdoctoral Researchers

A postdoctorate (postdoc) is a temporary position in academia, industry, a nonprofit organization, or government that is taken after the completion of a doctorate. It serves as a period of apprenticeship for the purpose of gaining additional scientific, technical, and professional skills. Ideally, the individual employed in a postdoc position gains these skills under the guidance of an adviser, with the administrative and infrastructural support of a host institution, and with the financial support of a funding organization. However, the conditions of postdoc employment vary widely between academic and nonacademic settings, across disciplines, and even within institutions, and formal job titles can be an unreliable guide to actual work roles.

Postdoctoral researchers are important to the S&E enterprise and perform a substantial portion of the nation's research. Most have recently earned their doctoral degree, and so they bring new techniques and perspectives that broaden their research teams' experience and make them more competitive in the job market. In addition to conducting research, postdoctoral researchers also educate, train, and supervise students engaged in research; help write grant proposals and papers; and present research results at professional society meetings (COSEPUP 2014).

Figure 5-22

S&E doctorate holders with academic employment in a postdoc position, by degree field: Selected years, 1973–2013



NA = not available; S = data suppressed for reliability.

NOTES: Academic employment is limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities, medical schools, and university research institutes, excluding those employed part time who are students or retired. Physical sciences include earth, atmospheric, and ocean sciences; life sciences include biological, agricultural, environmental, and health sciences.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2015) of the 2013 Survey of Doctorate Recipients.

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Table 5-20 S&E doctorate holders with academic employment in postdoc positions, by demographic group: Selected years, 1973–2013

(Percent distribution)

Demographic group	1973	1983	1993	2003	2013
Sex					
Female	16.7	30.1	30.8	37.6	40.6
Male	83.3	69.9	69.2	62.4	59.4
Race/ethnicity					

Demographic group	1973	1983	1993	2003	2013
White	85.7	81.9	68.4	63.1	52.5
Asian or Pacific Islander	11.9	13.3	27.1	30.6	36.6
Underrepresented minority	2.4	4.8	4.5	7.0	10.4
Place of birth					
United States	82.5	81.7	60.9	57.0	52.5
Foreign	17.5	18.3	39.1	43.0	47.5

NOTES: Academic employment is limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities, medical schools, and university research institutes, excluding those employed part time who are students or retired. Underrepresented minorities include blacks, Hispanics, and American Indians or Alaska Natives.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2015) of the 2003 and 2013 Survey of Doctorate Recipients.

Science and Engineering Indicators 2016

A temporary postdoc appointment has become a common stop along the career path of S&E doctorate holders, particularly during their early career stages. In 2013, 42% of recently degreed, U.S.-trained S&E doctorate holders in academia were employed in postdoc positions, while 29% were employed in full-time faculty positions (Appendix Table 5-19). For this discussion, *recently degreed* individuals are those who received their doctorate within 1–3 years prior to the 2013 Survey of Doctorate Recipients (SDR); they are a subset of *early career* individuals who received their doctorate within 1–7 years prior to the 2013 SDR. A lower share (17%) of U.S.-trained, academically employed S&E doctorate holders 4–7 years beyond their doctoral degree was employed in academic postdoc positions; 53% held full-time faculty positions (Appendix Table 5-19).

In 2013, just under three-fourths (74%) of recently degreed, U.S.-trained academic postdocs were employed at the most research-intensive universities (Table 5-21). The fields of life sciences and physical sciences have had the highest incidence of postdocs over the years (Figure 5-22).

Table 5-21 **S&E doctorate holders with academic employment in postdoc positions, by Carnegie classification of employer and years since doctorate: 2013**

(Percent distribution)

		Years since doctorate		
Institution type	Postdocs (thousands)	1–3	4–7	≥ 8
All institutions	20.2	100.0	100.0	100.0
Doctorate-granting, very high research	15.1	73.7	76.3	66.7
Other doctorate-granting institutions	1.7	6.3	8.6	20.0
Medical schools/medical centers	1.6	7.4	8.6	6.7
Other universities and colleges	1.7	12.7	4.3	6.7

NOTES: Academic employment is limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities, medical schools, and university research institutes, excluding those employed part time who are students or

	retired. Institutions are designated by the 2005 Carnegie classification code. For information on these institutional categories, see the Carnegie Classification of Institutions of Higher Education, http://carnegieclassifications.iu.edu/, accessed 1 April 2015. Detail may not add to total due to rounding.
SOURCE:	National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2015) of the Survey of Doctorate Recipients. *Science and Engineering Indicators 2016*

Federal Support of Doctoral Researchers in Academia

The federal government provides academic researchers with a substantial portion of overall research support. This support may include assistance in the form of fellowships, traineeships, and research grants. This section presents data from S&E doctorate holders in academia who reported on the presence or absence (but not magnitude or type) of federal support for their work. Comparisons are made over the approximately 40-year period between the early 1970s and 2013 and between the roughly two-decade-long period between the very early 1990s and 2013.

To ensure the accountability, transparency, and safety of federally funded research, doctoral researchers must fulfill a wide range of administrative and compliance requirements (see sidebar, National Science Board: Reducing Investigators' Administrative Workload for Federally Funded Research).

National Science Board: Reducing Investigators' Administrative Workload for Federally Funded Research

To ensure the transparency, accountability, and safety of federally funded research, academic researchers must comply with a wide range of regulations and administrative requirements. As these requirements have increased over time, the White House, Congress, federal agencies, and research universities themselves have all engaged in efforts to measure their impact and find ways to maximize their effectiveness. After two surveys by the Federal Demonstration Partnership revealed that administrative requirements occupy a substantial percentage of principal investigators' time, the National Science Board (NSB) in December 2012 convened a task force to examine the administrative workload of federally supported researchers. To identify ways to reduce inefficient requirements while upholding proper oversight of federally funded research, the task force issued a public request for information, held a series of town meetings across the country, and consulted with major associations. In concluding its work in March 2014, NSB issued a report (NSB 2014) with four broad policy recommendations:

- Focus on the Science
- Eliminate or Modify Ineffective Regulations
- Harmonize and Streamline Requirements
- Increase University Efficiency and Effectiveness

To *Focus on the Science*, NSB recommended that agencies limit proposal requirements to those essential for merit review. Nonessential materials could be submitted and reviewed later, once a proposal had been deemed a candidate for funding. NSB also recommended that research progress reports be focused on performance outcomes and scaled according to award size.

To *Eliminate or Modify Ineffective Regulations*, NSB proposed that the Office of Management and Budget (OMB) identify whether payroll certification could replace more burdensome, and arguably ineffective, time and effort reporting. For research involving human subjects, NSB recommended that recently proposed reforms be encouraged, including the use of a single Institutional Review Board for multi-site studies and simpler oversight of research involving minimal risks to people. With regard to animal research, NSB recommended that regulations that increase investigators' administrative workload without improving animal care be identified. Citing time-consuming but often fruitless literature searches by researchers to identify nonanimal alternatives in order to satisfy particular animal-welfare regulations, NSB recommended that alternative, more effective processes be adopted. NSB recommended that the U.S. Public Health Service's conflict-of-interest regulations not be adopted by other agencies and recommended that they be evaluated to assess their cost, effectiveness, and impact on entrepreneurial activities. And NSB recommended that industry-targeted safety and security requirements imposed on research be reexamined because they are not all appropriate for research settings.

To *Harmonize and Streamline Requirements*, NSB recommended that agencies work together to standardize and simplify proposal submission and post-award requirements and to eliminate agency-specific requirements, where possible. NSB emphasized that audit practices should be uniform, consistent, and more focused on larger expenditures and risks. The report also highlighted opportunities to scale back paperwork associated with subrecipient monitoring. Finally, NSB recommended that a high-level interagency committee with cross-sector representation, including OMB and university stakeholders, be created to respond to the recommendations from NSB and other reports and to ensure that new or modified regulations affecting researchers are efficient, performance oriented, and harmonized.

To *Increase University Efficiency and Effectiveness*, NSB recommended that universities communicate the sources of administrative and regulatory requirements, avoid adding unnecessary ones, and review their procedures governing human subject and animal research with the goal of establishing more efficient procedures for protecting research subjects. The report also recommended that universities provide their researchers with more assistance as they develop their human and animal protection protocols. NSB also recommended that federal agencies collaborate with university stakeholders (researchers, administration, and advocacy groups) to identify and share best practices.

Academic Scientists and Engineers Who Receive Federal Support

The share of S&E doctorate holders and researchers in academia who receive federal support has varied over time according to reported primacy of research activity and type of academic position held (Appendix Table 5-20). In general, a larger share of doctorate holders and researchers received federal support in the late 1980s and very early 1990s than in either the early 1970s or in 2013.[i] In 2013, 44% of all U.S.-trained S&E doctorate holders in academia and 57% of those for whom research was a primary or secondary activity reported federal government support for their work.[ii] About the same percentage (45%) of U.S.-trained, academically employed doctorate holders received federal support in the early 1970s as in 2013. In the very early 1990s, however, a somewhat higher percentage (49%) received federal support. A somewhat smaller share of those for whom research was a primary or secondary responsibility received federal support in 1973 (52%) than in 1991 (58%) or 2013 (57%). The share of full-time faculty who received federal support from 1973 to 2013 fluctuated in a similar fashion, with a somewhat higher share in 1991 (48%) than in 1973 (42%) or in 2013 (44%). By contrast, a larger share of academic doctorate holders employed in nonfaculty positions received federal support in 1973 (60%) and in the very early 1990s (59%) than in 2013 (43%).

Federal support varied by doctoral field. Over the past 40 years, doctorate holders in engineering, physical sciences, and life sciences have been more likely to report receiving federal support than their counterparts in mathematics, psychology, or social sciences (Appendix Table 5-20). The pattern of funding support for engineering and physical sciences was quite similar overall, with percentages ranging from about 50% in the early 1970s to about 55% in the 1980s to just below 60% in 2013 for engineering and about 53% for physical sciences. Federal funding for life sciences, with some dips in 1985 and 1993–97, generally remained around 60% in most years. Federal support for academic R&D in the relatively small field of computer sciences has grown from about 35% to 50% since its first measurement in the late 1970s.

Federal support is more prevalent in medical schools and in the most research-intensive universities (under Carnegie classification of *very high research activity* institutions) (Appendix Table 5-21). Just under 65% of S&E doctorate holders employed at the most research-intensive universities received federal support in 2013. At medical schools, about 60% of all doctorate holders and just under 55% of full-time faculty received federal support in 2013. The percentage with federal support was just over 45% at *high research activity* institutions; at other universities and colleges, it ranged from about 18% to 32%.

Differences exist by sex, race, and ethnicity in doctorate holders' success in receiving federal support. Among S&E doctorate holders employed at the nation's most research-intensive universities, white and Asian or Pacific Islander men were more likely than their female counterparts to be supported by federal grants or contracts in 2013 (Figure 5-23; Appendix Table 5-22).

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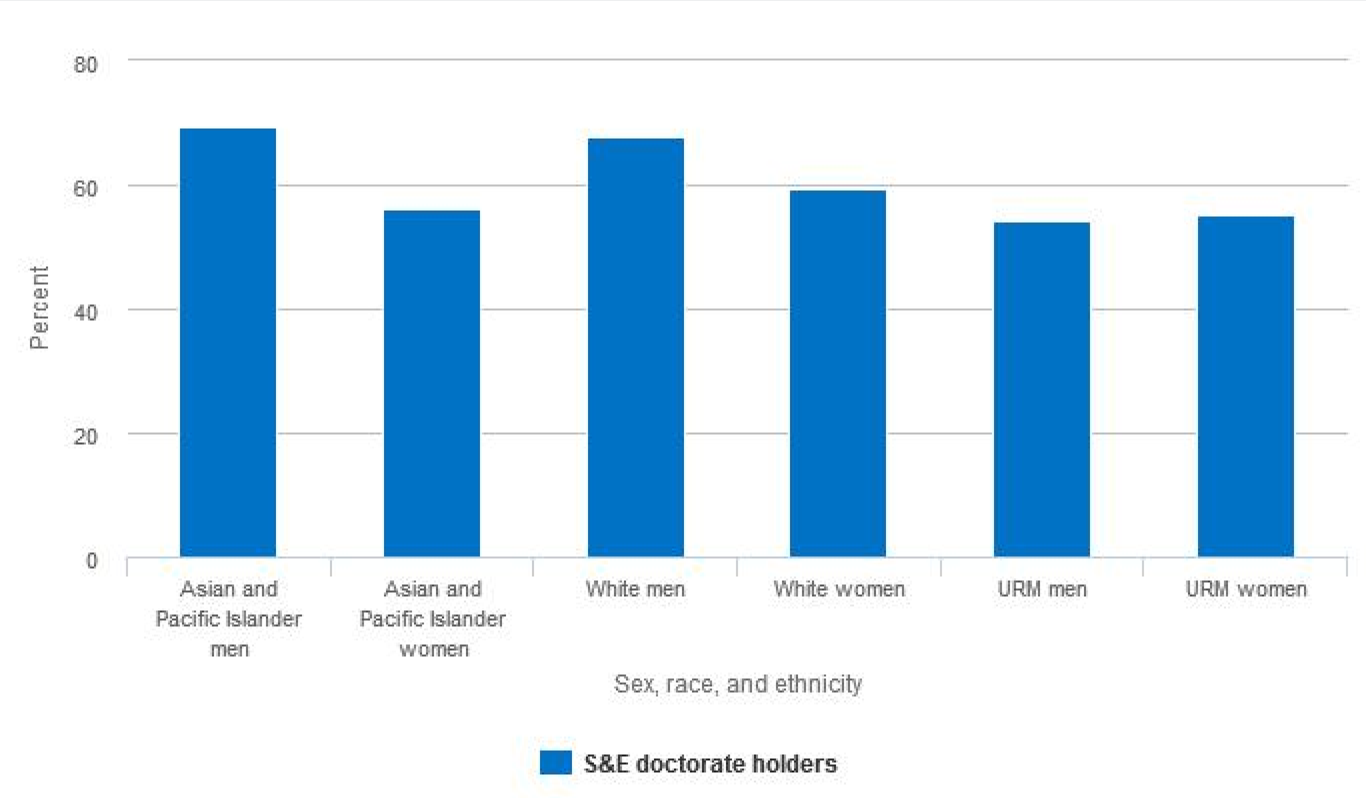
[i] Data on federal support of academic researchers for 1985 and 1993–97 cannot be compared with results for the earlier years or with those from 1999 to 2013 because of changes in the survey question. In 1985, the question focused on 1 month and, from 1993 to 1997, on 1 week. In most other survey years, the reference was to the entire preceding year. Because the volume of academic research activity is not uniform over the entire academic year, a 1-week (or 1-month) reference period seriously understates the number of researchers supported at some time during an entire year.

[ii] A somewhat larger share of the nation's foreign-trained academic doctoral personnel working full time (64%) received federal support in 2013.

Figure 5-23

S&E doctorate holders in very high research activity institutions with federal support, by sex, race, and ethnicity: 2013



URM = underrepresented minority (black, Hispanic, and American Indian or Alaska Native).

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, 2013 Survey of Doctorate Recipients. See appendix table 5-22.

Science and Engineering Indicators 2016

Available data on the rate at which reviewed research grant applications are funded indicate that funding success rates have declined since the middle of the 2000–09 decade at both NIH and NSF (Table 5-22). Looking over the period from 2001 to 2014, there was an increase during most years in the number of research grant applications that NIH and NSF received.

Table 5-22 NIH and NSF research grant applications and funding success rates: 2001–14

Agency	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
NIH														
Proposals	21,967	22,212	24,634	27,461	28,423	29,097	27,325	26,648	26,675	27,850	28,781	29,626	28,044	27,502
Awards	6,965	6,799	7,430	6,991	6,463	6,037	6,456	6,116	5,924	6,217	5,380	5,436	4,902	5,163
Success rates (%)	32	31	30	26	23	21	24	23	22	22	19	18	17	19
NSF														
Proposals	23,096	25,241	28,676	31,553	31,574	31,514	33,705	33,643	35,609	42,225	41,840	38,490	39,249	38,882
Awards	6,218	6,722	6,846	6,509	6,258	6,708	7,415	6,999	10,011	8,639	7,759	8,061	7,652	7,923
Success rates (%)	27	27	24	21	20	21	22	21	28	20	19	21	19	20

NIH = National Institutes of Health; NSF = National Science Foundation.

NOTES: Available data vary by agency and are not directly comparable to one another. NIH data shown are for R01-equivalent grants, calculated according to the NIH success-rate definition, which counts initial grant applications and resubmitted grant applications received in the same fiscal year as one application (see http://report.nih.gov/success_rates/index.aspx). NIH grant applications exclude grants funded by the American Recovery and Reinvestment Act of 2009 (ARRA). NSF data shown are based on research grant applications received and are counted in the fiscal year in which the award or decline action is taken. NSF data include ARRA grants.

SOURCES: NIH, Office of Extramural Research, Office of the Director; NSF, Office of Budget, Finance, and Award Management.

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Federal Support of Early Career S&E Doctorate Holders

In recent years, very recently degreed S&E doctorate holders have received relatively less federal support than in past decades. This holds for those in full-time faculty positions (22% in 2013 versus 38% in 1991) as well as for postdocs (77% in 2013 versus 84% in 1991) (Appendix Table 5-23). Individuals in full-time faculty positions who had received their doctorate 4–7 years earlier were more likely to receive federal support than those with more recently earned doctorates. This was not the case for those in postdoc positions, however, where similar percentages from each group received federal support. As with recent doctorate recipients, the share of full-time faculty and postdocs 4–7 years beyond their doctorate who received federal support also declined from the early 1990s. Looking across the academic doctoral workforce without regard to faculty or postdoc position, the shares of early career doctorate holders with federal support were generally higher in some fields (life sciences, physical sciences, and engineering) than in others (mathematics and social sciences) in 2013.

Outputs of S&E Research: Publications and Patents

Chapter 2 of this volume discusses the human capital outputs of higher education in S&E, and the preceding sections of the current chapter discuss key inputs to academic research, including spending, infrastructure, and academically employed doctorate holders. Despite the resources devoted to academic R&D, its impact and productivity are intangible and thus hard to quantify. This section provides metrics on two components of academic research output: publications and patents. Indicators show the overall distribution of these outputs, indicators of collaboration across nations, economies, and U.S. sectors, as well as citation-derived quality measures. Patents provide a measure of the portion of this knowledge that has been accorded the protection of private property. Citations in patent documents provide indications of the sources and recipients of inventive knowledge.

S&E research has traditionally been presented in peer-reviewed S&E journals, books, and conference proceedings. *Bibliometric* data are consistently organized information about these written publications (see sidebar, Bibliometric Data and Terminology) that can be used to understand the dimensions of national and global scientific activity. For example, a count of the coauthorships on U.S. publications is an indicator of the partnerships involved in the U.S. scientific effort. Likewise, measures involving citations and patents can be indicators of international patterns of scientific influence and of invention based on scientific research. These indicators are calculated for different countries. Because peer-reviewed publications are also produced outside of academia, these measures are also provided within the United States alone for different institutional sectors.

Overall, the indicators provide insight into five broad areas. The first section, "S&E Publication Output," examines the quantity, national origin, and U.S. sectoral origin of S&E publications. The second section, "Coauthorship and Collaboration in S&E Literature," investigates the national, international, and U.S. sectoral partnerships in these publications. The third section, "Trends in Citation of S&E Publications," looks at various patterns of knowledge flows and influences across regions, countries, and sectors. The fourth section, "Citation of S&E Publications by USPTO Patents," investigates the acknowledgment of S&E literature by inventors in patents filed with the U.S. Patent and Trademark Office (USPTO). Finally, the fifth section, "Academic Patenting," explores patenting and related activities in academia.

The following discussions of regional and country indicators examine patterns and trends for the largest producers of S&E publications, as well as for developed and developing countries, as classified by the International Monetary Fund (IMF). Countries classified by the IMF as advanced economies are considered *developed*; those classified as emerging market are considered *developing*.[i]

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[i] For more information on the IMF economic classification of countries, see http://www.imf.org/external/pubs/ft/weo/2014/02/weodata/groups.htm.

Bibliometric Data and Terminology

The counts, coauthorships, and citations discussed in this section are derived from research materials published in peer-reviewed scientific and technical journals, books, and conference proceedings that have been collected in Elsevier's Scopus database. The types of publications included are articles, conference papers, reviews, and short surveys.* The types of publications excluded from the data set are editorials, errata, letters, and other material whose purpose is not the presentation or discussion of scientific data, theories, methods, apparatuses, or experiments. Working papers, which are not generally peer reviewed, are also excluded from the data set. For *Science and Engineering Indicators 2016*, more than 17,000 journals were analyzed from the Scopus database for 2013.

Journal selection. The journals in the Scopus database are selected by an international group of subject-matter experts who evaluate candidate journals based on editorial policy, content quality, peer review, citation by other publications, editor standing, regularity of publication, and content availability. Although the publications do not need to be written in the English language, both the publication abstract and the journal home page must be in the English language.

Book selection. The books included in the Scopus database are fully referenced and represent original research or literature reviews. They are selected based on publisher characteristics. These include the reputation and impact of the publisher, the size and subject area of the booklist, the publication and editorial policy, and the quality of content.

Conference selection. The conference materials included in the Scopus database are selected by subject field based on quality and relevancy, including the reputation of the sponsoring organization and the publisher of the proceedings.

More information on the selection of documents is found at http://www.elsevier.com/online-tools/scopus/content-overview.

The bibliometric data are classified into the 13 broad fields of S&E that correspond to the National Center for Science and Engineering Statistics WebCASPAR database system. These fields and their subfields are shown in Appendix Table 5-24. To match the data to these fields, a multistage matching procedure creates a field of science category for each journal in the database. Articles, chapters and conference proceedings are first matched to the National Science Foundation's fields of science based on the ISSN field in the abstract. These articles and fields are then matched to journal titles, with additional analysis by subfield to resolve ambiguous matches (Science-Metrix 2015).

Bibliometric Indicators

The region/country/economy breakouts are reported in Appendix Table 5-25. Data reported in this section are grouped into 13 broad S&E fields and 125 subfields (Appendix Table 5-24).

Publication counts. Counts are the number of peer-reviewed publications produced, by the country, region, or institutional sector. Publications coauthored by multiple countries or institutional sectors are counted two ways. *Fractional counting* divides the publication count by the proportion of each of the countries or institutional coauthors named on the publication. Fractional counting allows the counts to sum up to the number of total publications (appendix tables 5-26–5-40). *Whole (integer) counting* assigns one count to each country or institutional sector coauthoring the publication (appendix tables 5-41–5-54). The sum of publications from countries or institutional sectors will exceed the total number of publications under whole counting. For the United States in 2013, there were 412,542 publications in the Scopus database as measured on a fractional-count basis and 510,047 as measured on a whole-count basis.

Coauthorship. Coauthorship provides a direct measure of collaboration across countries, regions, and institutional sectors. Publication counts of coauthorship use whole counting, resulting in a full count being assigned to each country or institutional sector contributing to the publication. A publication is counted as international coauthorship when there are institutional addresses for authors from at least two different countries. Appendix tables 5-41–5-54 show international coauthorship by field of science.

Index of international collaboration. Coauthorship or collaboration between countries is more likely between countries where each has large shares of international collaboration. The index of international collaboration weights each collaboration relationship by the size of each country's contribution to internationally coauthored publications. The result is a scaled index. The United States was a coauthor on 39.5% of the world's internationally coauthored publications in 2013, and the expected U.S. share of China's internationally coauthored publications would therefore be 39.5%. In fact, 45.6% of China's internationally coauthored publications in 2013 had a U.S. coauthor. Dividing the actual U.S. share of China's internationally coauthored publications by the expected share yields an index value of 1.15. Thus, China coauthors with the United States 15% more than expected. More broadly, if the measure is higher than expected, it will be greater than 1.00; if less than expected, it will be less than 1.00. Index values for any country pair are always symmetrical, so the United States also coauthors with China 15% more than expected. The data for calculating the 2013 indexes in Appendix Table 5-55 are contained in Appendix Table 5-56. U.S. sector publications coauthored with other U.S. sectors and foreign institutions for 1999 and 2013 are shown in Appendix Table 5-57.

Citations. Citations of S&E publications by other S&E publications provide an indicator of the impact of publications as well as of the flow of knowledge or linkage between sectors or geographic locations. Citations are presented for the year when a publication is published, showing the counts of subsequent citations from peer-reviewed literature. For example, 2012 citations are citations to papers published in 2012. At least 3 years of data following publication are needed for a meaningful measure, and more years are preferable (Wang 2012). A 3-year window is used in *Science and Engineering Indicators 2016* for international citations (Appendix Table 5-58) and for the relative citation index between country pairs (Table 5-24). For comparisons across fields of science and across countries, citations are calculated based on all available years of data, and 3 years is the minimum amount of data that is used.

Highly cited publications. Citations to S&E publications or to patents are concentrated on a small portion of the total number of publications or patents. These measures follow the power law, in which a relatively small share of the population is responsible for a relatively large share of the impact. In these highly skewed distributions, the average is substantially different from the median. As a result, average counts alone are an insufficient measure of the impact of S&E publications. Highly cited publications are shown as a relative share of the top percentile of publications (Appendix Table 5-59). Because highly cited articles can continue to receive citations for many years, highly cited publications are calculated for each year with the maximum years of subsequent data available. Thus, these citations can accumulate beyond 3 years.

Average of relative citations (ARC). Citations need to be normalized across fields of science and document types to correct for differences in the frequency and timing of citations (Narin and Hamilton 1996; Wang 2012). The relative citation divides each publication's citation count by the average citation count of all publications in that subfield and document type in that same year. For a given area of geography or sector, these relative citations for each publication are then averaged to create an ARC. An ARC value greater than 1.00 has more citations than average for subfield and year; an ARC value less than 1.00 has fewer citations. *Science and Engineering Indicators 2016* uses the ARC measure for relative citations by region/country/economy. ARCs are calculated for each year with the maximum years of subsequent data available. Thus, these citations can accumulate beyond 3 years. Appendix Table 5-60 shows ARCs for U.S. fields of science and engineering and Appendix Table 5-61 shows ARCs for regions, countries, and economies.

Measurement limitations of bibliometric data. The Scopus database indexes peer-reviewed S&E publications that have been collected and curated by Elsevier to conform to a set of quality standards, including the stipulation that the abstracts have been written in the English language. Bibliometric researchers have found an own-language preference in citations (Liang, Rousseau, and Zhong 2012). As a result, the indexing of publications with English-language abstracts can undercount citations associated with non-English publications. This linguistic bias has been found to be more substantial in social sciences than in physical sciences, engineering, and mathematics (Archambault et al. 2009). Further, fractional and whole counting allow publications with multiple authors to be attributed to countries, regions, economies, and sectors. The assumption underlying both fractional and whole counting is that each author's contribution is assigned the same weight. In reality, it is often the case that authors make different levels of contribution to a publication. For more information about the difference between Scopus and the data used in earlier years of *Science and Engineering Indicators,* see the sidebar "New Data Source for Indicators Expands Global Coverage."

* Short surveys are reviews of original research that are limited to a few pages but otherwise similar to reviews. For more information, see http://www.elsevier.com/__data/assets/pdf_file/0007/69451/sc_content-coverage-guide_july-2014.pdf.

S&E Publication Output

This section begins by describing and comparing the S&E publication output of the United States to other regions, countries, and economies in the world. After presenting data on S&E publication output by countries and fields of science, this section also examines U.S. publication output in academia, the largest producer of U.S. publications, and other institutional sectors. The bibliometric data presented are compiled and derived from the Scopus database (see sidebar, New Data Source for Indicators Expands Global Coverage). The publication output discussion is based on fractional counting, which divides the credit for a coauthored publication across the coauthors in proportion to their number. On this basis, there were 2,199,704 peer-reviewed S&E publications drawn from the database in 2013 for analysis (Table 5-23).

New Data Source for Indicators Expands Global Coverage

The bibliometric indicators in *Science and Engineering Indicators 2016* are based on Elsevier's Scopus database. This is a change from the bibliometric data set used in earlier volumes of *Science and Engineering Indicators,* which used a subset of Thomson Reuters Science Citation Index (SCI) and Social Science Citation Index (SSCI). This change in data sources is accompanied by several methodological changes intended to simplify the interpretation of the data and increase the cross-field and cross-country comparability of the data.

Motivation

Science and Engineering Indicators aims to provide an accurate comparison of the state of U.S. S&E activity in a global context. Although the United States has dominated S&E publication activity for decades, it has long been hypothesized that the level of S&E knowledge in the developing world would grow faster from a lower base level, eventually reaching parity with the United States (Price 1963). Tracking this growth accurately requires broad global coverage of S&E publications.

The use of the Scopus database for *Science and Engineering Indicators 2016* represents a substantial increase in the global coverage of bibliometric data compared to prior years. The SCI and SSCI data sets were originally chosen to provide good coverage of a core set of internationally recognized, peer-reviewed scientific journals. The included journals are notable for their high citation rank within their S&E fields and thus can be considered to represent the journals containing the highest-impact articles. For *Science and Engineering Indicators 2014*, the National Science Foundation (NSF) analyzed 5,087 journals from the SCI and SSCI for 2012. The change to the use of the Scopus database allows NSF to present data on the most highly cited S&E publications as well as on a broader set of publications that provide insight into trends in emerging and developing countries. For *Science and Engineering Indicators 2016*, approximately 17,000 S&E journals were analyzed.

In addition to expanded global coverage, the Scopus database used for *Science and Engineering Indicators 2016* includes research output from books and expanded coverage of conference proceedings. Research output from books is particularly important in the social sciences (Hicks 2005; Mingers and Leydesdorff 2015), and conference proceedings are particularly important in computer sciences (Lisée, Larivière, and Archambault 2008; Moed and Visser 2007). For more information on the selection process, see the sidebar "Bibliometric Data and Terminology."

This expansion of global coverage of S&E publications has costs as well as benefits. In particular, the move from SCI and SSCI to Scopus provides greater global coverage at the cost of a somewhat shorter time series of bibliometric data because Scopus data currently begin in 1996. Additionally, Scopus's comprehensive global coverage of journals may include some journals that are not highly cited or have limited international visibility. Further information comparing the bibliometric data from earlier editions of Science and Engineering Indicators to this edition's data can be found in the report, Comparison of 2016 Bibliometric Indicators to 2014 Indicators, at http://science-metrix.com/en/publications/reports#/en/publications/reports/bibliometrics-and-patent-indicators-for-the-science-and-engineering-indicator-0.

Methodological Changes

Fractional counting: The Scopus database allows *Science and Engineering Indicators 2016* to use fractional counting at the level of individual authors instead of at the level of the institution, which was the basis for fractional counting in the past. This change from institution to authors for fractional counting improves the precision of the country and field measures. However, fractional counting remains an imperfect measure of the contribution of each author to a jointly authored publication.

Citations: In *Science and Engineering Indicators 2016,* citations are calculated for each publication in the year that it is published and sum all subsequent citations to that publication. Because it takes at least 3 years to measure citations reliably (Bornmann 2013), citations are presented for publication years through 2012; averages of relative citations are not restricted to a 3-year window and therefore can continue to incorporate citations over time.

In earlier editions of *Science and Engineering Indicators,* citation counts reported for a given year were calculated for the year that the citation was made instead of the year in which the cited article was published. Citations were calculated as the total number of citations made to papers published in a prior 3-year window, with the first of these 3 years of publication beginning 4 years before the citing year. Thus, citations reported in 2012 were to papers published in 2008, 2009, and 2010. Citations to publications outside of that 3-year window were not captured.

Table 5-23 **S&E articles in all fields, by country/economy: 2003 and 2013**

Rank	Country/economy	2003	2013	Average annual change (%)	2013 world total (%)	2013 cumulative world total (%)
-	World	1,117,866	2,199,704	7.0	na	na
1	United States	299,876	412,542	3.2	18.8	18.8
2	China	71,113	401,435	18.9	18.2	37.0
3	Japan	87,389	103,377	1.7	4.7	41.7
4	Germany	67,491	101,074	4.1	4.6	46.3
5	United Kingdom	69,741	97,332	3.4	4.4	50.7
6	India	26,100	93,349	13.6	4.2	55.0
7	France	49,850	72,555	3.8	3.3	58.3
8	Italy	39,096	66,310	5.4	3.0	61.3
9	South Korea	21,802	58,844	10.4	2.7	64.0
10	Canada	35,740	57,797	4.9	2.6	66.6
11	Spain	27,657	53,342	6.8	2.4	69.0
12	Brazil	15,874	48,622	11.8	2.2	71.2
13	Australia	23,274	47,806	7.5	2.2	73.4
14	Russia	24,487	35,542	3.8	1.6	75.0
15	Taiwan	14,415	34,331	9.1	1.6	76.6
16	Iran	3,459	32,965	25.3	1.5	78.1
17	Netherlands	18,739	30,412	5.0	1.4	79.4
18	Turkey	12,689	30,402	9.1	1.4	80.8
19	Poland	14,424	28,753	7.1	1.3	82.1
20	Switzerland	12,436	21,060	5.4	1.0	83.1
21	Sweden	14,034	19,362	3.3	0.9	84.0
22	Malaysia	1,336	17,720	29.5	0.8	84.8
23	Belgium	10,239	16,511	4.9	0.8	85.5
24	Czech Republic	6,134	14,022	8.6	0.6	86.2
25	Portugal	4,203	13,556	12.4	0.6	86.8
26	Mexico	6,330	13,112	7.6	0.6	87.4
27	Denmark	6,988	12,482	6.0	0.6	87.9
28	Austria	7,412	12,031	5.0	0.5	88.5
29	Greece	6,330	11,370	6.0	0.5	89.0
30	Israel	9,269	11,300	2.0	0.5	89.5
31	Romania	2,080	11,164	18.3	0.5	90.0
32	Singapore	5,343	10,659	7.2	0.5	90.5

Rank	Country/economy	2003	2013	Average annual change (%)	2013 world total (%)	2013 cumulative world total (%)
33	Finland	7,259	10,157	3.4	0.5	91.0
34	Norway	4,913	9,854	7.2	0.4	91.4
35	South Africa	4,077	9,679	9.0	0.4	91.9
36	Egypt	3,045	9,199	11.7	0.4	92.3
37	Thailand	2,105	8,631	15.2	0.4	92.7
38	Argentina	4,485	8,053	6.0	0.4	93.0
39	Pakistan	1,282	7,772	19.7	0.4	93.4
40	Saudi Arabia	1,660	7,636	16.5	0.3	93.7
41	New Zealand	4,233	7,244	5.5	0.3	94.1
42	Ukraine	3,976	7,218	6.1	0.3	94.4
43	Ireland	2,904	6,874	9.0	0.3	94.7
44	Hungary	4,153	6,249	4.2	0.3	95.0
45	Serbia	1,227	5,169	15.5	0.2	95.2
46	Chile	2,002	5,158	9.9	0.2	95.5
47	Slovakia	2,083	4,730	8.5	0.2	95.7
48	Colombia	655	4,456	21.1	0.2	95.9
49	Croatia	2,226	4,359	7.0	0.2	96.1
50	Tunisia	975	4,207	15.7	0.2	96.3

na = not applicable.

NOTES: The countries/economies shown each produced 4,000 publications or more in 2013. The countries/economies are ranked based on the 2013 total. Articles are credited on a fractional-count basis (i.e., for articles from multiple countries/economies, each country/economy receives fractional credit on the basis of the proportion of its participating authors). Detail does not add to total because of countries/economies not shown.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com). See appendix table 5-26.

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From the perspective of trends in international S&E publication, the key observation is that the publication output volume of China and other developing countries has increased much more rapidly than that of the United States and other developed countries in recent years. The crossover point, when China's publications would exceed those of the United States, has long been anticipated and has nearly been reached. Although the United States remains a major producer of S&E publications, in 2013 China has a comparable share of S&E publications.

Publication Output, by Country

The top five countries producing S&E publications in 2013 are the United States (18.8%), China (18.2%), Japan (4.7%), Germany (4.6%) and the United Kingdom (4.4%). When treated as one entity, the European Union (EU) accounts for 27.5% of the world's S&E publications in 2013 (Figure 5-24).[i] The EU, the United States, and Japan have been major producers for several decades. Together, the United States, the EU, and Japan account for 51% of the world's S&E publications in 2013 (Appendix Table 5-26). China emerged as a major producer in the mid-2000s.

India's publication volume has grown more gradually and in 2013 reached 4.2% (Figure 5-24). Overall, 50 countries—a quarter of those that produced S&E publications in 2013—account for 96.3% of global output (Table 5-23).

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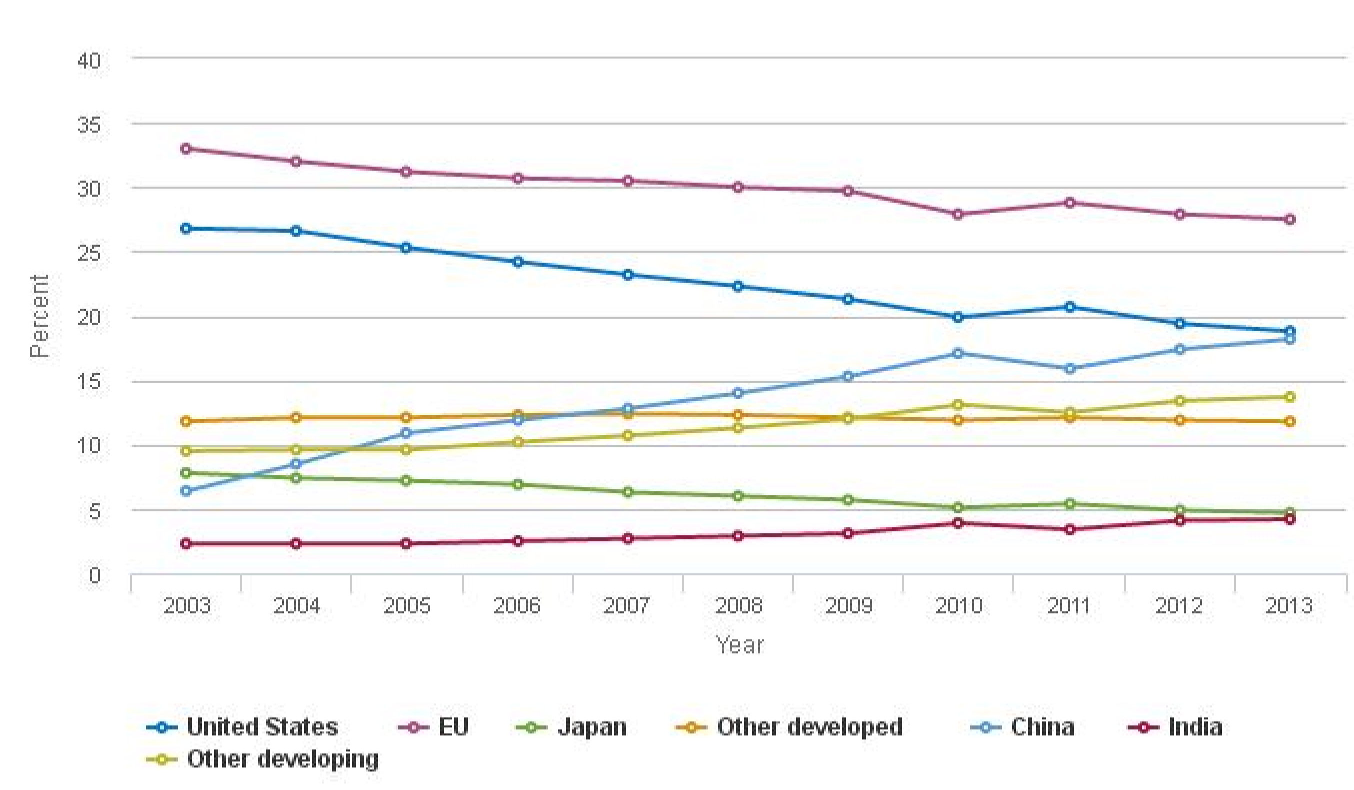
[i] Country assignments refer to the institutional address of authors, with partial credit given for international coauthorship. See the sidebar Bibliometric Data and Terminology for more information on how S&E article production and collaboration are measured.

Figure 5-24

S&E articles, by global share of selected region/country/economy: 2003–13



EU = European Union.

NOTES: Publication counts are from a selection of journals, books, and conference proceedings in S&E from Scopus. Publications are classified by their year of publication and are assigned to a region/country/economy on the basis of the institutional address(es) listed in the article. Articles are credited on a fractional-count basis (i.e., for articles from multiple countries/economies, each country/economy receives fractional credit on the basis of the proportion of its participating authors). Some publications have incomplete address information for coauthored publications in the Scopus database and cannot be fully assigned to a country or economy. These unassigned counts, 1% of the world total in 2013, are used to calculate this figure but are not shown. See appendix table 5-26.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com).

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S&E publications are growing especially fast from authors with institutional addresses in the developing world. Between 2003 and 2013, total world S&E publication output grew at an average annual rate of 7.0%; by 2013, 199 countries had at least one S&E publication. The total for developing countries grew more than twice as fast (14.6%) as the world total.[ii] This growth in S&E publications in the developing world suggests rapidly increasing science and technology capabilities. China (18.9% growth rate of publications) propelled growth of developing countries, resulting in their collective global share climbing from 18.2% to 36.1% (Figure 5-24).

China's growth in S&E publications is concurrent with its enormous increase in gross domestic product over the last decade. This growth is consistent with findings by many researchers that there is a high correlation between these two measures (Narin, Stevens, and Whitlow 1991; Price 1963; Shelton 2008). Given China's demographic, economic, and scientific progress in recent decades, it has long been anticipated that China will overtake the United States in S&E publication output (Royal Society 2011; Price 1963). In 2013, based on Scopus data, China's

S&E publications (18.2%) are within less than 1 percentage point of those of the United States (18.8%) in their share of the world's total S&E publications.

Among other larger emerging economies, publications from India grew at a 13.6% average annual rate over the decade, and those from Brazil grew at an 11.8% average annual rate. As a result, India's and Brazil's global shares increased to 4.2% and 2.2%, respectively (Table 5-23). In 2013, India was the sixth-largest producer of S&E publications after the United States, China, Japan, Germany, and the United Kingdom (Table 5-23). Rapid growth of S&E publications in India and China coincided with increased R&D expenditures and growth in S&E degrees awarded at the bachelor's-degree and doctoral-degree levels (see Chapter 2 Section; International S&E Higher Education).

Smaller developing countries with more than 4,000 publications in 2013 and rapid S&E publication growth (15%–29% annual average rate) were Colombia, Iran, Malaysia, Pakistan, Romania, Saudi Arabia, Serbia, Thailand, and Tunisia.

Developed economies' S&E publication production grew more slowly (4.5%) than that of developing economies (14.6%) over the decade. U.S. growth in S&E publication production was even slower (3.2%) than the average for all developed economies. As U.S. publications leveled off and developing economies' publications grew more rapidly, the U.S. global share fell from 26.8% to 18.8% (Appendix Table 5-26).

The EU, the world's largest producer, grew slightly faster than all developed countries. Among EU member countries, growth rates were slower for the three largest—France, Germany, and the United Kingdom—and generally much faster in smaller member countries. Several countries that are relatively new members of the EU, including the Czech Republic, Estonia, Lithuania, Poland, Slovakia, Romania, and Croatia, had growth rates above 6.0% for the decade. Although EU publication production grew slightly faster than that of the United States, the EU's global share fell from 33.0% in 2003 to 27.5% in 2013 because of the far more rapid growth of developing countries (Figure 5-24). S&E publications of Japan, the fourth-largest producer, grew relatively slowly, with a 1.7% annual average rate over the decade. As a result, Japan's global share dropped from 7.8% in 2003 to 4.7% in 2013.

Publication output by developed economies outside of the EU, the United States, and Japan grew much faster, primarily due to rapid growth (7%–10% annual average) in Australia and three Asian locations: South Korea, Taiwan, and Singapore.

The distribution of S&E publication output by field provides an indication of the priority and emphasis of scientific research in different locations. The S&E publication portfolios of the five major producers—the United States, the EU, China, Japan, and India—have distinct differences by field (Table 5-25; Appendix Table 5-27, Appendix Table 5-28, Appendix Table 5-29, Appendix Table 5-30, Appendix Table 5-31, Appendix Table 5-32, Appendix Table 5-33, Appendix Table 5-34, Appendix Table 5-35, Appendix Table 5-36, Appendix Table 5-37, Appendix Table 5-38, and Appendix Table 5-39). Almost half (48.7%) of the United States' publications are focused on biological sciences, medical sciences, and other life sciences, compared to 38.2% for the world at large. The United States also produces a higher proportion of S&E publications than the rest of the world in psychology and social sciences.[iii] In this context, it is useful to keep in mind that publications in the Scopus database must have an abstract in the English language to be included in the publication counts and that social science publications are frequently published in local languages (Archambault et al. 2009).

[ii] Calculated from Appendix Table 5-26 and the IMF definition of developing countries.

[iii] Social science literature, like the humanities, is more likely to be published in a country's national language.

Table 5-25 S&E research portfolios of selected regions/countries/economies, by field: 2013

(Percent)

Field	World	United States	EU	China	Japan	India
All articles (*n*)	2,199,704	412,542	605,536	401,435	103,377	93,349
Engineering	19.8	12.4	13.9	37.7	19.3	20.6
Astronomy	0.6	0.9	0.9	0.2	0.5	0.4
Chemistry	7.9	5.6	7.0	10.6	9.7	12.5
Physics	9.2	7.9	9.4	9.9	14.0	8.5
Geosciences	5.3	4.8	5.3	6.1	3.7	4.7
Mathematics	2.5	2.0	2.7	2.5	1.7	2.1
Computer sciences	8.1	6.2	8.8	9.3	8.0	10.4
Agricultural sciences	2.2	1.2	2.0	1.9	1.7	2.9
Biological sciences	15.8	19.2	15.4	12.1	14.8	19.6
Medical sciences	21.2	27.2	24.2	8.7	24.5	16.4
Other life sciences	1.2	2.3	1.2	0.1	0.3	0.2
Psychology	1.7	3.5	2.1	0.2	0.5	0.1
Social sciences	4.5	6.7	6.9	0.7	1.2	1.5

EU = European Union.

NOTES: Article counts are from a selection of journals in S&E from Scopus. Articles are classified by their year of publication and are assigned to a region/country/economy on the basis of the institutional address(es) listed in the article. Articles are credited on a fractional-count basis. See appendix table 5-25 for countries/economies included in the EU. Percentages may not add to 100% because of rounding.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com). See appendix tables 5-27–5-39.

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Like the United States, the EU is more focused on biological sciences, medical sciences, and other life sciences than the world as a whole (40.8%). Relative to the United States, the EU has higher shares of publications in physics, chemistry, and engineering. Japan's publications are more focused on chemistry, medical sciences, and physics than the world as a whole.

Relative to the world as a whole, S&E publications of China are more heavily focused on engineering and chemistry. Engineering publications made up 37.7% of 2013 output for China, and chemistry publications made up 10.6% of output. China's portfolio also has shares above the world average in computer sciences and physics.

Engineering publications with institutional addresses from India are also above the average for the world as a whole, making up 20.6% of India's S&E output in 2013. India's portfolio has the heaviest concentration of these countries and regions in biological sciences, with a 19.6% share, and is above world average concentrations in chemistry and computer science.

In summary, of the top producers, the United States has the highest concentration of publications in medical sciences, followed by the EU and Japan. India and the United States have the highest concentration of publications in biological sciences. China has the highest concentration in engineering, followed by India.

Publication Output, by U.S. Sector

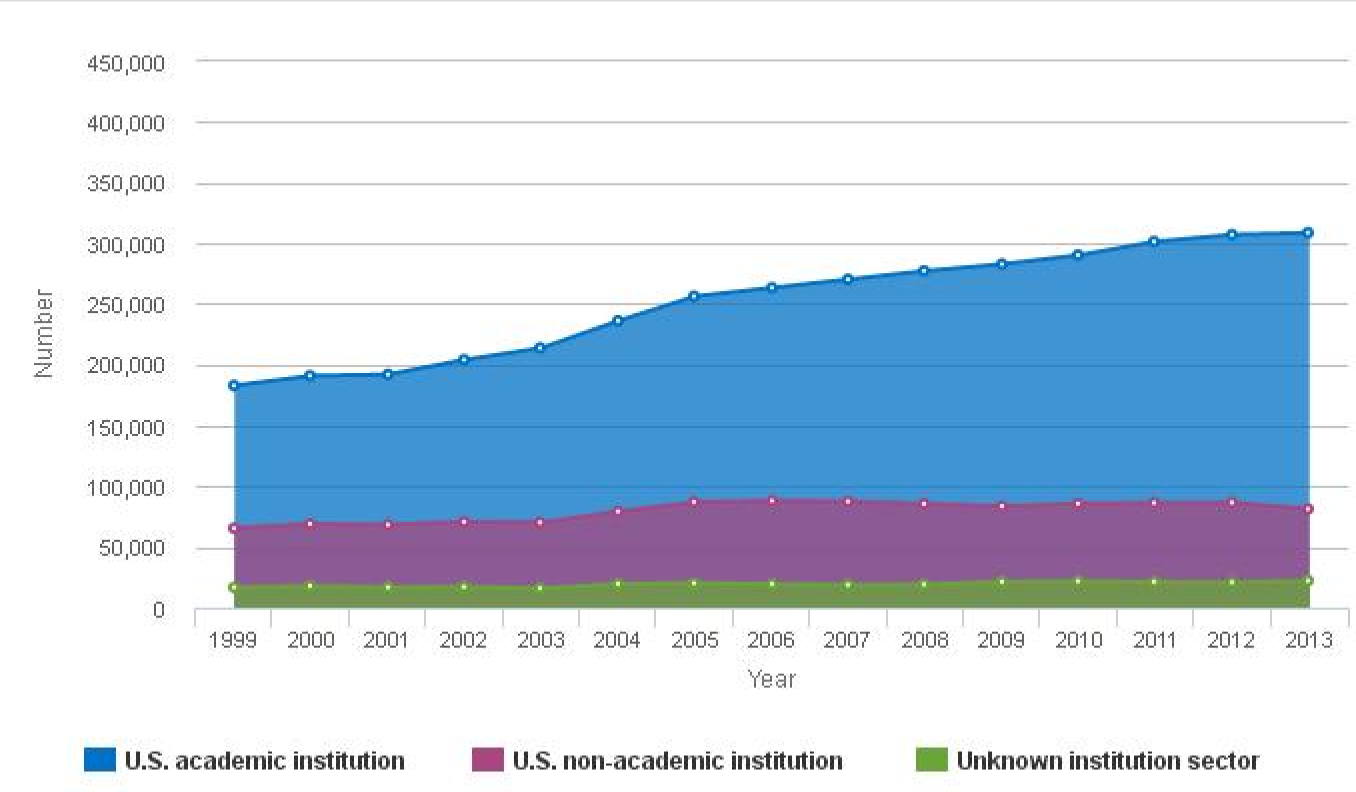
Six U.S. institutional sectors produce S&E publications: the federal government, industry, academia, federally funded research and development centers (FFRDCs), private nonprofit organizations, and state and local governments.[iv] This section describes patterns and trends in the sector distributions of U.S. publication output.

The U.S. academic sector is the largest producer of S&E publications, accounting for three-fourths of U.S. S&E publication output. This sector was largely responsible for the growth of U.S. S&E publication output between 1999 and 2013. The number of academic S&E publications rose from 182,547 to 308,650 between these years. As a result, academia's share of all U.S. publications rose from 69% to 75% (Figure 5-25). Public universities accounted for 45% of all U.S. publications, and private universities accounted for 25% (Appendix Table 5-40).

[iv] In 2013, 5.1% of the U.S. publications could not be assigned to a sector based on the information in the Scopus database. Sector identification is not yet available for other countries.

Figure 5-25

U.S. academic and non-academic S&E articles: 1999–2013



NOTES: Articles refer to publications from a selection of journals, books, and conference proceedings in S&E from Scopus. Articles are classified by their year of publication and are assigned to fields of science by matching the journal in Scopus to the National Science Foundation's subfields (appendix table 5-24). Articles are credited on a fractional-count basis (i.e., for articles from multiple regions/economies/sectors, each region/country/economy receives fractional credit on the basis of the proportion of its participating authors). The sum of sectors may not add to field total because of rounding. See appendix table 5-40.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com).

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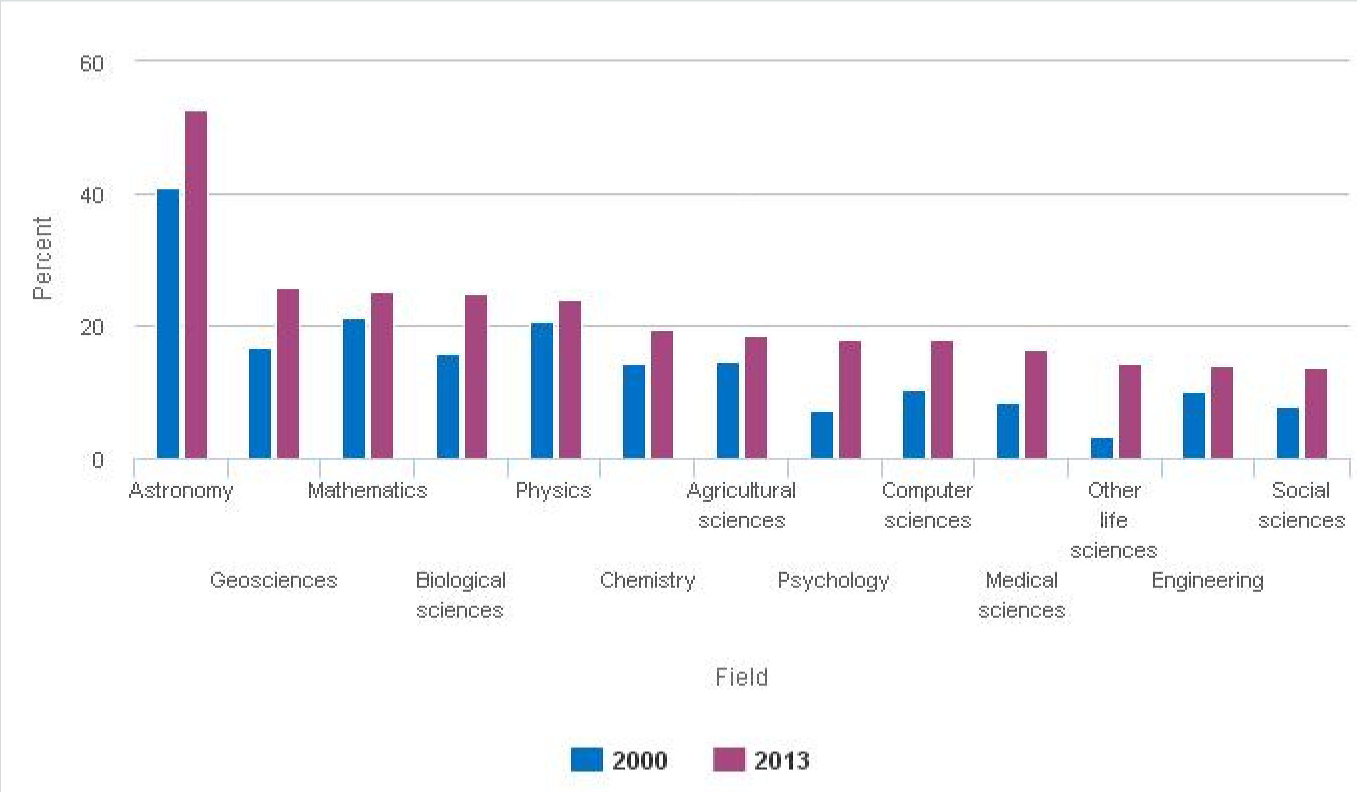
S&E publications in U.S. non-academic sectors rose from 65,661 to 81,521 during this period. These sectors had divergent trends (Appendix Table 5-40):

- Publications with institutional addresses in the private nonprofit sector grew from 16,195 in 1999 to 20,792 in 2013, accounting for 5.0% of U.S. publications in 2013.
- Publications from FFRDCs grew to a peak of 10,487 in 2005, declined until 2010, and recovered to above 10,000 for the years 2011–13.
- Federal government publications also grew in the early 2000s and then leveled off after 2006, accounting for 5.4% (22,309) of the U.S. total in 2013.
- Industry publications reached a high of 31,625 in 2005 and then declined steadily to 26,322, or 6.4% of the U.S. total in 2013.

The research portfolios of U.S. sectors are generally dominated by life sciences (biological sciences, medical sciences, and other life sciences), with nearly half or more of all publications in these fields (Table 5-26). The dominance of life sciences is especially pronounced in the nonprofit sector, where 58.1% of the publications are in medical sciences, 23.8% are in biological sciences, and 4.7% in other life sciences. With a much larger number of publications, academia has 49% of its S&E literature in life sciences. The exception to this focus on life sciences is in the research portfolio of FFRDCs. They are dominated by the physical sciences, physics (33.1%), chemistry (14.2%), and engineering (25.8%).

Figure 5-27

Share of world S&E articles with international collaboration, by S&E field: 2000 and 2013



NOTES: Articles refer to publications from a selection of journals, books, and conference proceedings in S&E from Scopus. Articles are classified by their year of publication and are assigned to a region/country/economy on the basis of the institutional address(es) listed in the article. Articles with international collaboration are counts of articles with institutional addresses from more than one country/economy. Articles are credited on a whole-count basis (i.e., each collaborating country /economy is credited with one count).

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com).

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Table 5-26 Share of U.S. S&E articles, by sector and field: 2013

(Percent)

Sector	Federal government	Industry	Academic	FFRDCs	Private nonprofit	State/local government	Unknown institutional sector
All fields combined (*n*)	22,309	26,322	308,650	10,002	20,792	2,096	22,370
Agricultural sciences	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Astronomy	1.6	0.2	0.9	2.4	0.3	0.0	0.3

Sector	Federal government	Industry	Academic	FFRDCs	Private nonprofit	State/local government	Unknown institutional sector
Biological sciences	27.0	13.7	19.5	7.1	23.8	30.3	14.5
Chemistry	4.2	8.0	5.7	14.2	1.4	1.7	3.3
Computer sciences	2.3	11.6	6.5	5.4	0.8	0.9	5.3
Engineering	12.2	29.5	10.9	25.8	2.0	6.3	17.0
Geosciences	10.6	6.4	4.0	8.2	2.1	19.1	7.6
Mathematics	0.7	0.9	2.5	1.0	0.2	0.2	0.9
Medical sciences	23.5	12.8	27.2	1.7	58.1	29.2	30.1
Other life sciences	1.3	1.6	2.3	0.1	4.7	3.9	3.9
Physics	8.5	12.5	7.4	33.1	1.0	1.0	5.0
Psychology	1.7	0.8	4.2	0.1	1.6	1.8	3.4
Social sciences	3.0	1.2	7.8	0.6	3.7	3.7	7.5

NOTES: FFRDC = federally funded research and development center.
Articles refer to publications from a selection of journals, books, and conference proceedings in S&E from Scopus. Articles are classified by their year of publication and are assigned to fields of science by matching the journal in Scopus to the National Science Foundation's subfields (appendix table 5-24). Articles are credited on a fractional-count basis (i.e., for articles from multiple countries/economies/sectors, each country/economy /sector receives fractional credit on the basis of the proportion of its participating authors). The sum of sectors may not add to field total because of rounding.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com). See appendix table 5-40.

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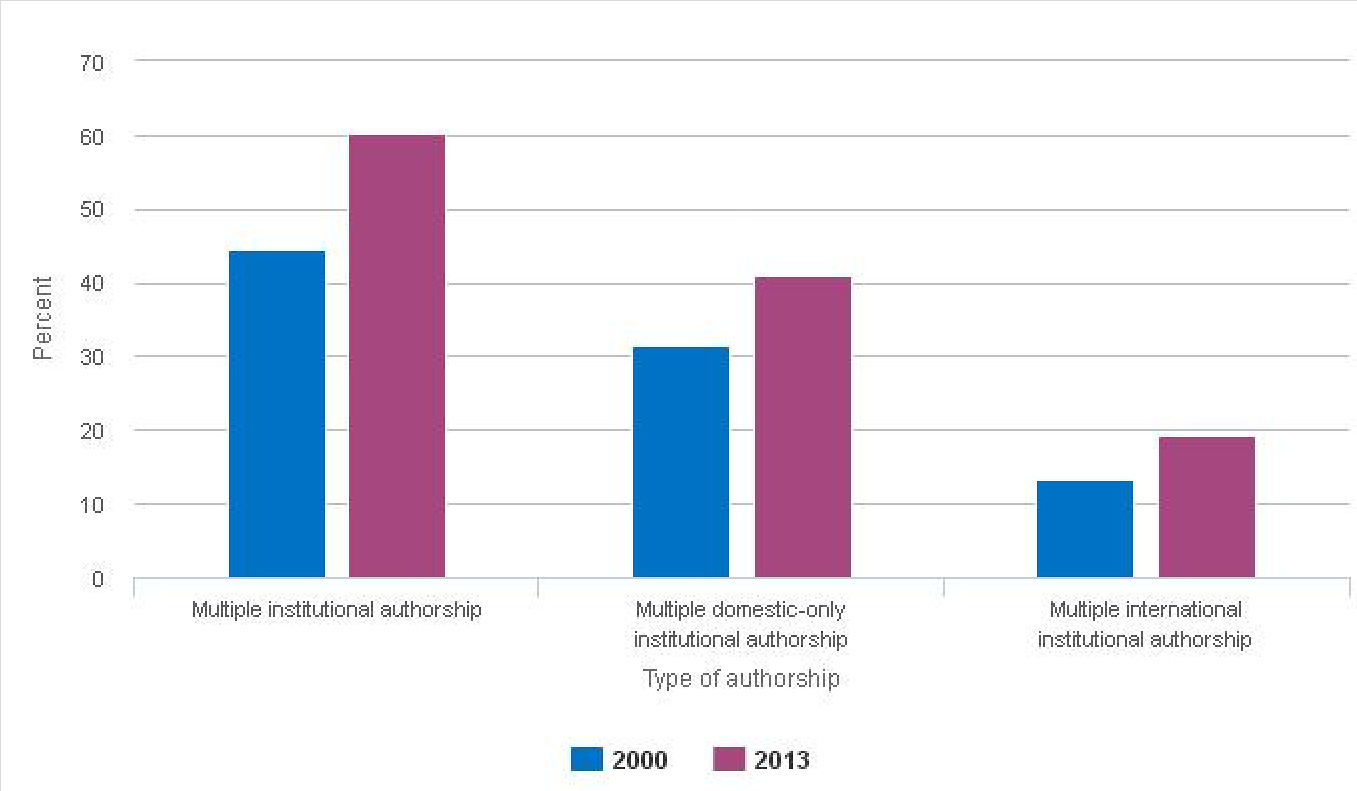
Coauthorship and Collaboration in S&E Literature

Collaboration on S&E research publications can be an indicator of interconnections among researchers in different institutional settings and of the growing capacity of researchers to address complex problems by drawing on diverse skills and perspectives. Collaborative S&E research facilitates knowledge transfer and sharing among individuals, institutions, and nations. Between 2000 and 2013, collaboration has been increasing, with higher shares of scientific publications with institutional and international coauthorships (Figure 5-26). The following two sections explore the growth of collaborative publication.

Figure 5-26

Share of world articles in all fields with authors from multiple institutions, domestic-only institutions, and international coauthorship: 2000 and 2013



NOTES: Article counts refer to publications from a selection of journals, books, and conference proceedings in S&E from Scopus. Articles are classified by their year of publication and are assigned to a region/country/economy on the basis of the institutional address(es) listed in the article. Articles are credited on a whole-count basis (i.e., each collaborating country /economy is credited with one count). Articles with multiple institutions are counts of articles with two or more institutional addresses. Articles with multiple domestic institutions only are counts of articles with more than one institutional address within a single country/economy. Articles with international institutions are counts of articles with institutional addresses from more than one country/economy. See appendix table 5-41.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com).

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Collaboration among U.S. Sectors

U.S. coauthorship data at the sector level—academic, nonprofit, industry, FFRDCs, federal and state government—are indicators of collaboration among U.S. sectors and between U.S. sectors and foreign institutions. Over the last decade, the number of collaborations with other U.S. sectors and with foreign institutions increased in all sectors, along with the share of publications that are coauthored with foreign institutions (Table 5-27).[i] The proportion of academic publications coauthored with other U.S. sectors and foreign institutions increased from 45% in 2000 to 61% in 2013. The increase for publications coauthored with foreign institutions was from 19% to 33%. FFRDCs, where the research conducted focuses on the physical sciences, have the highest percentages of international coauthorship of U.S. sectors, at 41% in 2013.

[i] Note that coauthorship counts use *whole counting,* which means that a publication with a foreign coauthor as well as a domestic author from a different sector will be counted as a coauthored paper with another U.S. sector as well as counted as coauthored with a foreign institution.

Table 5-27 **Shares of U.S. sector publications coauthored with other U.S. sectors and foreign institutions: 2000 and 2013**

	U.S. sector					
Year	Academic	Federal government	Industry	FFRDCs	Private nonprofit	State/local government
2000						
All publications (*n*)	264,295	30,741	38,745	11,717	28,565	2,723
Total coauthored	61.8	70.2	60.1	69.2	71.2	74.6
Total coauthored with another U.S. sector and/or foreign institution	45.0	59.4	50.8	64.5	58.5	67.4
Coauthored with another U.S. sector	32.3	49.7	40.2	50.0	50.8	63.9
Coauthored with academic sector	na	42.3	33.9	42.3	46.3	53.9
Coauthored with non-academic sector	32.3	17.1	13.8	16.3	13.4	28.7
Coauthored with foreign institutions	19.3	19.3	18.0	30.1	16.4	11.3
2013						
All publications (*n*)	496,276	48,504	51,146	20,998	46,192	5,566
Total coauthored	75.4	86.9	78.6	82.8	85.0	90.2
Total coauthored with another U.S. sector and/or foreign institution	61.0	80.2	69.4	78.5	76.9	85.8
Coauthored with another U.S. sector	40.5	69.1	52.8	62.8	66.7	80.1
Coauthored with academic sector	na	61.6	46.2	56.5	62.7	69.5
Coauthored with non-academic sector	40.5	23.5	17.8	18.3	17.7	36.0
Coauthored with foreign institutions	32.5	30.9	30.7	40.8	29.5	20.0

na = not applicable.

FFRDCs = federally funded research and development centers.

NOTES:	Article counts are from a selection of journals, books, and conference proceedings in S&E from Scopus. Articles are classified by their year of publication and are assigned to a sector on the basis of the institutional address(es) listed in the article. Articles are credited on a whole-count basis (i.e., each collaborating institution type is credited one count in each qualifying group). The sum of articles coauthored with various sectors could exceed the total number of articles coauthored with another sector and/or foreign sector due to articles coauthored by multiple sectors. Articles from unknown U.S. sectors are not shown.
SOURCES:	National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com).
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International Collaboration

The percentage of publications with authors from different countries rose from 13.2% to 19.2% between 2000 and 2013 (Figure 5-26). This increase in part reflects increasing global capabilities in R&D and an expanding pool of trained researchers, as well as improvements in communication technology. These collaborations may also reflect the strengthening of a network of international scholars who increasingly collaborate with each other (Wagner, Park, and Leydesdorff 2015). Finally, the substantial challenges of climate change, food, water, and energy security are ones that are fundamentally global in scope, rather than national (Royal Society, 2011). While these factors affect the overall trend, the patterns of international scientific collaborations also reflect wider relationships among countries, including linguistic and historical factors (Narin, Stevens, and Whitlow 1991), and geography, economic, and cultural relations (Glänzel and Schubert 2005).

Percentages of international collaboration by field. This increase in international coauthorship occurs in every broad field of science. Astronomy is the most international field, with over half of its publications internationally coauthored (52.7%) (Figure 5-27). Geosciences, mathematics, biological sciences, and physics also have percentages of international collaboration above 20%. Factors influencing variations among fields include the existence of formal international collaborative programs and the use of costly research equipment (e.g., atomic colliders and telescopes), which result in cost sharing and collaboration among countries. However, even those fields with relatively low percentages of international collaboration have experienced increases in collaboration between 2000 and 2013.

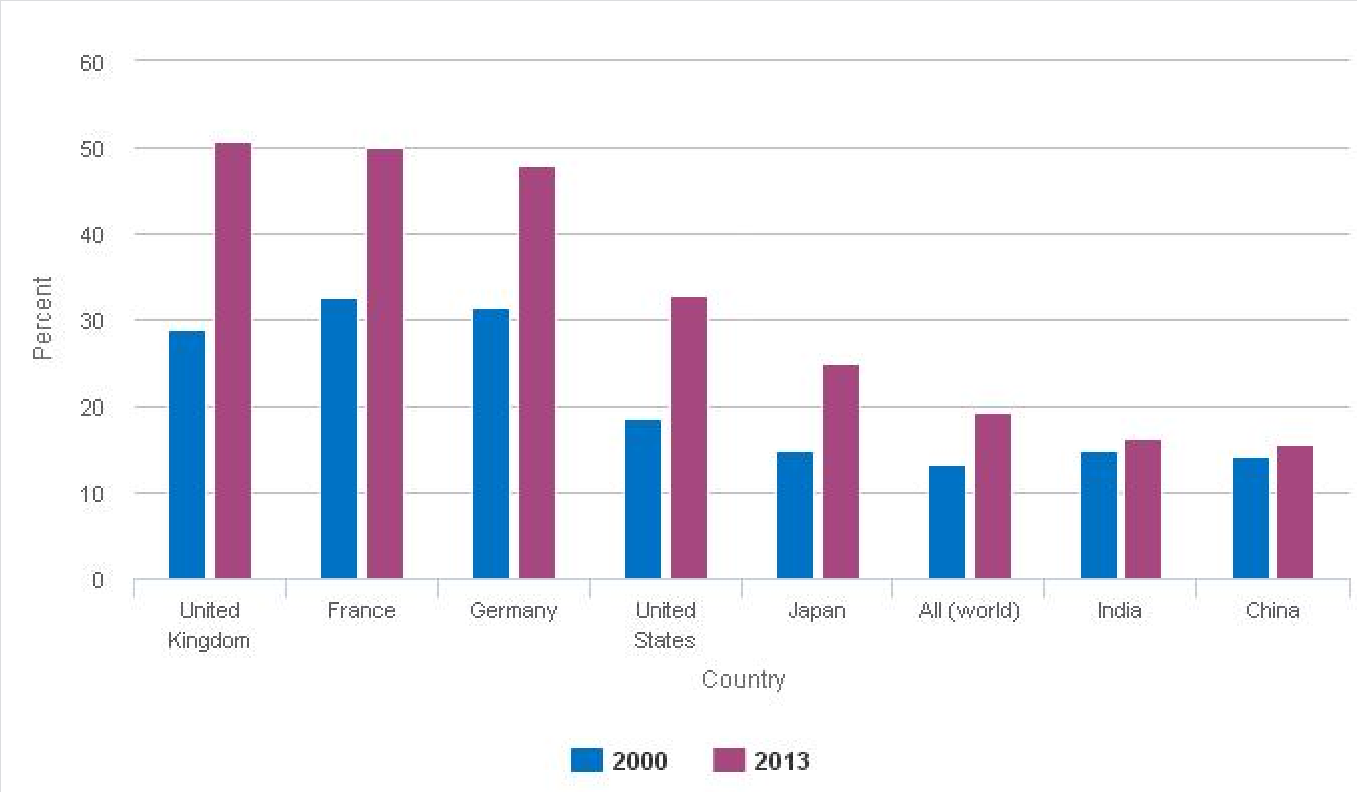
International collaboration, by region/country. Countries vary widely in the proportion of their S&E publications that are internationally coauthored. Scale effects alone play a role in this. Countries with large communities of researchers have many potential domestic coauthors in their field. Researchers in smaller countries are more likely to reach beyond their national borders to find collaborators.

In the publication output data described earlier from Figure 5-24, the 28 nations of the EU are shown as one region.[ii] By individual country, Figure 5-28 shows the percentages of international collaboration for the largest producers of S&E publications in 2013. The nations within this group that had the highest percentages of international collaboration in 2013 were the three EU nations of the United Kingdom, France, and Germany, which are also the three largest European producers of S&E publications. Collaboration increased for each country between 2000 and 2013. China and India increased their percentages of collaboration across the same period but did so at a slower rate than the other nations appearing in Figure 5-28 and were well below the global average.

[ii] Recent analytical work has approached the comparison between the United States and Europe as a comparison of collaboration between the nation states of Europe and the states that make up the United States (Kamalski and Plume 2013).

Figure 5-28

Share of S&E articles internationally coauthored, by selected country: 2000 and 2013



NOTES: Articles refer to publications from a selection of journals, books, and conference proceedings in S&E from Scopus. Articles are classified by their year of publication and are assigned to a region/country/economy on the basis of the institutional address(es) listed in the article. Articles are credited on a whole-count basis (i.e., each collaborating country /economy is credited with one count). Articles with international institutions are counts of articles with institutional addresses from more than one country/economy. See appendix table 5-41.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com).

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Collaboration partnerships. Authors from each country have, on average, different propensities to partner with coauthors from other countries for international scientific collaboration. The remainder of this section describes global partnership patterns, with special focus on patterns of U.S. involvement in international collaboration.

U.S. institutional authors collaborate most frequently with authors from the second-largest producer of S&E publications, China. China accounted for 18.7% of U.S. internationally coauthored publications in 2013 (Table 5-28). Other substantial partners for the United States include the United Kingdom (12.7%), Germany (11.8%), Canada (10.4%), France (7.8%), Italy (6.7%), and Japan (5.9%).

Table 5-28 International coauthorship of S&E articles with the United States, by selected country/economy: 2013

(Percent)

Country/economy	U.S. share of country's/economy's international articles	Country's/economy's share of U.S. international articles
World	39.5	na
China	45.6	18.7
United Kingdom	29.0	12.7
Germany	28.8	11.8
Canada	44.4	10.4
France	25.1	7.8
Italy	29.9	6.7
Japan	32.9	5.9
Australia	29.3	5.8
South Korea	50.0	5.4
Spain	25.2	4.9
Netherlands	29.4	4.6
Switzerland	30.4	4.3
India	33.2	3.4
Brazil	35.5	3.2
Sweden	26.9	2.9

na = not applicable.

NOTES: Articles refer to publications from a selection of journals, books, and conference proceedings in S&E from Scopus. Articles are classified by their year of publication and are assigned to a country/economy on the basis of the institutional address(es) listed in the article. Articles are credited on a whole-count basis (i.e., each collaborating country/economy is credited with one count). Articles with international institutions are counts of articles with institutional addresses from more than one country/economy. See appendix table 5-56.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com).

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China and Canada are notable among these countries for having unusually high percentages of U.S. participation in their own internationally coauthored publications (45.6% and 44.4%, respectively). For the other five countries, the comparable shares range from 25.1% to 32.9%.

As a way to gauge the relative impact of relationships between countries, an index of international collaboration highlights shares of international scientific collaboration that differ substantially from what would be expected proportionally, based on country size. Eliminating other factors (language, geography, etc.), one might expect a country's internationally coauthored publications to have coauthors from a nation with a large number of internationally coauthored S&E publications. The index of international collaboration presented in Table 5-29 is 1.00 (unity) when coauthorship between two countries is exactly proportional to their overall shares of international collaborative authorship. A higher index value means that a country pair has a stronger-than-expected tendency to collaborate, and a lower index value means the pair has a weaker tendency to collaborate.

Table 5-29 **Index of international collaboration on S&E articles, by selected country/economy pair: 1999 and 2013**

(International collaboration index)

Country/economy pair	1999	2013
North/South America		
Canada–United States	1.15	1.12
Mexico–United States	0.99	1.02
Mexico-Argentina	2.31	3.81
Mexico-Chile	2.57	3.66
Argentina-Brazil	4.06	4.98
Argentina-Chile	5.90	8.25
Europe		
France-Germany	0.74	1.04
France-UK	0.73	0.94
UK-Ireland	2.27	2.15
Belgium-Netherlands	2.23	3.09
Poland–Czech Republic	2.14	4.81
Hungary-Romania	4.72	7.20
Spain-Portugal	2.78	3.27
Scandinavia		
Finland-Sweden	3.70	3.93
Finland-Norway	3.94	3.18
Sweden-Denmark	2.90	3.51
Middle East		
Saudi Arabia–Egypt	25.17	18.92
Turkey-Iran	0.66	3.40
Turkey-Israel	0.59	1.39
Asia/South Pacific		
China-Japan	1.63	1.23
South Korea–Japan	1.92	1.89
Australia-Malaysia	1.14	1.39
Australia-China	1.03	1.12
Australia–New Zealand	4.58	3.55

Country/economy pair	1999	2013
India–South Korea	0.91	1.85

UK = United Kingdom.

NOTES: The international collaboration index shows the first country's rate of collaboration with the second country, divided by the second country's rate of international coauthorship. Articles are credited on a whole-count basis (i.e., each collaborating country/economy is credited with one count). Articles with international institutions are counts of articles with institutional addresses from more than one country/economy. See appendix table 5-55.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com).

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Regional collaboration, as measured by this index of international collaboration, shows trends that reflect geographic proximity and other historical factors (Table 5-29; Appendix Table 5-55 and Appendix Table 5-56). In North America, the Canada-U.S. index shows a percentage of collaboration that is 12% (1.12) greater than would be expected by size of overall international collaboration alone and has not changed much between 1999 and 2013. Proximity alone does not explain these relationships: the U.S.-Mexico index is also relatively stable and is just what would be expected by size alone—near unity.

Mexico in turn has very strong collaboration with the Spanish-speaking South American nations of Argentina and Chile (3.81 and 3.66, respectively, for 2013). In turn, Argentina is particularly likely to collaborate with regional neighbors Brazil and Chile. Collaboration between the United Kingdom and Ireland is more than twice what would be expected, 2.15 in 2013. Hungary shares a particularly high collaboration index with Romania, 7.20 in 2013. These countries are not only neighbors; a relatively large share of Romania's population speaks Hungarian.[iii]

In addition to the above-average relationships that reflect geographic proximity, Appendix Table 5-55 shows other strong collaboration relationships that reflect historical and other ties between nations. For example, Spain had a collaboration index measure in 2013 that is between two and three times higher than expected with Mexico, Argentina, and Chile. Despite the substantial geographic distances, the United Kingdom has a higher-than-expected collaboration index with Australia and New Zealand. Malaysia has greater-than-expected collaboration ties with the Middle East nations Iran, Saudi Arabia, and Egypt.

[iii] Six percent of Romania's population speak Hungarian, according to the Central Intelligence Agency's *World Factbook* (https://www.cia.gov/library/publications/the-world-factbook/geos/ro.html).

Trends in Citation of S&E Publications

This section provides indicators of S&E publications that are cited in other S&E publications. Citations indicate impact, and they are increasingly international in scope. Measured by citations and by the shares of the most highly cited publications, the developed world continues to maintain a substantial advantage over the developing world. The developing world is nevertheless making rapid gains.

The next sections examine two aspects of publication citations in a global context: the overall rate of citation of a country's scientific publications, and the share of the world's most highly cited literature authored by different countries. The discussion of publication citations will conclude with an examination of citations to publications authored by researchers at U.S. academic institutions and in other U.S. sectors.

The rate of citations to S&E literature vary across fields of science and are most frequent within a few years following publication. However, even very old publications can "awaken" to receive citations many years after publication (Ke et al. 2015). The average of relative citations (ARC) presented in this chapter is an index designed to allow for lags of varying length and to normalize across fields and countries (see sidebar on Bibliometric Data and Terminology). The international citations patterns presented in Science and Engineering Indicators 2016 are calculated based on only a subsequent 3 years of data.

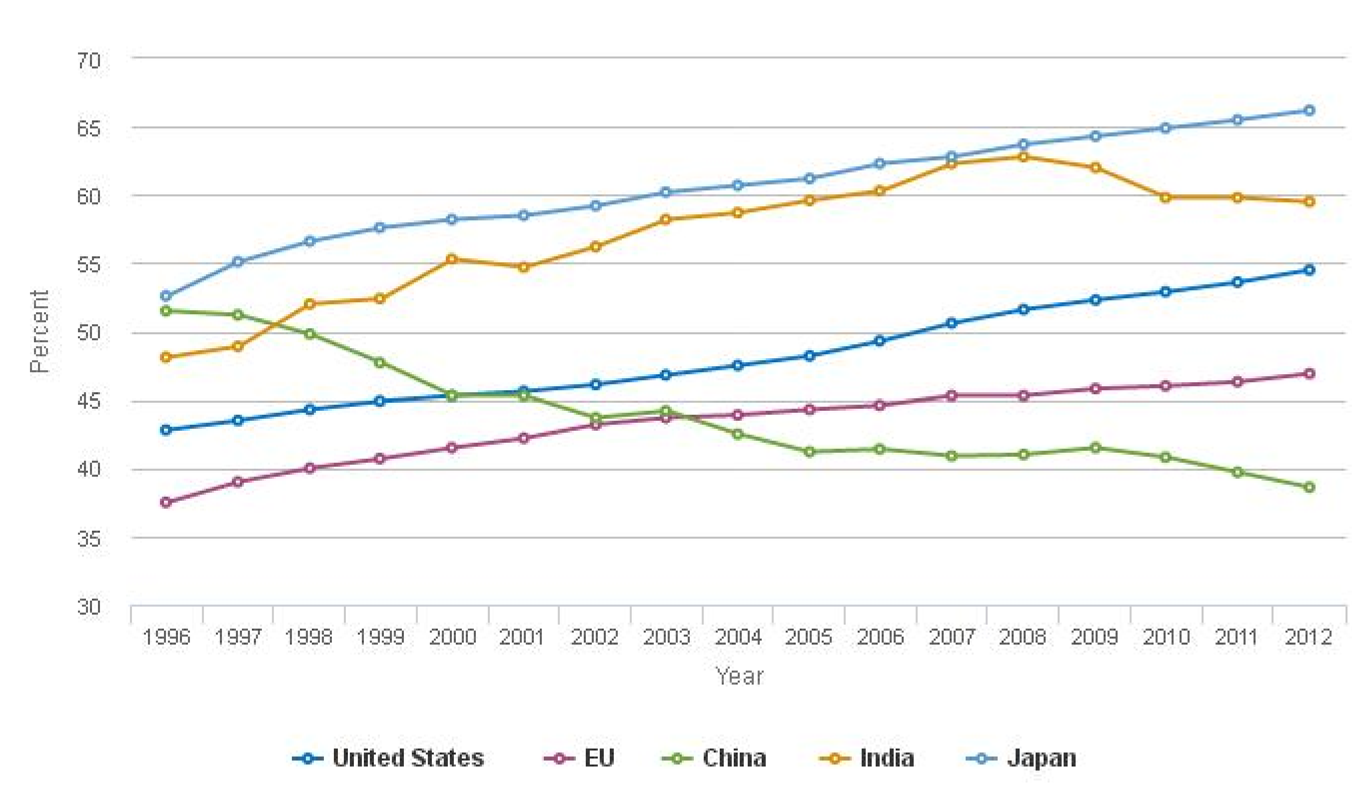
International Citation Patterns

Like the indicators of international coauthorship discussed earlier, cross-national citations provide evidence that S&E research is increasingly international in scope. Citations to a country's publications that come from publications authored outside that country are referred to as *international citations.* Simply due to the scale of S&E research activity, the United States, the EU, and China would be expected to account for large shares of the international citations. This section first reports these shares, then provides a relative measure that normalizes for each country's number of publications.

Between 1996 and 2012, the United States' international share of citations increased from 42.8% in 1996 to 54.5% in 2012 (Figure 5-29). The shares of international citations increased in most countries of the world and in all but one of the world's major S&E publication–producing countries (Appendix Table 5-58). China is the exception. In 1996, 51.5% of citations to Chinese S&E publications came from outside China; by 2012, the proportion had dropped to 38.6% (Figure 5-29). This suggests that China's expanding S&E publication output is being used mostly *within* China. Language barriers are one explanation; many Chinese-language articles are cited by other Chinese-language articles rather than by English-language articles (Li et al. 2014). A relatively small number of Chinese journals serve as citation windows, transmitting results between international and Chinese scholars (Zhou and Leydesdorff 2006).

Figure 5-29

Share of selected region/country/economy citations that are international: 1996–2012



EU = European Union.

NOTES: Articles refer to publications from a selection of journals, books, and conference proceedings in S&E from Scopus. Articles are classified by their year of publication and are assigned to a region/country/economy on the basis of the institutional address(es) listed in the article. Citations are presented for the year when the publication is published, showing the counts of subsequent citations from peer-reviewed literature. At least 3 years of data following publication are needed for a meaningful measure. See appendix table 5-58.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com).

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Russia, the 14th-largest producer of S&E publications in 2013, also experienced a drop in its share of international citations. This pattern is different from that of China, however. The decline in international citations is in the recent years of 2007–12, while Russia's share of world publications is shrinking. For Russia, this decline parallels a longer-term trend toward a shrinking R&D workforce. According to the Organisation for Economic Co-operation and Development, total R&D personnel in full-time equivalents declined from 1.1 million in 1996 to 827,000 in 2013 (OECD 2015).

Between 1996 and 2012, almost all of the countries in the EU increased their share of international citations (Appendix Table 5-58).[i] For the EU as a unit, the share of external citations increased from 37.5% to 46.9%. EU internal citations continue to make up over half of EU citations, indicating strength in the EU's scientific base, supported by the Framework Programme to enhance European research and other incentives.[ii]

The impact of one country's S&E publications on S&E researchers of the other country is shown in the patterns of international citations between country pairs. The relative citation index normalizes cross-national citation data for variations in relative size of publication output, much like the collaboration index (see sidebar, Bibliometric Data and Terminology). The expected value is 1.00, but unlike the collaboration index, citation indexes are not symmetric. For example, if country A cites publications by country B 15% more than expected, this does not mean that country B also cites publications by country A 15% more than expected. Table 5-24 shows the relative citation index for the year 2012 for major publishing locations in four regions: North America, the EU, Asia, and South America. These data show the following:

- From among the major producers of S&E publications, U.S. publications cite publications from Canada (1.17) and the United Kingdom (1.15) with shares higher than expected, based on size.
- U.S. authors cite Chinese (0.24), Indian (0.18), and other Asian S&E publications much less than expected.
- Mexico is heavily cited in publications from Argentina and Chile. Likewise, Mexican authors cite South American publications more than they cite publications from other areas of the world.

Inter-European influence is strong, with most country pairs exhibiting index values greater than 1.00.

Similar to the patterns in coauthorship, these data indicate the strong influence that geographic, cultural, and language ties—and, in the case of the EU, long-active incentives—have on citation patterns.

The publication counts and collaboration rates described above provide partial indicators of the quantity of S&E research output and the ties between researchers. Citations provide an additional indicator of the impact of research on subsequent work (Martin and Irvine 1980). The ARCs presented below are calculated to allow for citation lags of varying lengths and to normalize for field and country size (see the Bibliometric Data and Terminology sidebar).

Appendix Table 5-61 provides the ARC for 1996–2012 for countries and regions with enough citations to create valid measures. Through 2012, the United States' ARC held steady around 1.4, or 40% higher than would be expected, based on the number of peer-reviewed publications and representation by fields. China's ARC measure increased across the period, from 0.5 to 0.9, improving from 50% fewer citations as would be expected, based on size, to 10% fewer than would be expected.

When viewed as a group, the countries of the EU increased from as many citations as would be expected by size (1.0) to 20% more (1.2), based on ARCs (Figure 5-30). Appendix Table 5-61 provides country-level measures for the EU that show that Austria, Belgium, Cyprus, Denmark, Estonia, Finland, Ireland, the Netherlands, Sweden, and the United Kingdom had the highest ARCs in 2012, in each case starting with a relative measure below that of the United States in 1996 and rising above the United States by 2012. In East and Southeast Asia, Singapore has the highest ARCs, reaching 1.9 in 2012.

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[i] There were three exceptions, the relatively small S&E producers Latvia, Luxembourg, and Malta.

[ii] The European Union's Framework Programme provides competitive funding for research, including €8.1 billion in 2013 (http://ec.europa.eu/research/fp7/index_en.cfm).

Table 5-24 Relative citation index, by selected country/economy pair: 2012

	Cited country/economy													
	North America			South America			European Union			Asia				
Citing country /economy	Canada	Mexico	United States	Argentina	Brazil	Chile	France	Germany	United Kingdom	China	India	Japan	South Korea	Taiwan
North America														
Canada	8.82	0.35	1.54	0.52	0.32	0.57	0.90	0.94	1.36	0.28	0.22	0.49	0.46	0.45
Mexico	1.01	31.25	1.08	1.60	1.08	1.66	0.89	0.82	0.99	0.42	0.75	0.52	0.67	0.76
United States	1.17	0.31	2.90	0.41	0.26	0.45	0.76	0.92	1.15	0.24	0.18	0.54	0.49	0.38
South America														
Argentina	0.95	1.21	1.09	58.71	1.47	3.42	1.04	1.01	1.04	0.28	0.47	0.46	0.45	0.44
Brazil	0.88	0.99	0.89	2.04	13.98	1.24	0.79	0.74	0.91	0.32	0.60	0.45	0.55	0.56
Chile	1.19	1.16	1.22	3.61	0.97	73.61	1.09	1.00	1.16	0.29	0.36	0.49	0.55	0.46
European Union														
France	1.05	0.39	1.21	0.61	0.34	0.65	7.51	1.27	1.34	0.25	0.23	0.62	0.47	0.37
Germany	0.96	0.26	1.24	0.46	0.25	0.49	1.07	6.21	1.35	0.24	0.19	0.63	0.47	0.33
United Kingdom	1.16	0.29	1.34	0.41	0.28	0.50	1.00	1.16	6.11	0.22	0.20	0.51	0.41	0.34
Asia														
China	0.73	0.39	0.83	0.43	0.30	0.35	0.59	0.67	0.63	2.53	0.57	0.70	1.19	1.09
India	0.63	0.63	0.70	0.59	0.52	0.46	0.58	0.62	0.68	0.69	8.15	0.54	0.98	0.96
Japan	0.75	0.26	1.08	0.34	0.22	0.34	0.81	0.98	0.89	0.37	0.26	7.56	0.89	0.65
South Korea	0.75	0.36	1.05	0.38	0.30	0.35	0.57	0.73	0.72	0.69	0.54	0.92	10.93	1.26
Taiwan	0.78	0.50	0.97	0.39	0.34	0.30	0.60	0.65	0.74	0.74	0.56	0.81	1.51	16.69

NOTES:	Citations refer to publications from a selection of journals, books, and conference proceedings in S&E from Scopus. Articles are classified by their year of publication and are assigned to a country/economy on the basis of the institutional address(es) listed in the article. Articles are credited on a fractional-count basis (i.e., for articles with collaborating institutions from multiple countries/economies, each country/economy receives fractional credit on the basis of the proportion of its participating institutions). Citation counts are based on all citations made to articles in their publication year and in the following 2 years (i.e., 3-year citation window, for instance, scores in 2012 are based on citations to articles published in 2012 that were made in articles published in 2012–14.
SOURCES:	National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com).
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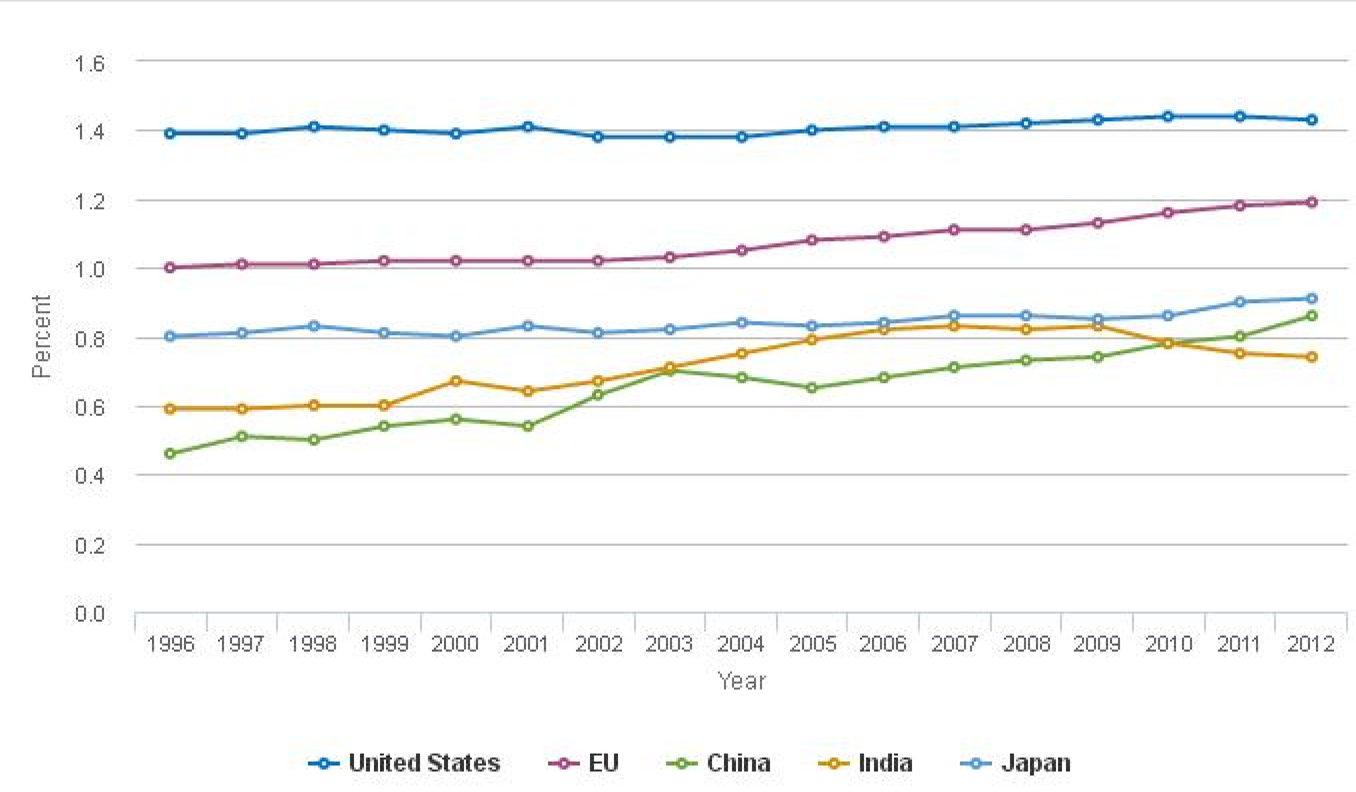
Figure 5-30

Average of relative citations, by region/country/economy: 1996–2012



EU = European Union.

NOTES: Articles are classified by the publication year and are assigned to a region/country/economy on the basis of the institutional address(es) listed in the article. The average of relative citations is presented for the year of publication showing the counts of subsequent citations from peer-reviewed literature. At least 3 years of data following publication are needed for a meaningful measure. See appendix 5-61.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com).

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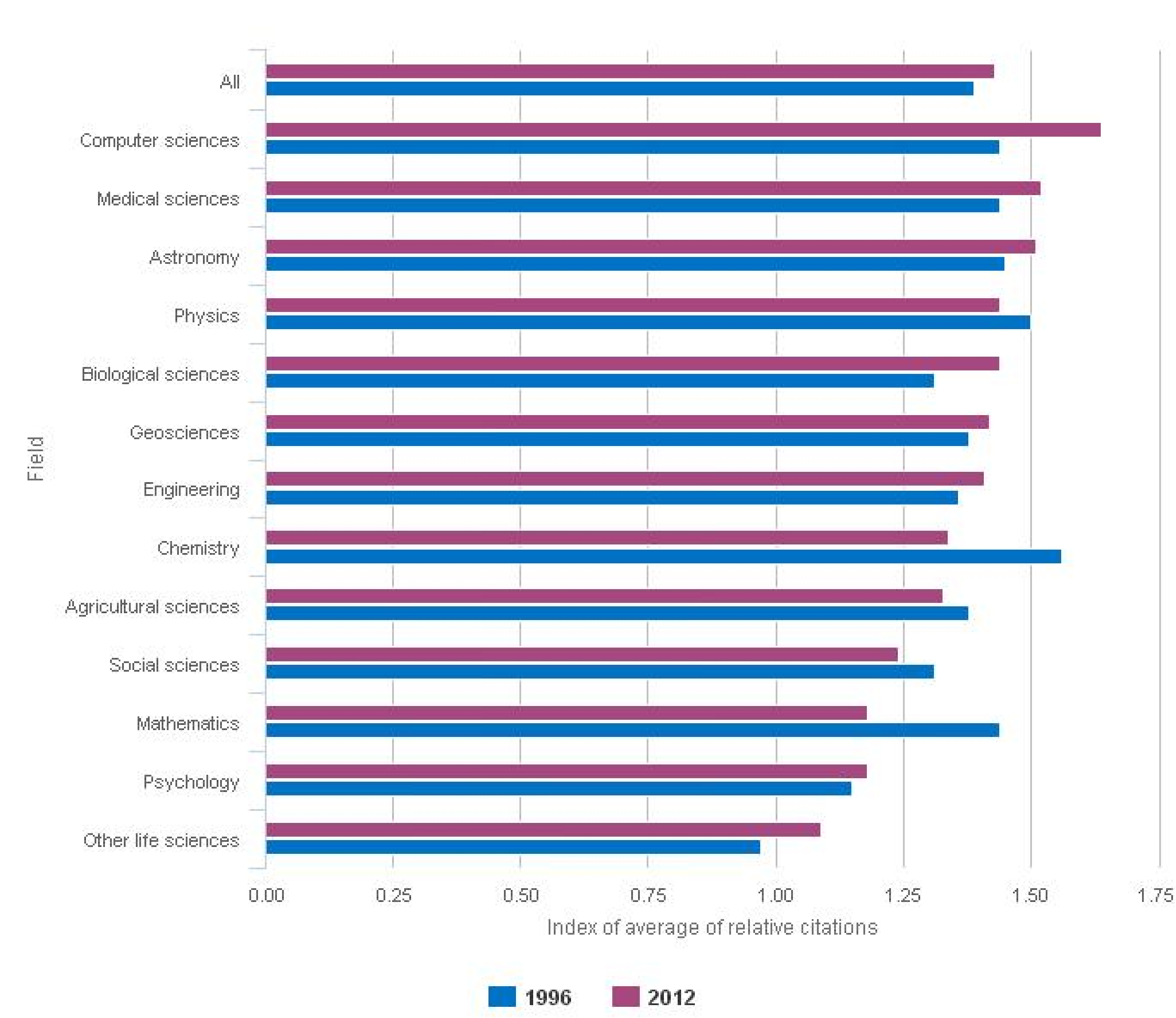
At the field level, the ARC impact of U.S publications is also higher than would be expected based on the number of U.S. peer-reviewed publications and representation by fields, and it increased between 1996 and 2012. U.S. citation impacts for computer sciences are especially high, at 60% higher than the world average value. While U.S. citation impacts remain above the world average for almost all fields, for 5 of the 13 broad fields of science, the U.S. measure has been decreasing relative to the world average between 1996 and 2012. These are physics, agricultural sciences, chemistry, social sciences, and mathematics (Figure 5-31).

Figure 5-31

Average of relative citations for the United States, by scientific field: 1996 and 2012



NOTES: Articles are classified by the publication year and are assigned to a region/country/economy on the basis of the institutional address(es) listed in the article. The average of relative citations is presented for the year of publication showing the counts of subsequent citations from peer-reviewed literature. At least 3 years of data following publication are needed for a meaningful measure. See appendix 5-60.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com).

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Trends in Highly Cited S&E Literature, by Country

Among all publications, only a small share receives more than a handful of citations. Publications that are in the top 1% of total global citations can be considered to have the highest impact, once properly adjusted for subfield and year. This top 1% of publications can be segmented by the institutional addresses of authors to show which countries and regions are producing S&E publications with the highest impact. Similar to the ARCs, country and region citation rates for highly cited publications need to be normalized for the share of total publications produced. Citations are calculated by percentile rankings, showing what share of publications are in the top 1% of the most highly cited literature. A country with a 2% share of the top 1% has twice as many highly cited articles as would otherwise be expected, based on its number of publications.

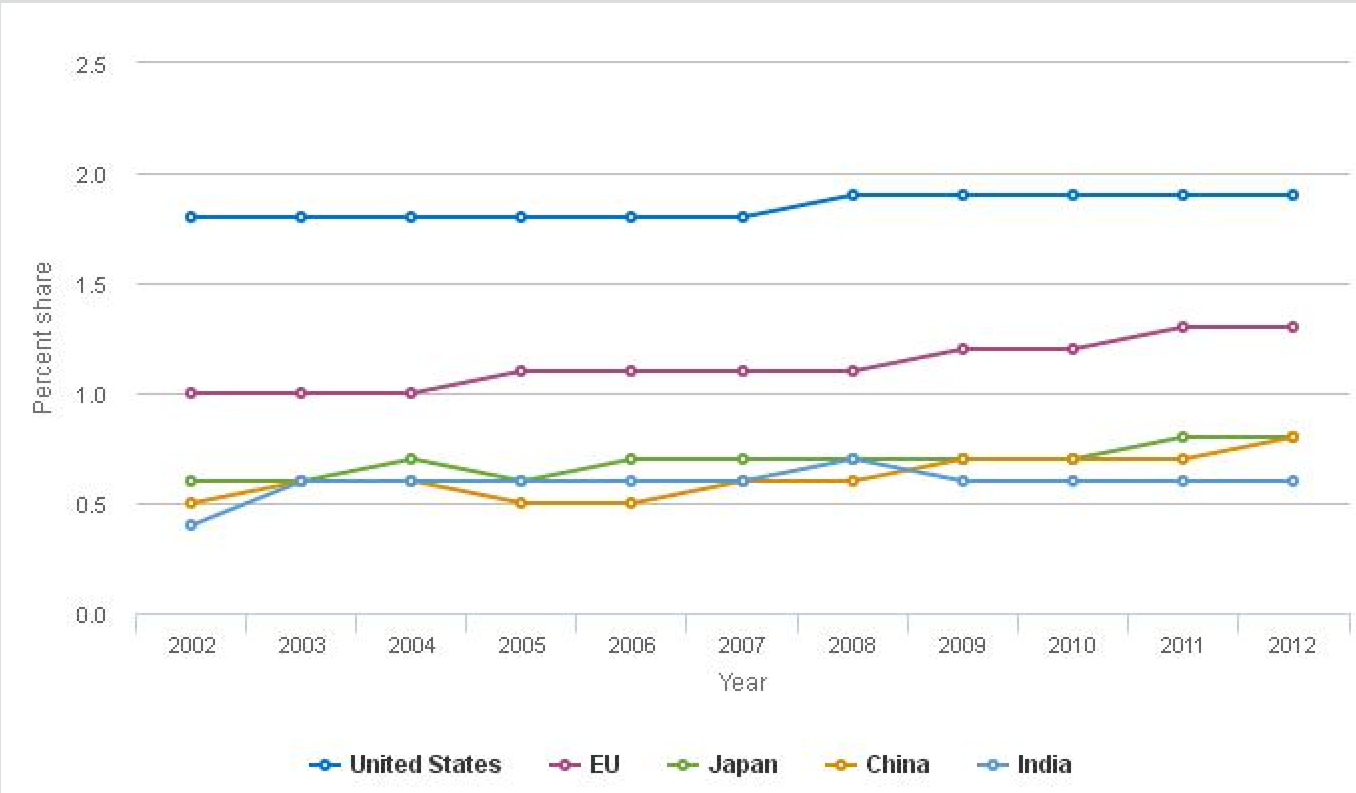
World citations to U.S. research publications show that, in all broad fields of S&E, U.S. publications continue to have citation rates that are among the highest for major S&E producers, even when normalized for overall publication share. In 2012, U.S. S&E publications have a 1.94 share of the top 1%, meaning that these publications were almost twice as likely to be among the top 1% as would be expected, based on the number of U.S. publications produced. This pattern of citations to U.S. publications being higher than expected holds throughout the top half of the percentage distribution; U.S. publications are more likely to be in the top 5%, 10%, and 20% and also are less likely to be in the bottom 50% of the distribution of cited articles (Appendix Table 5-59).

U.S. publications in the fields of medical sciences, computer sciences, physics, and engineering are a growing share of the top 1% articles, with at least twice as many citations as would be expected based on size in 2012. In five fields, the United States' relative share of the top 1% of articles declined between 2002 and 2012; these fields are astronomy, chemistry, mathematics, agricultural sciences, and social sciences (Appendix Table 5-59).

Between 2002 and 2012, China and the EU experienced more rapid growth than the United States in their share of the world's most highly cited publications (Figure 5-32). The share of China's publications in the top 1% increased from 0.5 to 0.8. S&E articles in astronomy, mathematics, chemistry, and social sciences have the highest representation in the top 1% for Chinese authors (Appendix Table 5-59).

Figure 5-32

Share of U.S., EU, Japan, China, and India S&E articles that are in the world's top 1% of cited articles: 2002–12



EU = European Union.

NOTES: This figure depicts the share of publications that are in the top 1% of the world's citations, relative to all the country's publications in that period and field. It is computed as follows: $Sx = HCPx/Px$, where *Sx* is the share of output from country *x* in the top 1% most cited articles; *HCPx* is the number of articles from country *x* that are among the top 1% most cited articles in the world; and *Px* is the total number of papers from country *x* in the database that were published in 2012 or earlier. Citations are presented for the year of publication, showing the counts of subsequent citations from peer-reviewed literature. At least 3 years of data following publication are needed for a meaningful measure. Publications that cannot be classified by country or field are excluded. Articles are classified by the publication year and assigned to country/economy on the basis of the institutional address(es) listed in the article. See appendix table 5-24 for countries included in the EU. The world average stands at 1.00% for each period and field.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com).

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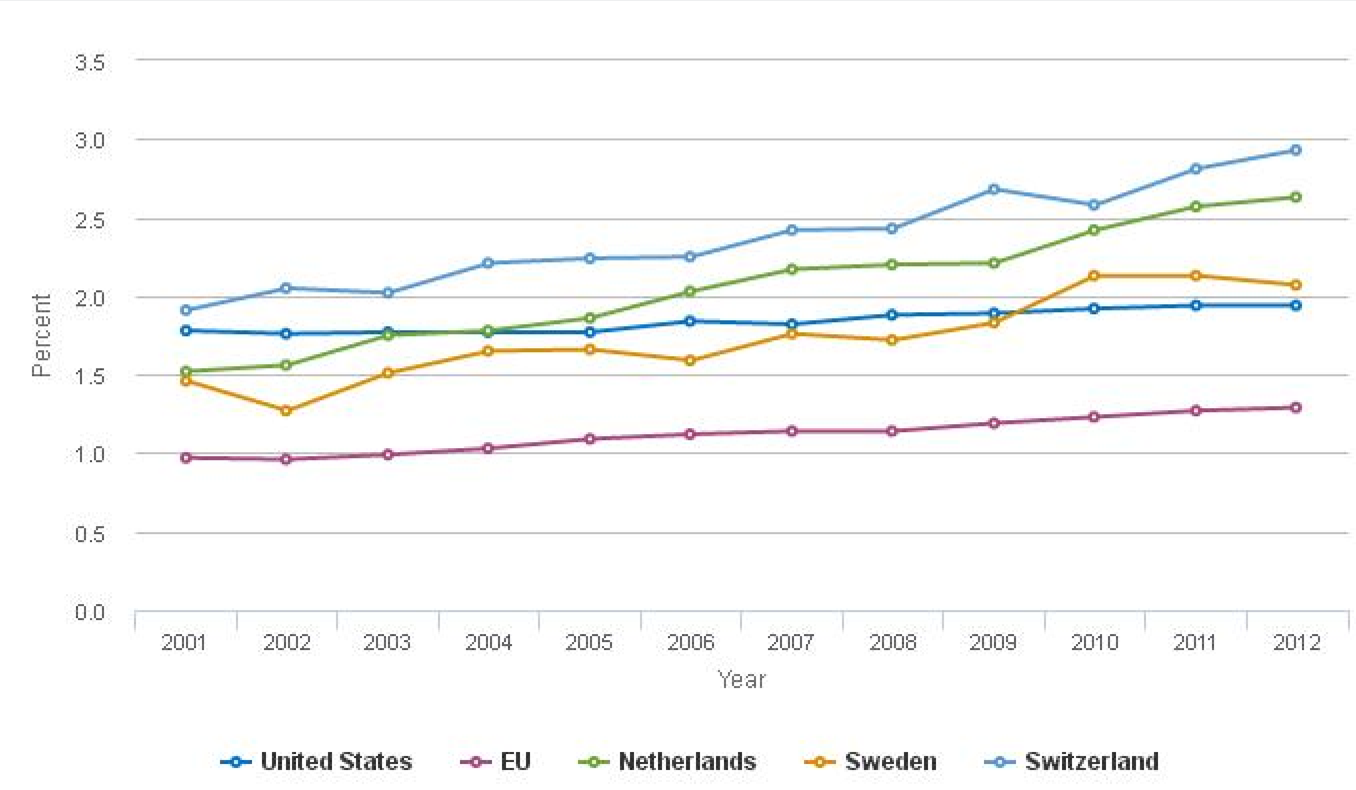
During this same period, several of the smaller research-intensive nations of the EU have made large gains in their relative share of the top 1% of highly cited publications—notably, Denmark, Finland, the Netherlands, Sweden, Iceland, and Switzerland (Appendix Table 5-62). Each of these nations had a top 1% share of world citations, relative to their share of S&E publications, which was above that of the United States in 2012 (Leydesdorff et al. 2014). Figure 5-33 shows the top 1% shares for the United States, the EU, the Netherlands, Sweden, and Switzerland. The relatively new EU nations of Estonia, Lithuania, and Slovenia also had rapidly rising 1% shares in recent years.

Figure 5-33

Share of U.S., EU, and selected European countries' S&E articles that are in the world's top 1% of cited articles: 2001–12



EU = European Union.

NOTES: This figure depicts the share of publications that are in the top 1% of the world's citations, relative to all the country's publications in that period and field. It is computed as follows: *Sx* = *HCPx*/*Px*, where *Sx* is the share of output from country *x* in the top 1% most cited articles; *HCPx* is the number of articles from country *x* that are among the top 1% most cited articles in the world; and *Px* is the total number of papers from country *x* in the database that were published in 2012 or earlier. Citations are presented for the year of publication, showing the counts of subsequent citations from peer-reviewed literature. At least 3 years of data following publication are needed for a meaningful measure. Publications that cannot be classified by country or field are excluded. Articles are classified by the publication year and assigned to country/economy on the basis of the institutional address(es) listed in the article. See appendix table 5-25 for countries included in the EU. The world average stands at 1.00% for each period and field.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com).

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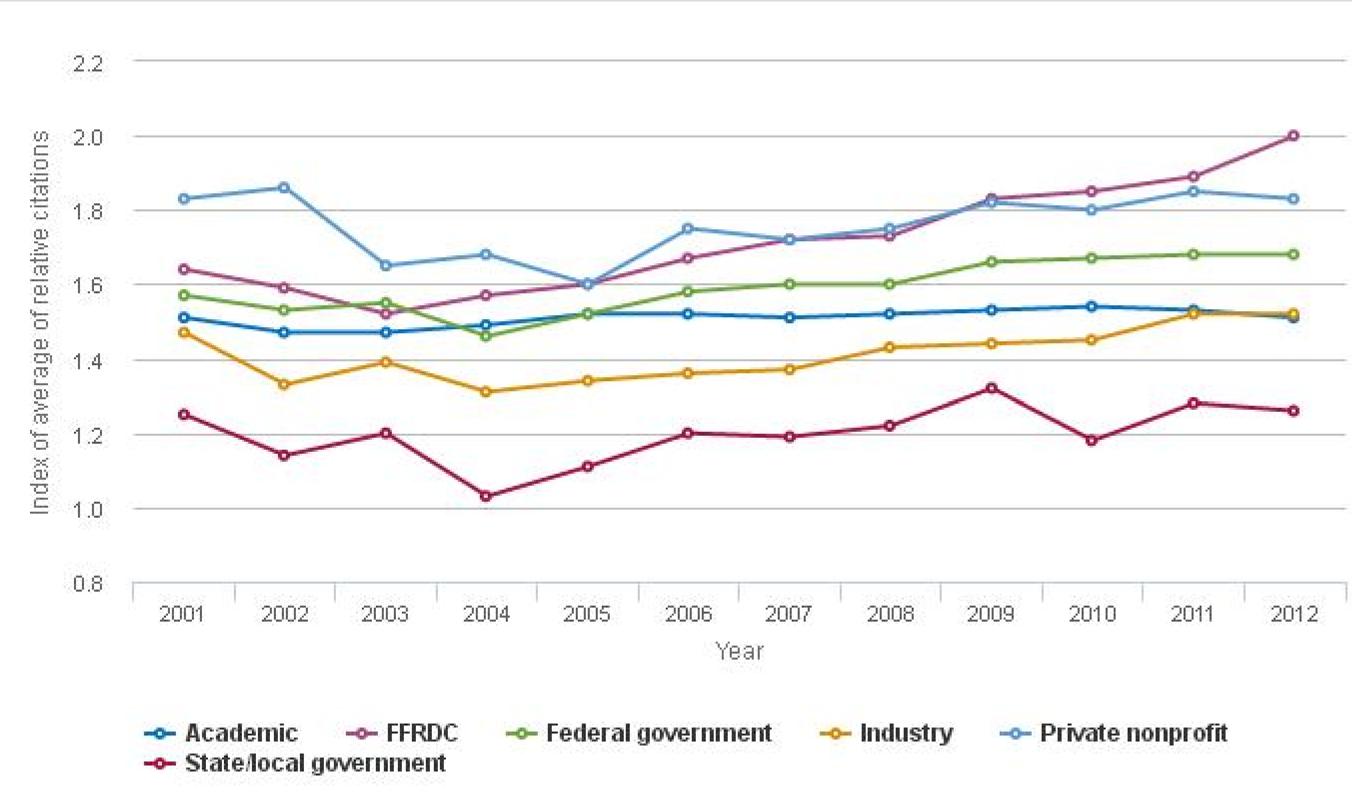
U.S. Cross-Sector Citation Trends

Relative citations can also be used to examine the citation impact of publications by each U.S. sector. Figure 5-34 shows the ARC index values for each of the six sectors of U.S. institutions relative to world output, normalized by field and document type, and how they have changed between 2001 and 2012. U.S. academic publications, which make up the vast majority of U.S. publications, held constant at about 50% higher than would be expected based on the number of publications. Publications authored at FFRDCs have shown a marked improvement since 2003 and in 2012 received the highest index value of all U.S. sectors, 100% more citations than would have been expected when based on size alone.

Figure 5-34

Average of relative citations of U.S. S&E articles, by sector: 2001–12



FFRDC = federally funded research and development center.

NOTES: Articles refer to publications from a selection of journals, books, and conference proceedings in S&E from Scopus. Articles are classified by their year of publication and are assigned to a region/country/economy on the basis of the institutional address(es) listed in the article. Citations are presented for the year when the publication is published, showing the counts of subsequent citations from peer-reviewed literature. At least 3 years of data following publication are needed for a meaningful measure.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; Elsevier, Scopus abstract and citation database (www.scopus.com).

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Citation of S&E Articles by USPTO Patents, and Energy- and Environment-Related Patent Citations

Compared with the production of S&E publications, patenting is a rarer event. In 2013, 412,542 S&E publications were produced by U.S.-affiliated authors (Appendix Table 5-26). By contrast, in the same year 138,496 USPTO utility patents were assigned to U.S. owners. USPTO patents are, like S&E publications, increasingly international. In recent years, half of all USPTO patents were awarded to foreign owners (Appendix Table 5-63). Although patenting by U.S. academic inventors is increasing, it is still relatively rare; in 2014, only 5,990 utility were assigned to U.S. academic owners (Appendix Table 5-63).

In addition to direct patenting by universities, citations to the S&E literature on the cover pages of issued patents are an indicator of the contribution of research to the development of inventions (Narin, Hamilton, and Olivastro

1997). In 2014, a total of 302,485 S&E articles are cited by 72,435 USPTO utility patents (Appendix Table 5-64). Appendix Table 5-64 presents sector characteristics of the assignees of USPTO utility patents that cite S&E literature and the sector characteristics of the publication authors cited by USPTO utility patents.

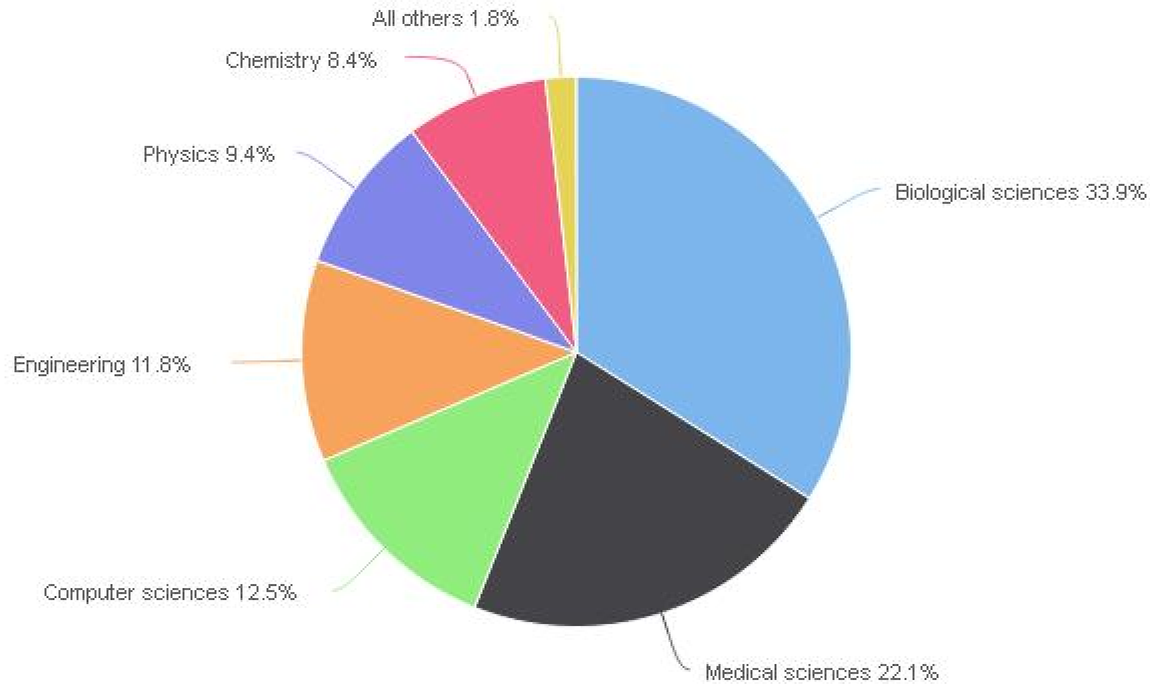
These USPTO patents cited more foreign articles (54%) than U.S. articles (44%).[iii] The share of patent citations to foreign S&E articles has increased with other measures of internationalization, coinciding with a growth in the percentage of U.S. utility patents awarded to foreign assignees and the share of world articles authored outside the United States.

S&E publications can be cited by more than one patent, so the total number of citations can exceed both the number of patents and the number of articles cited. Citations to U.S. articles in 2014 USPTO patents were dominated by articles in biological sciences (34%), medical sciences (22%), computer sciences (13%), engineering (12%), physics (9%), and chemistry (8%). These six fields account for 98% of the total (Figure 5-35; Appendix Table 5-65).

[iii] The remaining 2% of articles could not be attributed to particular country.

Figure 5-35

Citations of U.S. S&E articles in U.S. patents, by selected S&E article field: 2014



SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; LexisNexis and U.S. Patent and Trademark Office patent data; Elsevier, Scopus abstract and citation database (www.scopus.com). See appendix table 5-65.

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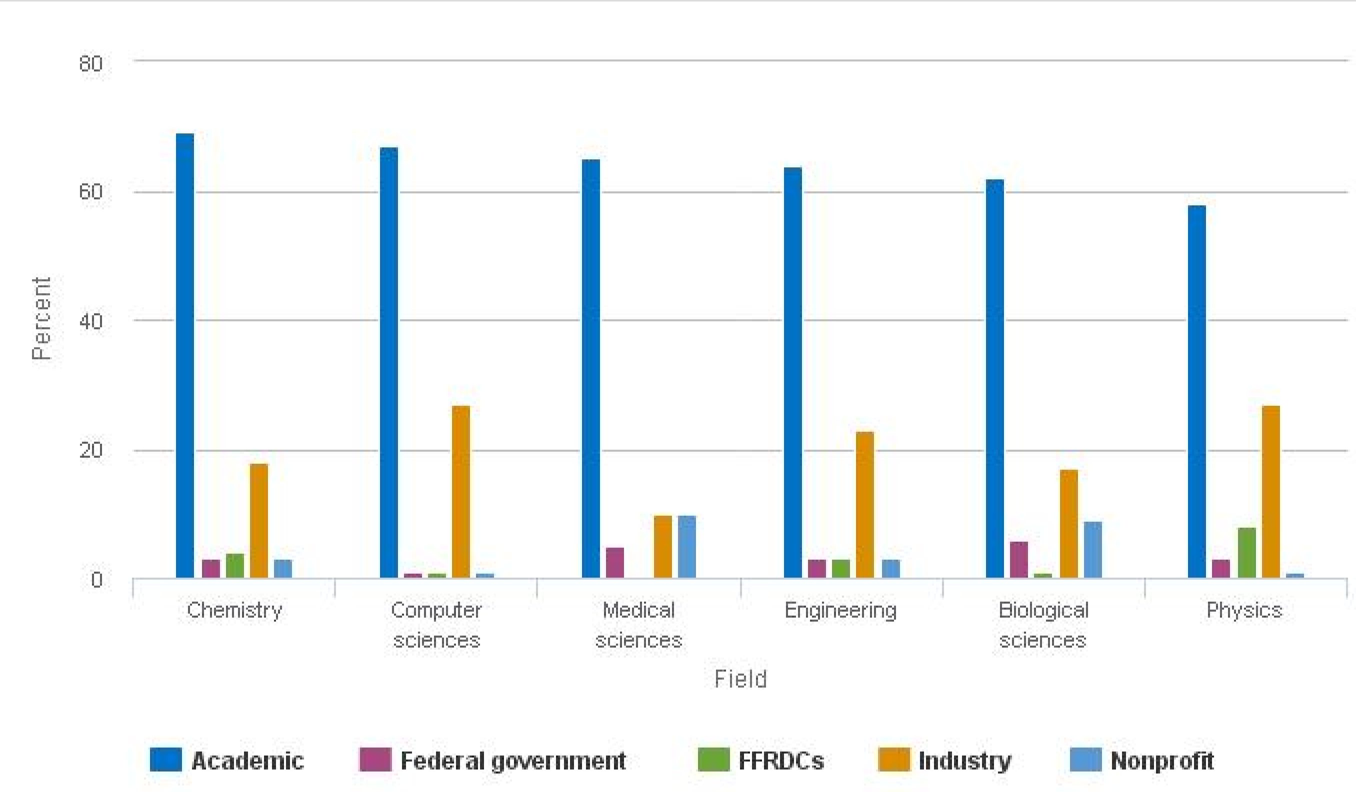
Consistent with its large share of all S&E publications and citations overall, the academic sector receives the majority of U.S. citations in patents (Appendix Table 5-65). Articles from other sectors receive far fewer citations in patents, but this varies by field (Figure 5-36). After academia, industry articles capture the next-largest share of citations overall, with particularly high citations in computer sciences (27%), physics (27%), and engineering (23%). In medical sciences, industry and nonprofit articles each account for 10% of patent citations. Compared with other fields, federal government S&E articles receive the largest number of citations in biological sciences (6%), and FFRDCs receive the largest number of citations in physics (8%).

Figure 5-36

Citation of U.S. S&E articles in U.S. patents, by selected S&E field and article author sector: 2014



FFRDC = federally funded research and development center.

NOTES: Fields with less than 5% in 2014 are omitted. Citations where the sector is unknown sectors are not shown. Citations to state and local government S&E articles are also not shown.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; LexisNexis and U.S. Patent and Trademark Office patent data; Elsevier, Scopus abstract and citation database (www.scopus.com). See appendix table 5-65.

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Clean energy and energy conservation and related technologies—including biofuels, solar, wind, nuclear, energy efficiency, pollution prevention, smart grid, and carbon sequestration—are closely linked to scientific R&D. With growing attention being given to climate change, this area has become a policy focus in the United States and other countries. These developing technology areas span four broad S&E fields—engineering, chemistry, physics, and biological sciences—indicating a wide base of S&E knowledge. Thus, performance in these technology areas is also an indicator of the capacity of the U.S. S&E enterprise to address large-scale challenges. The prior two editions of *Science and Engineering Indicators* have reported on the number of patents with potential application in these technologies.

Chapter 6 of this volume presents extensive data on the patents in four technology areas related to clean energy—alternative energy, pollution mitigation, smart grid, and energy storage—including the nationality of their inventors. (See chapter 6, "Industry, Technology, and the Global Marketplace," section Patenting of Clean Energy and Pollution Control Technologies) This section reports on the citations in those patents to the S&E literature, using those citations to indicate the linkages between S&E R&D and the potential for practical use of the results of those R&D projects in new inventions and technologies. The citation data are based on patents issued between 2011 and 2014. See sidebar Identifying Clean Energy and Pollution Control Patents.

U.S. patents in these four areas of clean energy technology account for 3.4% of all utility patents issued in 2014 (Appendix Table 5-64 and Appendix Table 5-66). As is the case with U.S. utility patents overall, patents in clean energy technology areas have consistently cited more foreign literature than U.S. literature, with 60% for foreign citations in 2014, compared to 39% for U.S. citations (Appendix Table 5-66).[iv] Within citations to U.S. literature, articles authored by the academic sector accounted for the most citations (63%) among U.S. sectors in 2014. Industry and FFRDCs were the next largest, accounting for 13% and 12% of citations, respectively.

These four categories of energy and environment–related patents show somewhat different patterns of reliance on S&E literature. For alternative energy patents, engineering makes up the largest share (31%), but chemistry and physics each make up more than one-fifth of citations. For energy storage patents, over half of all citations are to chemistry articles. Pollution mitigation citations are dominated by chemistry (33%) and engineering (30%), with geosciences and biological sciences accounting for more than 10% each. Smart grid patents draw overwhelmingly from engineering (68%), with additional shares from computer sciences (15%) and physics (12%) (Table 5-30).

Using patent citations as an indicator, the data show that engineering research contributes heavily to invention in all areas of green technology and that chemistry contributes to each area, with the exception of smart grid. Physics, biological sciences, and geoscience research (which in this taxonomy includes environmental sciences) are all prominent in each area of energy and environment–related technology.

[iv] The remaining 1% cannot be assigned to a country.

Identifying Clean Energy and Pollution Control Patents

The technology areas used for identifying clean energy and pollution control patents are the same ones used in *Science and Engineering Indicators 2012* and *Science and Engineering Indicators 2014* (see Table 5-D, below). However, the methodology used for matching the patents to technology areas has been modified for *Science and Engineering Indicators 2016* to adapt to new data sources. The S&E fields cited by these patents are shown in Table 5-30.

Table 5-D **Categories of Energy- and Environment-Related Patents**

Categories of Energy- and Environment-Related Patents

Alternative energy	Energy storage	Smart grid	Pollution mitigation
Bioenergy	Batteries	Advanced components	Recycling
Geothermal	Flywheels	Sensing and measurement	Air
Nuclear	Superconducting magnetic energy systems	Advanced control methods	Solid waste

Categories of Energy- and Environment-Related Patents

Alternative energy	Energy storage	Smart grid	Pollution mitigation
Solar	Ultracapacitors	Improved interfaces and decision support	Water
Wave/tidal /ocean	Hydrogen production and storage	Integrated communications	Environmental remediation
Wind	Thermal energy storage		Cleaner coal
Electric/hybrid vehicles	Compressed air		Carbon and greenhouse gas storage and capture
Fuel cells			

SOURCE: D'Amato T, Hamilton K, Hill D, Identifying clean energy supply and pollution control patents, Working Paper, National Science Foundation, National Center for Science and Engineering Statistics (2015), http://www.nsf.gov/statistics/2015/ncses15200/, accessed 20 October 2015.

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Table 5-30 **Patent citations to S&E articles, by selected patent technology area and article field: 2011–14**

Technology/field	Citations (*n*)	Percent
Alternative energy	27,858	100.0
Engineering	8,608	30.9
Chemistry	7,236	26.0
Physics	6,017	21.6
Biological sciences	4,423	15.9
Geosciences	722	2.6
Agricultural sciences	614	2.2
All others	238	0.9
Energy storage	9,049	100.0
Chemistry	4,776	52.8
Engineering	2,536	28.0
Physics	898	9.9
Biological sciences	528	5.8
Geosciences	152	1.7
All others	159	1.8

Technology/field	Citations (*n*)	Percent
Pollution mitigation	8,999	100.0
Chemistry	2,971	33.0
Engineering	2,730	30.3
Geosciences	1,556	17.3
Biological sciences	985	10.9
Physics	336	3.7
Medical sciences	224	2.5
Agricultural sciences	156	1.7
All others	41	0.5
Smart grid	4,918	100.0
Engineering	3,318	67.5
Computer sciences	742	15.1
Physics	586	11.9
Chemistry	72	1.5
Biological sciences	72	1.5
Medical sciences	34	0.7
Geosciences	30	0.6
Social sciences	29	0.6
All others	35	0.7

NOTES: Article/citation counts are from the set of journals covered by Scopus. Articles are assigned to a sector on the basis of the institutional address(es) listed in the article. Articles/citations are credited on a fractional-count basis (i.e., for articles with collaborating institutions from multiple sectors, each sector receives fractional credit on the basis of the proportion of its participating institutions). Citation counts are based on an 11-year window with a 5-year lag (e.g., citations for 2012 are references in U.S. patents issued in 2012 to articles published in 1997–2007). Detail may not add to total because of rounding.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; LexisNexis and U.S. Patent and Trademark Office patent data; Elsevier, Scopus abstract and citation database (www.scopus.com).

Science and Engineering Indicators 2016

Academic Patenting

The Bayh-Dole Act (Patent and Trademark Act Amendments of 1980) gave colleges and universities a common legal framework for claiming ownership of income streams from patented discoveries that resulted from their federally funded research. Other countries implemented policies similar to the Bayh-Dole Act by the early 2000s, giving their academic institutions (rather than inventors or the government) ownership of patents resulting from government-funded research (Geuna and Rossi 2011). To facilitate the conversion of new knowledge produced in their laboratories to patent-protected public knowledge that potentially can be licensed by others or form the basis for a startup firm, many U.S. research institutions established technology management/transfer offices (AUTM 2009).

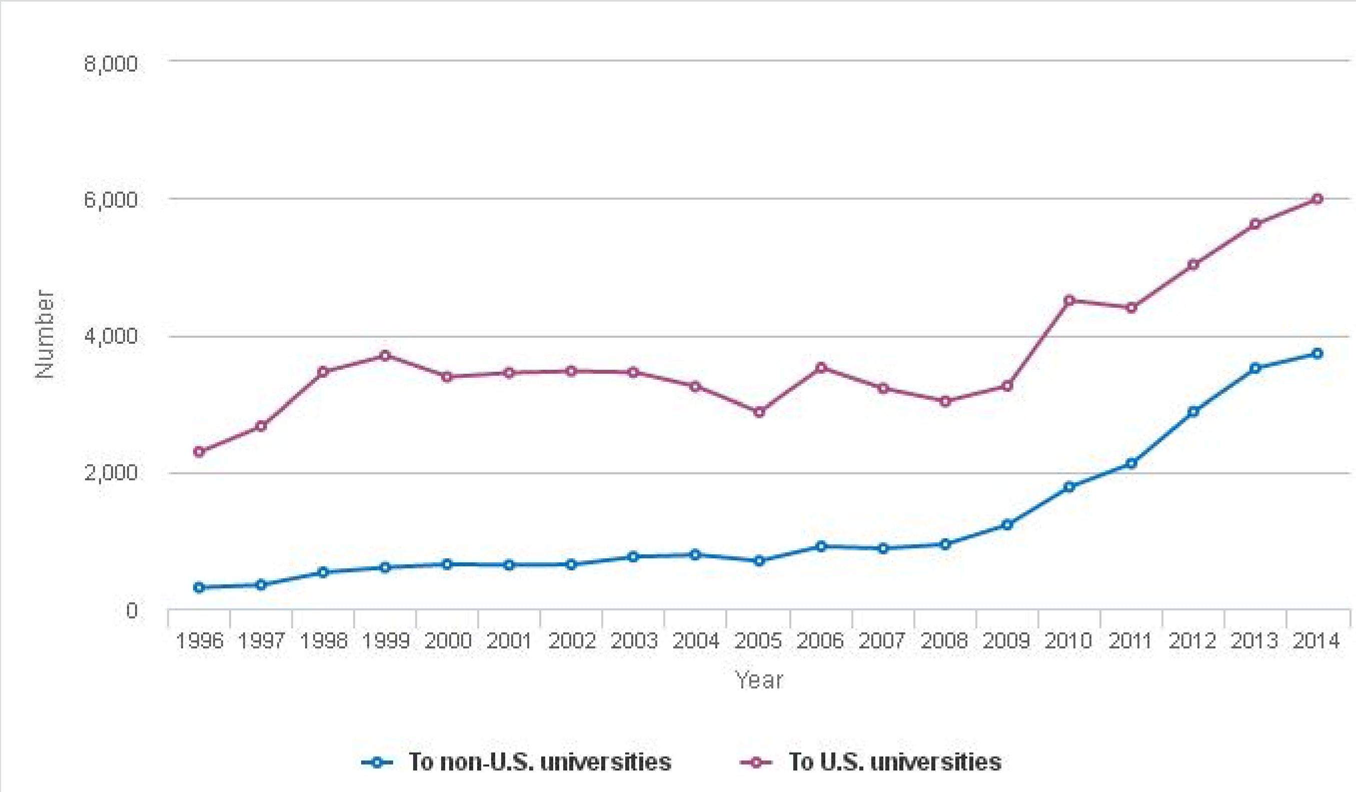
The following sections discuss overall trends in university patenting and related indicators through 2013 and 2014.

Trends and Patterns in Academic Patenting

The USPTO granted 9,716 patents to U.S. and foreign universities and colleges in 2014, 3.3% of USPTO patents granted to all U.S. and foreign inventors (Figure 5-37, Appendix Table 5-63). U.S. universities and colleges were granted 5,990 USPTO patents, with foreign universities receiving 3,726 patents. Patenting by both U.S. and foreign academic institutions has increased markedly since 2007. Although the number of U.S. academic patents continued to grow through 2014, the U.S. university and college share of all USPTO patents held constant around 2.0%. The share of U.S. patents from non-U.S universities increased from 0.3% in 1996 to 1.3% in 2014 (Figure 5-37, Appendix Table 5-63).

Figure 5-37

USPTO patents granted to U.S. and non-U.S. academic institutions: 1996–2014



USPTO = U.S. Patent and Trademark Office.

NOTE: Patents are credited on a fractional-count basis (i.e., for articles with collaborating institutions, each institutions receives fractional credit on the basis of the proportion of its participating institutions).

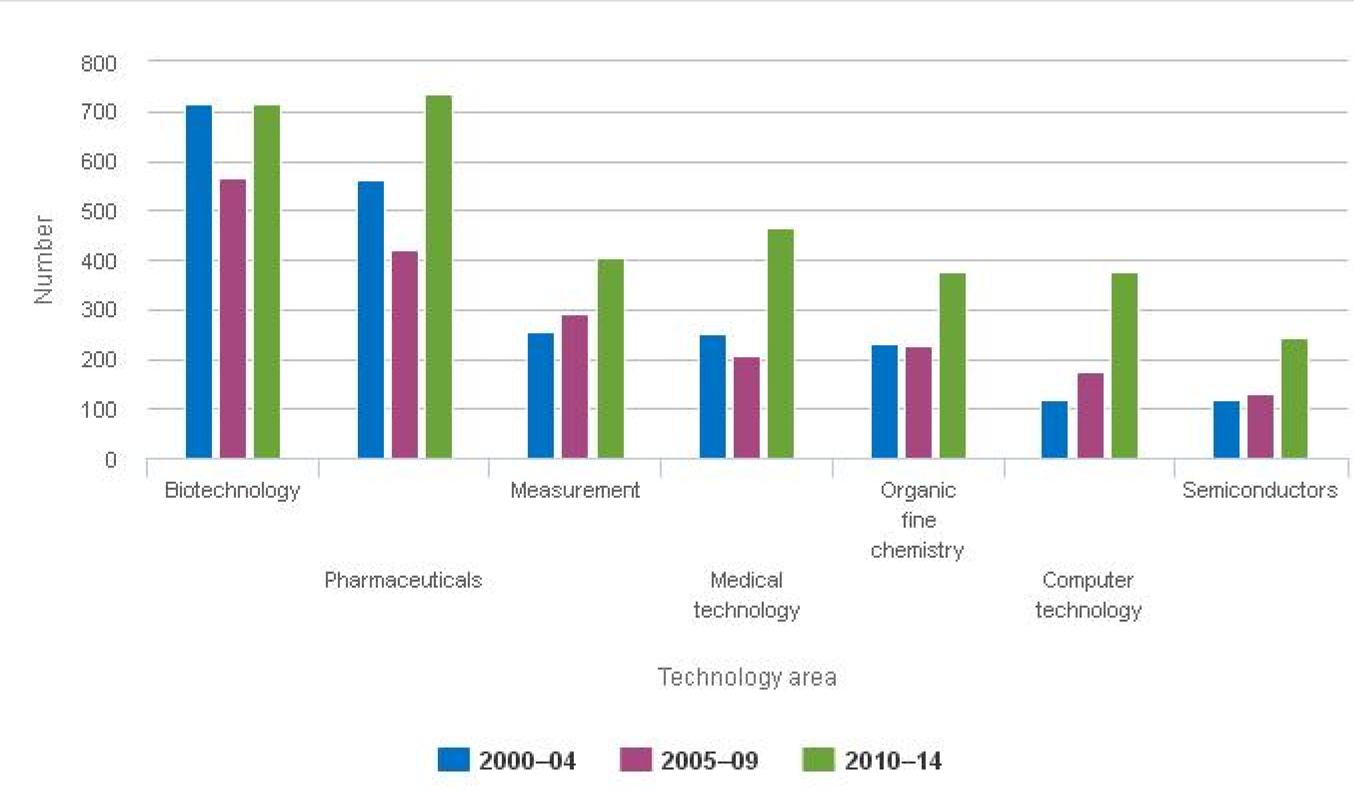
SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; U.S. Patent and Trademark data.

Science and Engineering Indicators 2016

Patenting data in *Science and Engineering Indicators 2016* are presented in 35 technical fields classified by the international patent classification used by the World Intellectual Property Organization (Appendix Table 5-67). Biotechnology patents accounted for the largest share (18.2%) of U.S. university patents between 1996 and 2014, followed by pharmaceuticals (15.1%) and measurement (7.8%) (Appendix Table 5-67). Biotechnology has been the largest technology area for U.S. academic patenting across the entire time period. Both biotechnology and pharmaceuticals, the next-largest technology area, had a declining number of patents between 2005 and 2009, but both have grown since 2010 (Figure 5-38). Biotechnology, medical technology, and organic fine chemistry share the rebounding pattern of pharmaceuticals since 2009. Computer technology and semiconductor patents rose across all three 5-year periods.

Figure 5-38

U.S. academic patents, by technology area: Selected 5-year averages, 2000–14



SOURCES: National Science Foundation, National Center for Science and Engineering Statistics; SRI International; Science-Metrix; LexisNexis and U.S. Patent and Trademark Office patent data; Elsevier, Scopus abstract and citation database (www.scopus.com). See appendix table 5-67.

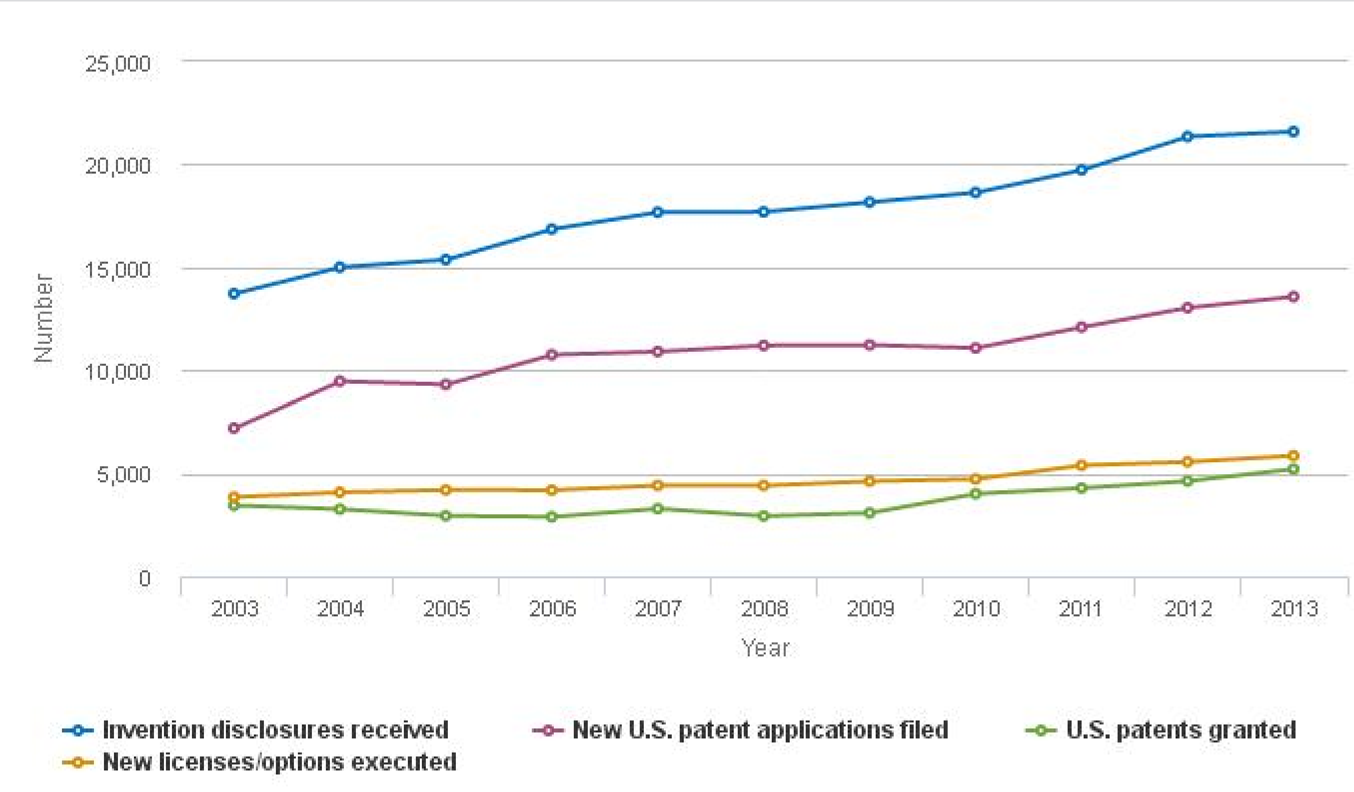
Science and Engineering Indicators 2016

Commercialization of U.S. Academic Patents

Universities commercialize their intellectual property by granting licenses to commercial firms and supporting startup firms formed by their faculty. Data from the Association of University Technology Managers (AUTM) indicate continuing growth in a number of such patent-related activities. Invention disclosures filed with university technology management/transfer offices describe prospective inventions and are submitted before a patent application is filed. These grew from 13,718 in 2003 to 21,596 in 2013 (notwithstanding small shifts in the number of institutions responding to the AUTM survey over the same period) (Figure 5-39). Likewise, new U.S. patent applications filed by AUTM university respondents also increased, nearly doubling from 7,203 in 2003 to 13,573 in 2013. U.S. patents awarded to AUTM respondents stayed flat between 2003 and 2009, rising to reach 5,220 in 2013 (see Appendix Table 5-68).

Figure 5-39

U.S. university patenting activities: 2003–13



SOURCE: Association of University Technology Managers (AUTM), AUTM Licensing Surveys: 2003–13. See appendix table 5-68.

Science and Engineering Indicators 2016

The top 201 patenting universities received 99% of the total patents granted to U.S. universities between 1996 and 2014 (Appendix Table 5-63). Among these institutions, 20 accounted for more than 50% of all patents granted to U.S. universities. (Some of these were multicampus systems, like the University of California and the University of Texas.) The University of California system received 10.2% of all U.S. patents granted to U.S. universities over the period, followed by Harvard, with 4.6%, and the Massachusetts Institute of Technology, with 4.2%.

AUTM data also provide counts of new startups formed and of operational startups still operating. The number of new startup companies formed continued to rise through the period from 2001 to 2013, reaching 759 in 2013. The number of past startups still operating was 3,948 in 2013 (Appendix Table 5-68). Licenses and options that generated revenues also increased over the period. Active licenses increased steadily from 18,845 in 2001 to 37,445 in 2013.

Although the maximization of royalty income is not the dominant objective of university technology management offices (Thursby, Jensen, and Thursby 2001), the 162 institutions that responded to the AUTM survey reported a total of $1.8 billion in net royalties from their patent holdings in 2013. This amount has grown from $754 million dollars in 2001 (Appendix Table 5-68).

Conclusion

The nation's universities and colleges play a key role in U.S. R&D by providing the following services:

- Educating and training S&E students in research practices and other advanced skills
- Performing a large share of the nation's basic research
- Building and operating world-class research facilities and supporting the national research cyberinfrastructure
- Producing intellectual output through published research articles and patents

Over the past several decades, academic expenditures on R&D have continued to increase, with slowing growth trends in recent years and no growth from 2013 to 2014. Although the federal government has long provided the majority of funding for academic S&E R&D, its share of total academic R&D funding has declined in recent years while the share paid for universities and colleges has increased. Other important sources of academic R&D funding are state and local governments, businesses, and nonprofit organizations.

Academic R&D expenditures have long been concentrated in a relatively small number of universities. For over 20 years, fewer than 12 schools each year have received about one-fifth of total academic R&D funding, about 20 schools have received close to one-third of this funding, and about 100 have received four-fifths of the total. (The identities of the universities in each group have varied over time.)

For decades, more than half of all academic R&D spending has been in the broad field of life sciences. Since the mid-1990s, about one-third of all U.S.-trained, academically employed S&E doctorate holders received their degree in life sciences. (In 2013, about 60% of their foreign-trained counterparts had doctorates in life sciences.) The dominance of life sciences is also seen in physical infrastructure, where two subfields of life sciences—biological sciences and biomedical sciences—account for the bulk of growth in research space and where the largest share of new university research construction has been undertaken to advance health and clinical sciences.

Academic R&D is increasingly collaborative and less field specific. R&D funds passed through universities to other universities or to nonacademic institutions have grown substantially over the past 15 years. There has also been growth in recent years in spending that cannot be classified within a single field. Spending on engineering R&D has outpaced growth in spending in the sciences in the aggregate.

The structure of academic employment of S&E doctorate holders within the nation's universities and colleges has undergone substantial changes over the past 20–30 years. Although full-time faculty positions in the professoriate continue to be the norm in academic employment, S&E doctorate holders are increasingly employed in part-time and nontenured positions. Since 1995, there has been a decrease in the percentage of doctorate holders with tenured positions even as the academic doctoral workforce has aged. The share of academic researchers receiving federal support, including early career S&E faculty, has declined since 1991. Funding success rates have declined at both NIH and NSF over the past decade. Shoring up support for early career academic faculty has received increasing policy attention in recent years.

Higher education has also experienced notable changes in demographic diversity. In particular, the share of academic doctoral positions held by white, male, native-born citizens has declined. Women represent a growing share of academic doctoral employment in S&E, as do the foreign born and foreign trained. The share of Asians or Pacific Islanders employed in the S&E academic doctoral workforce has grown dramatically over the past three decades, while the shares held by blacks, Hispanics, and American Indians or Alaska Natives have grown much more slowly; these latter groups remain underrepresented in the academic doctoral workforce.

There have been further shifts in the degree to which the academic doctoral workforce is focused on research activities versus teaching. Among full-time doctoral S&E faculty, there was a shift in priority from teaching to research from 1973 to 2003; since 2003, however, the shares of faculty who primarily teach and those who primarily conduct research have remained relatively stable. Of those in the academic doctoral workforce reporting research as their primary activity, two-thirds are employed at the nation’s most research-intensive academic institutions. Those who primarily teach are more evenly distributed across academia.

The bibliometric data described in this chapter show U.S. research maintaining global strength in the life sciences, as demonstrated by publication output and citations. This focus is accompanied by academic patenting in biotechnology and pharmaceuticals. Overall, the United States remains the most influential individual nation in its contribution to S&E publications. This influence is based both on the overall size of its contribution and the relative impact, as measured by citations by S&E publications. In terms of S&E research quantity, but not impact, China is now on a par with the United States. Taking measures of quantity and impact into account, the United States maintains overall preeminence in S&E research output. However, growth trends in S&E publications reflect the spread of overall economic and social development across the world. Building from a higher base, the developed world, including the United States, the EU, and Japan, is growing more slowly in S&E publications.

In addition to the increased performance in the developing world, individual nations within the EU and the developed world have emerged as centers of research excellence, as demonstrated by their citations. Unlike the competition for finite resources, the creation of S&E publications adds to the knowledge base available for use worldwide, as international collaboration and citations attest. International research collaboration is increasing, reflecting traditional cross-country ties as well as new ones that stem from growing capabilities in the developing world. This international collaboration and the accompanying rise in international citations indicate that S&E knowledge is flowing with increasing ease across the world.

Glossary

Average of relative citations (ARC): The ARC is a citation measure normalized across fields of science and document types to correct for differences in the frequency and timing of citations. It is constructed from a relative citation that divides each publication's citation count by the average citation count of all publications in that subfield and document type in that same year. Then, for a given area of geography or sector, these relative citations for each publication are then averaged to create an ARC. An ARC value greater than 1.00 has more citations than average for subfield and year; an ARC value less than 1.00 has fewer citations.

Doctoral academic S&E workforce: Includes those with a research doctorate in science, engineering, or health who are employed in 2- or 4-year colleges or universities, including medical schools and university research institutes, in the following positions: full and associate professors (referred to as *senior faculty*); assistant professors (referred to as *junior faculty*); postdoctorates (postdocs); other full-time positions, such as instructors, lecturers, adjunct faculty, research associates, and administrators; and part-time positions of all kinds. Unless otherwise specified, these individuals earned their doctorate at a U.S. university or college.

European Union (EU): As of September 2015, the EU comprised 28 member nations: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom. Unless otherwise noted, Organisation for Economic Co-operation and Development data on the EU include all of these 28 members.

Federally funded research and development center (FFRDC): R&D organization exclusively or substantially financed by the federal government, either to meet particular R&D objectives or, in some instances, to provide major facilities at universities for research and associated training purposes. Each FFRDC is administered by an industrial firm, a university, or a nonprofit institution.

Fractional counting: Method of counting S&E publications in which credit for coauthored publications is divided among the collaborating institutions or countries based on the proportion of their participating authors.

Index of highly cited articles: A country's share of the top 1% most-cited S&E publications divided by the country's share of all relevant S&E publications. An index greater than 1.00 means that a country has a disproportionately higher share in highly cited publications; an index less than 1.00 means a lower share.

Index of international collaboration: A country's share of another country's internationally coauthored publications divided by the other country's share of all internationally coauthored publications. An index greater than 1.00 means that a country pair has a stronger-than-expected tendency to collaborate; an index less than 1.00 means a weaker-than-expected tendency to collaborate.

Net assignable square feet (NASF): Unit for measuring research space. NASF is the sum of all areas on all floors of a building assigned to, or available to be assigned to, an occupant for a specific use, such as research or instruction. NASF is measured from the inside face of walls.

Relative citation index: A country's share of another country's cited S&E publications divided by the other country's share of all cited S&E publications. An index of greater than 1.00 means that the country has a higher-than-expected tendency to cite the other country's S&E literature; an index less than 1.00 means a lower-than-expected tendency to cite the other country.

Research space: The budgeted and accounted for space used for sponsored R&D activities at academic institutions. Research space is the net assignable square feet of space in buildings within which research activities take place. Research facilities are located within buildings. A building is a roofed structure for permanent or temporary shelter of persons, animals, plants, materials, or equipment. Structures are included as research space if they are (1) attached to a foundation; (2) roofed; (3) serviced by a utility, exclusive of lighting; and (4) a source of significant maintenance and repair activities.

Underrepresented minority: Race and ethnic groups, including blacks, Hispanics, and American Indians or Alaska Natives, that are considered to be underrepresented in academic institutions.

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Chapter 6.

Industry, Technology, and the Global Marketplace

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Highlights

Knowledge and Technology Infrastructure in the World Economy

Knowledge- and technology-intensive (KTI) industries have been a major and growing part of the global economy.

- Ten KTI industries, consisting of five knowledge-intensive (KI) services industries and five high-technology (HT) manufacturing industries, represented 29% of world gross domestic product (GDP) in 2014.
- The commercial KI services—business, financial, and information—have the highest share of GDP (17%). The public KI services—education and health—have a 9% share.
- The HT manufacturing industries—aircraft and spacecraft; communications and semiconductors; computers; pharmaceuticals; and testing, measuring, and control instruments—have a combined 2% share of world GDP.

The United States has the highest KTI share of GDP of any large economy.

- KTI industries accounted for 39% of the U.S. economy in 2014. The KTI concentrations for the European Union (EU) and Japan were considerably lower at 30% each.
- Major developing countries have lower KTI shares than developed countries. The KTI shares in Brazil, China, and India were 19%–21%.

Worldwide Distribution of Knowledge- and Technology-Intensive Industries

The United States had the largest global shares of commercial KI services in 2014.

- The United States accounted for 33% of global commercial KI services (business, financial, and information), followed by the EU (25%).
- China's commercial KI services industries continued to grow rapidly, and China surpassed Japan to become the world's third-largest provider with a global share of 10%.
- In HT manufacturing, the United States and China are the largest global producers (29% and 27% global share, respectively). China surpassed both Japan and the EU in the late 2000s.

U.S. KTI industries have had a stronger recovery from the global recession than those in the EU and Japan.

- Value-added output of U.S. commercial KI services in 2014 was 23% higher than in 2008. Output in the EU and Japan was stagnant.
- Output of U.S. HT manufacturing industries was 18% higher in 2014 than in 2008. The EU's and Japan's output contracted.

KTI industries play a special role in the U.S. economy and in U.S. business R&D.

- U.S. commercial KI services industries employ one in seven U.S. workers (20 million), pay higher-than-average wages, have an above-average share of skilled workers, and fund 29% of U.S. business R&D.

- U.S. HT manufacturing industries, although much smaller than commercial KI services industries, employ 1.8 million workers, have a higher share of highly skilled workers, and fund nearly half of U.S. business R&D.
- Value-added output had a strong recovery, but not employment. The number of jobs in commercial KI services in 2014 was slightly above the pre-recession levels but remains lower than pre-recession levels in HT manufacturing.

Trade and Other Globalization Indicators

The EU is the world's leading exporter of commercial KI services, followed by the United States; both have substantial surpluses in this trade.

- The EU's commercial KI services exports more than doubled to reach nearly $500 billion between 2004 and 2013.
- U.S. exports of commercial KI services grew as fast as the EU's over this period, reaching $271 billion.
- China and India's KTI exports grew rapidly, resulting in their global export shares each reaching 7% in 2013.

Global trade in HT manufactured goods: lesser role for developed countries.

- China is the world's largest exporter of HT products, with a 24% global share and a surplus of $130 billion. But China's value-added exports and trade surplus are likely lower because China imports components and inputs from the United States, the EU, and Asia for final assembly in China.
- U.S. HT exports grew from $157 billion in 2003 to $302 billion in 2014. The U.S. global share of HT exports declined slightly to 12% in 2014; the U.S. HT trade deficit narrowed to $41 billion.
- The U.S. trade deficit in HT goods is largely anchored in products in information and communications technologies—communications, computers, and semiconductors. In other HT manufactured goods, notably aircraft and spacecraft, the United States has a substantial trade surplus.

Innovation-Related Indicators of the United States and Other Major Economies

U.S. firms in commercial KTI industries reported much higher incidences of innovation—the introduction into the marketplace of a new product or service—than firms in other industries.

- Five HT manufacturing industries—aircraft; computers; communications and semiconductors; testing, measuring, and control instruments; and pharmaceuticals—reported rates of product innovation that were at least double the U.S. manufacturing sector average.
- In the U.S. nonmanufacturing sector, software firms had the highest rate of innovation, with 69% of companies reporting the introduction of a new product or service compared with the 9% average for all nonmanufacturing companies.
- The rate of innovation in computer systems design; data processing, hosting, and related services; and scientific R&D services is two to three times higher than the nonmanufacturing average.

Inventors in the United States received nearly half of U.S. Patent and Trademark Office (USPTO) patents granted in 2013. Japan and the EU were the second- and third-largest recipients.

- The share of patents granted by USPTO to U.S. inventors declined from 52% in 2003 to 48% in 2014. Strong growth in China, India, South Korea, and Taiwan pushed up their global shares during this period.
- U.S. inventors are relatively more active in patenting several advanced and science-based technologies, including information technology management, digital communications, medical technology, pharmaceuticals, and biotechnology.

Japan is the leading recipient of triadic patents, closely followed by the EU and the United States. Triadic patents are considered an indicator of higher-value inventions.

- Triadic patents are patents sought for protection in the world's largest markets—the United States, Europe, and Japan.
- The share of triadic patents granted to the United States and Japan each fell slightly over the last decade. China's share quadrupled to reach 4%, consistent with its rapid growth in USPTO patents.

Investment and Innovation in Clean Energy Technologies

Global commercial energy investment in 2014 was $281 billion, largely concentrated in solar and wind technologies. China leads the United States and the EU in attracting clean energy investment.

- Clean energy investment in China, largely in solar and wind technologies, rose steeply over the last decade to reach $86 billion in 2014. China led the world in attracting commercial clean energy investment (31% global share).
- The United States was the third largest (behind the EU) in attracting clean energy investment. U.S. investment has been about $40 billion in 2012–14, down from its peak of $57 billion in 2011 because of policy uncertainty and the falling per-unit cost of investment in solar and wind technology.
- Commercial investment in the EU fell sharply because of cutbacks in clean energy incentives in many countries in response to the EU's recession, scheduled tapering of temporary support, and falling per-unit cost of investing in solar and wind technologies. The EU's global share fell from 40% in 2011 to 18% in 2014.

The EU, the United States, and Japan were the largest investors in 2013 in public research, development, and demonstration (RD&D) of clean energy and other non-fossil fuel technologies.

- Global expenditures on public RD&D of clean energy and other non-fossil fuel technologies was an estimated $12.7 billion in 2013. Renewables was the largest area, receiving $3.7 billion. The next two largest areas were nuclear ($3.4 billion) and energy efficiency ($3.2 billion).
- The EU was the largest investor in public RD&D of these technologies ($4.4 billion), followed by the United States ($3.5 billion) and Japan ($2.6 billion).
- U.S. public RD&D investment increased from $2.2 billion to $3.5 billion (2006 to 2013), driven by increases in solar, biofuels, and energy efficiency.

Introduction

Chapter Overview

Policymakers in many countries increasingly emphasize the central role of knowledge, particularly R&D and other activities that advance science and technology (S&T), in a country's economic growth and competitiveness. This chapter examines the downstream effects of these activities—their embodiment in goods and services—on the performance of the United States and other major economies in the global marketplace.

This chapter covers two main areas. The first is knowledge- and technology-intensive (KTI) industries; the second focuses on innovation.

KTI industries encompass both service and manufacturing sectors, based on 10 categories of industries classified by the Organisation for Economic Co-operation and Development (OECD 2001, 2007) that have a particularly strong link to S&T:[i]

- Five knowledge-intensive (KI) services industries incorporate high technology (HT) either in their services or in the delivery of their services. Three of these—financial, business, and information services (including computer software and R&D)—are generally commercially traded. The others—education and health services—are publicly regulated or provided and remain relatively more location bound.
- Five HT manufacturing industries spend a large proportion of their revenues on R&D and make products that contain or embody technologies developed from R&D. These are aircraft and spacecraft, pharmaceuticals, computers and office machinery, semiconductors and communications equipment (treated separately in the text), and scientific (medical, precision, and optical) instruments.[ii] Aircraft and spacecraft and pharmaceuticals are less market driven than the other three industries because of public funding, procurement, and regulation.[iii]

This chapter gives special attention to KTI industries in information and communications technology (ICT). ICT combines the HT manufacturing industries of computers and office machinery, communications equipment, and semiconductors with the KI services of information and computer programming (a subset of business services). ICT industries are important because they provide the infrastructure for many social and economic activities, and they facilitate innovation and economic growth.[iv] Non-KTI industries are also very important in the world economy and therefore receive some attention in this chapter (see sidebar, Industries That Are Not Knowledge or Technology Intensive).

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[i] See OECD (2001) for a discussion of classifying economic activities according to their degree of "knowledge intensity." Like all classification schemes, the OECD classification has shortcomings. For example, KTI industries produce some goods or services that are neither knowledge intensive nor technologically advanced. In addition, multiproduct companies that produce a mix of goods and services, only some of which are KTI, are assigned to their largest business segment. Nevertheless, data based on the OECD classification allows researchers and analysts to trace, in broad outline, worldwide trends toward greater interdependence in science and technology and the development of KTI sectors in many of the world's economies.

[ii] In designating these HT manufacturing industries, the OECD estimated the degree to which different industries used R&D expenditures made directly by firms in these industries and R&D embedded in purchased inputs (indirect

R&D) for 13 countries: the United States, Japan, Germany, France, the United Kingdom, Canada, Italy, Spain, Sweden, Denmark, Finland, Norway, and Ireland. Direct R&D intensities were calculated as the ratio of total R&D expenditure to output (production) in 22 industrial sectors. Each sector was weighted according to its share of the total output among the 13 countries, using purchasing power parities as exchange rates. Indirect intensities were calculated using the technical coefficients of industries on the basis of input-output matrices. The OECD then assumed that, for a given type of input and for all groups of products, the proportions of R&D expenditure embodied in value added remained constant. The input-output coefficients were then multiplied by the direct R&D intensities. For further details concerning the methodology used, see OECD (2001). It should be noted that several nonmanufacturing industries have R&D intensities equal to or greater than those of industries designated by the OECD as HT manufacturing. For additional perspectives on the OECD's methodology, see Godin (2004).

[iii] Aircraft and spacecraft trends are affected by public funding for military aircraft, missiles, and spacecraft, and by different national flight regulations. Public funding and regulation of drug approval, prices, patent protection, and importation of foreign pharmaceuticals can affect pharmaceuticals.

[iv] See Atkinson and McKay (2007:16–17) for a discussion of and references to the impact of IT on economic growth and productivity.

Industries That Are Not Knowledge or Technology Intensive

Science and technology (S&T) are used in many industries besides HT manufacturing and KI services. Service industries not classified as KI services—which include wholesale and retail trade, restaurant and hotel, transportation and storage, and real estate—may incorporate advanced technology in their services or in the delivery of their services. Manufacturing industries not classified as HT by the Organisation for Economic Co-operation and Development (OECD) may use advanced manufacturing techniques, incorporate technologically advanced inputs in manufacturing or perform or rely on R&D. Industries not classified as either manufacturing or services—agriculture, construction, mining, and utility—also may incorporate recent S&T in their products and processes. For example, agriculture relies on breakthroughs in biotechnology, construction uses knowledge from materials science, mining depends on earth sciences, and utilities rely on advances in energy science.

In the non-KI services industries—wholesale and retail trade, restaurant and hotel, transportation and storage, and real estate—patterns and trends of the four largest producers, the United States, the EU, Japan, and China, were similar to those in HT manufacturing and commercial KI services (Table 6-A). The United States and the EU, the two largest providers, had modest declines in their global shares of value added between 1999 and 2014. Japan's share declined more sharply. China's global share grew rapidly to surpass or reach Japan's share in restaurant and hotel, transportation and storage, and wholesale and retail during this period.

Table 6-A **Global value added for selected industries, by selected region/country/economy: 2014**

(Percent)

Region/country/economy	Agriculture	Construction	Mining	Real estate	Restaurants and hotels	Transport and storage	Wholesale and retail
Global value added (current $billions)	3,042	3,987	3,538	6,219	1,817	3,093	8,515
China	31.0	17.7	16.3	8.8	11.3	15.6	12.3
EU	9.7	22.6	3.5	26.9	25.6	23.8	20.9
Japan	2.4	8.5	0.1	10.0	9.1	8.0	7.7
United States	7.7	17.3	14.3	35.2	26.3	16.5	25.4

NOTES: EU = European Union.

Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. China includes Hong Kong. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Industry Service database (2014).

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Non-HT manufacturing industries are divided into three categories, as classified by the OECD: medium-high technology, medium-low technology, and low technology.* In these industries, patterns and trends were somewhat divergent from those in HT manufacturing (Table 6-B). China's global share of value added grew rapidly between 1999 and 2014, and it became the world's largest manufacturer in the three non-HT manufacturing segments. The global shares of the United States and the EU declined sharply in contrast to their relatively more stable positions in HT manufacturing. Japan's share also declined sharply in all three segments.

Table 6-B **Global value added for manufacturing industries, by selected technology level and selected region/country/economy: 2014**

(Percent)

Region/country/economy	Medium high	Medium low	Low
Global value added (current $billions)	3,840	3,756	3,734
China	31.5	35.4	34.3
EU	21.2	16.2	19.3
Japan	8.8	7.4	6.0
United States	17.1	14.0	15.2

NOTES: EU = European Union.

Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. The technology level of manufacturing is

	classified by the Organisation for Economic Co-operation and Development on the basis of R&D intensity of output. China includes Hong Kong. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.
SOURCE:	IHS Global Insight, World Industry Service database (2014).
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The positions of the United States, the EU, China, and Japan in nonmanufacturing and nonservices industries—agriculture, construction, and mining—are fairly similar to their positions in KTI industries (Table 6-A). China's global share grew rapidly between 1999 and 2014, and it became the world's largest producer in agriculture and mining. The global shares of the United States and the EU fell moderately. Japan had a steeper decline in these industries.

* Medium-high technology includes motor vehicle manufacturing and chemicals production, excluding pharmaceuticals; medium-low technology includes rubber and plastic production and basic metals; and low technology includes paper and food product production.

The globalization of the world economy involves the rise of new centers of KTI industries.[v] Although the United States continues to be a leader in these industries, China, India, Brazil, and other developing economies have vigorously pursued national innovation policies in an effort to become major producers and exporters of KTI goods and services. Advances in S&T have enabled companies to spread KTI activity to more locations around the globe and to develop strong interconnections among geographically distant entities.

Innovation, the second major focus of the chapter, is closely associated with technologically led economic growth. Therefore, the analysis of innovation focuses on the role of KTI industries. The measurement of innovation is an emerging field, and current data and indicators are limited. However, activities related to commercializing inventions and new technologies are important components of innovation indicators. Such activities include patenting, financing new HT firms, and investing in intangible goods and services.

This chapter pays special attention to clean energy technologies. In recent years, innovations aimed at developing improved technologies for generating clean and affordable energy have become increasingly important in developed and developing countries. Energy has a strong link to S&T and, like ICT, is a key element of infrastructure. Its availability affects prospects for growth and development, with clean energy an increasingly important element of energy infrastructure.

Several themes cross-cut the various indicators examined in the chapter:

- The HT manufacturing industries are the most globalized among the KTI industries. Two HT manufacturing industries—communications; and semiconductors and computers—have the most complex global value chains, where China is the dominant locale for final production.
- KTI industries remain concentrated in developed countries despite much more rapid growth by China and other developing countries. Developed countries account for three-fourths of global production of commercial KI services industries, which are the largest category of KTI industries.
- Globalization is increasing rapidly in the much larger commercial KI services industries but remains substantially lower than in HT manufacturing. Data on trade and U.S. foreign investment suggest that these industries have substantial linkages among developed countries. Industries in developed countries also contract out some of their activities to developing countries.
- Although KTI activity has increased in Brazil, India, Indonesia, Turkey, and other developing countries, China plays a unique role in this arena. Despite a per capita income comparable with that of other developing

countries, China's economic activity in several KTI industries has grown unusually quickly and is now comparable with or exceeds that of the United States, the European Union (EU; see "Glossary" for member countries), and Japan.

- KTI industries in developing countries have recovered more strongly and have been growing faster after the 2008–09 global recession than in developed countries. Among the KTI industries in developed countries, those in the United States rebounded most robustly from the economic downturn.

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[v] See Mudambi (2008) and Reynolds (2010) for a discussion of the shift to knowledge-based production and geographical dispersion of economic activity.

Chapter Organization

This chapter focuses on the United States, the EU, Japan, and the large and rapidly developing economy of China. Other major developing countries, including Brazil, India, and Indonesia, also receive attention. The time span is from the late 1990s to the present.

This chapter is organized into five sections:

- The first section discusses the prominent role of KTI industries in regional and national economies around the world.
- The second section describes the global spread of KTI industries and analyzes regional and national shares of worldwide production. It discusses shares for the KTI industry group as a whole, for KI services and HT manufacturing overall, and for particular services and manufacturing industries within these groups. Because advanced technology is increasingly essential for non-HT industries, some data on these industries are also presented.
- The third section examines indicators of increased interconnection of KTI industries in the global economy. Data on patterns and trends in global trade in KTI industries make up the bulk of this section. Data on domestic and foreign production and on employment in U.S. multinational companies (MNCs) in KTI industries are presented as indicators of the increasing involvement of these economically important firms in cross-border activities. To further illustrate the effects of globalization on the United States, the section presents data on U.S. and foreign direct investment abroad, showing trends by region and for individual KTI industries.
- The fourth section presents innovation-related indicators. It examines countries' shares in all patents granted by the United States in various technology areas. It next examines countries' shares of high-value patents. It presents innovation-related data on U.S. industries. In addition, it presents data on global venture capital investment, an important financing source for small HT-based firms.
- The last section presents data on clean energy and related technologies, which have become a policy focus in many developed and developing nations. These energy technologies, like KTI industries, are closely linked to scientific R&D. Production, investment, and innovation in these energies and technologies are rapidly growing in the United States and other major economies.

Data Sources, Definitions, and Methodology

This chapter uses a variety of data sources. Although several are thematically related, they have different classification systems. The sidebar Data Sources describes these systems and aims to clarify the differences among them. The discussion of regional and country patterns and trends includes an examination of developed and developing countries using the International Monetary Fund's categorization. Countries classified by the Fund as *advanced* are developed countries, whereas those classified as *emerging* and *developing* are considered to be developing.

Data Sources

This chapter uses a variety of data sources. Although several are thematically related, they have different classification systems. The below Table 6-C, describes these systems and aims to clarify the differences among them.

Table 6-C **Data Sources**

Topic	Data Provider	Variables	Basis of classification	Coverage	Methodology
Knowledge-intensive (KI) services and high-technology (HT) manufacturing industries	IHS Global Insight, World Industry Service database (proprietary)	Production, value added	Industry basis using International Standard Industrial Classification of All Economic Activities	KI services — business, financial, information, health, and education HT manufacturing — aircraft and spacecraft, pharmaceuticals, office and computer equipment, communications, and scientific and measuring equipment	Uses data from national statistical offices in developed countries and some developing countries and estimates by IHS Global Insight for some developing countries
		ICT expenditures, by businesses	ICT consumer spending of population, by country ICT business spending, by	Not applicable	Uses data from national statistical offices and other sources and estimates by IHS Global

Topic	Data Provider	Variables	Basis of classification	Coverage	Methodology
Information and communications technologies (ICT) spending	IHS Global Insight, Global ICT Navigator (proprietary database)	and consumers	category of industry and by country		Insight for some developing countries
Trade in commercial KI services	World Trade Organization	Exports and imports	Product basis using Extended Balance of Payments Services classification	KI services — business, financial, information, and royalties and fees	Uses data from national statistical offices, the International Monetary Fund, and other sources
Trade in HT goods	IHS Global Insight, World Trade Service database (proprietary)	Exports and imports	Product basis using Standard International Trade Classification	Aerospace, pharmaceuticals, office and computing equipment, communications equipment, and scientific and measuring instruments	Uses data from national statistical offices and estimates by IHS Global Insight
Globalization of U.S. multinationals	U.S. Bureau of Economic Analysis (BEA)	Value added, employment, and inward and outward direct investment	Industry basis using North American Industrial Classification System (NAICS) Investment position on a historical cost, which is based on the value recorded in the financial accounts of the enterprise at	Commercial KI services — business, financial, and information HT manufacturing — aerospace, pharmaceuticals, office and computer equipment, communications, and scientific and	BEA annual surveys of U.S. multinationals and U.S. subsidiaries of non-U.S. multinationals

Topic	Data Provider	Variables	Basis of classification	Coverage	Methodology
			the time the asset was acquired	measuring equipment	
U.S. industry innovation activities	National Science Foundation, Business R&D and Innovation Survey	Innovation activities	U.S. businesses with more than five employees	Industries classified on an industry basis using NAICS	Survey of U.S.-based businesses with more than five employees using a nationally representative sample
U.S. Patent and Trademark Office (USPTO) patents	Science-Metrix/SRI International/Scopus /LexisNexis	Patent grants	Inventor country of origin, technology area as classified by the Patent Board	More than 400 U.S. patent classes, inventors classified according to country of origin and technology codes assigned to the grant	Source of data is USPTO
Triadic patent families	Organisation for Economic Co-operation and Development (OECD)	Patent applications	Inventor country of origin and selected technology area as classified by the OECD	Broad technology areas as defined by the OECD, inventors classified according to country of origin	Sources of data are USPTO, European Patent Office, and Japan Patent Office
Venture capital	Dow Jones VentureSource	Investment, technology area, country of investor origin	Technology areas as classified by the Dow Jones classification system	Twenty-seven technology areas, investment classified by venture firms' country location	Data collected by analysts from public and private sources, such as public announcements of venture capital investment deals

Topic	Data Provider	Variables	Basis of classification	Coverage	Methodology
Clean energy investment	Bloomberg New Energy Finance (BNEF)	Investment, technology area, country	Technology area classified by BNEF	Ten technology areas, investment classified by country receiving investment	Data collected by analysts from public and private sources, such as public announcements of venture capital investment deals
Public research, development, and demonstration (RD&D) in clean energy and related technologies	International Energy Agency (IEA)	Type of RD&D, technology area, country	Technology area classified by IEA	Six broad technology areas and numerous subtechnology areas	Data collected by IEA survey of its member countries
Public and private investment in energy infrastructure	IEA	Investment, type of energy source	Energy source classified by IEA	Six broad and numerous fine technology areas	Data collected by IEA survey of its member countries

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Knowledge and Technology Infrastructure in the World Economy

The first section of this chapter examines the importance of knowledge and technology infrastructure in the global economy. (For an explanation of KTI industries, please see "Chapter Overview.") One key indicator is the KTI industries' share of gross domestic product (GDP) in the global economy, developed economies, and developing economies. (For a discussion of value added and other measures of economic activity, see sidebar, Industry Data and Terminology.) Two critical components of the knowledge and technology infrastructure are education and ICT. Education plays an important role in building human capital for future high-skilled workers employed in KTI and other scientific and KI industries. ICT is regarded as a general-purpose technology that is important for providing the infrastructure for many social and economic activities and for facilitating innovation and economic growth.

The knowledge and technology infrastructure, as measured by the KTI industries' share of global GDP, is a major part of the global economy. KTI industries—commercial KI services, public KI services, and HT manufacturing—make up 29% of world GDP (Figure 6-1; Appendix Table 6-1, Appendix Table 6-2, and Appendix Table 6-3). Among the KTI industries, the commercial KI services—business, financial, and information—have the highest share (17% of GDP) (Appendix Table 6-4). The public KI services—education and health—are the second largest (9%) (Appendix Table 6-3, Appendix Table 6-5, and Appendix Table 6-6).[i] The HT manufacturing industries—aircraft and spacecraft; communications; computers; pharmaceuticals; semiconductors; and testing, measuring, and control instruments—are much smaller, with a 2% share (Appendix Table 6-7).

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[i] Data on the health care sector include social services.

Industry Data and Terminology

The data and indicators reported here permit the tracing and analysis of broad patterns and trends that shed light on the spread and shifting distribution of global knowledge- and technology-intensive (KTI) capabilities. The industry data used in this chapter are derived from a proprietary IHS Global Insight database that assembles data from the United Nations (UN) and the Organisation for Economic Co-operation and Development to cover 70 countries consistently. IHS estimates some industry data for developing countries, including China, that are missing or not available on a timely basis.

The industry data follow the International Standard Industrial Classification of All Economic Activities, a UN system for classifying economic activities. Firms are classified according to their primary activity; a company that primarily manufactures pharmaceuticals, for example, but also operates a retail business would have all of its economic activity counted under pharmaceuticals.

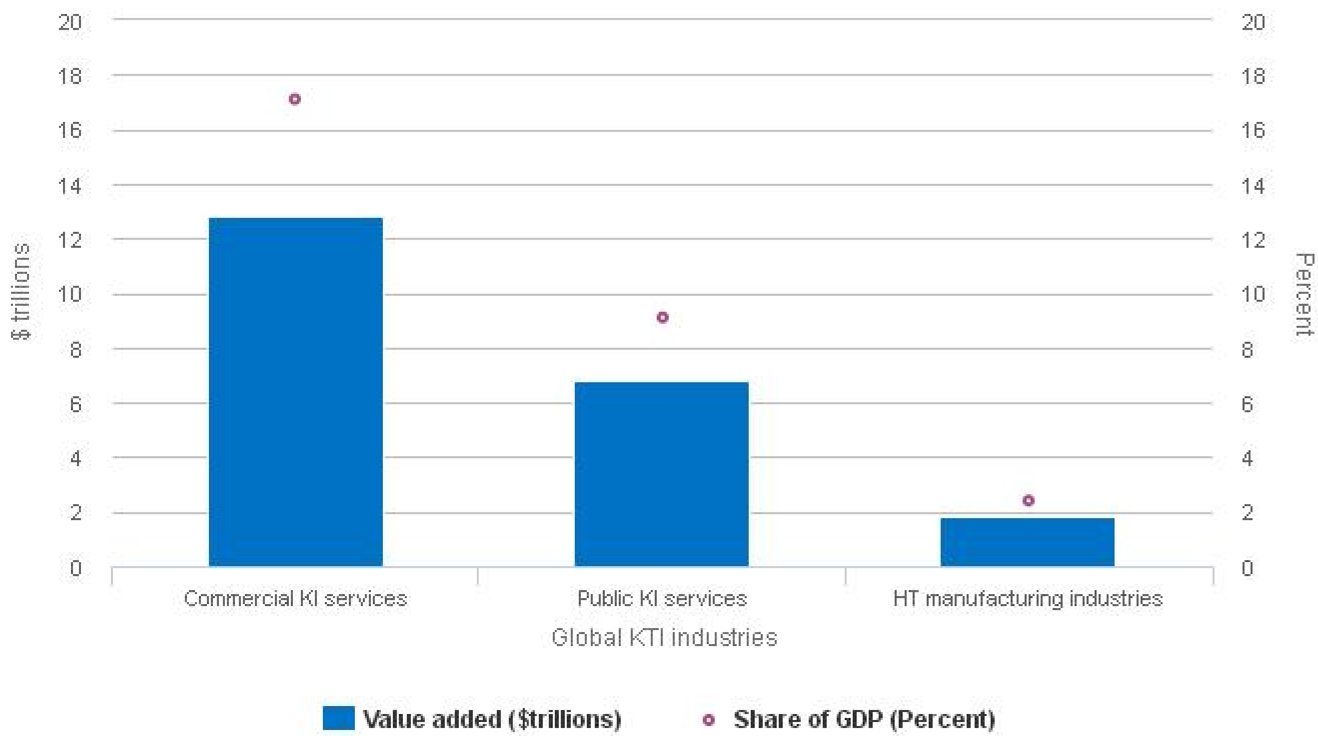
Production is measured as value added. Value added is the amount contributed by an economic entity—country, industry, or firm—to the value of a good or service. It excludes purchases of domestic and imported supplies as well as inputs from other countries, industries, or firms.

Value added is measured in current dollars. For countries outside the United States, value added is recorded in the local currency and converted at the prevailing nominal exchange rate. Industry data are reported in current dollar terms because most KTI industries are globally traded and because most international trade and foreign direct investment is dollar denominated. However, current dollars are an imperfect measure of economic performance. Economic research has found a weak link between nominal exchange rates of countries' currencies that are globally traded and differences in their economic performance (Balke, Ma, and Wohar 2013). In addition, the exchange rates of some countries' currencies are not market determined.

Value added is also an imperfect measure of output. It is credited to countries or regions based on the reported location of the activity, but globalization and the fragmentation of supply chains mean that the precise location of an activity is often uncertain. Companies use different reporting and accounting conventions for crediting and allocating production performed by their subsidiaries in foreign countries. Moreover, the value added from a diversified company's activity is assigned to a single industry based on the industry that accounts for the largest share of the company's business. However, a company classified as manufacturing may include services, and a company classified in a service industry may include manufacturing or may directly serve a manufacturing company. For China and other developing countries, industry data may be estimated by IHS Global Insight or may be revised frequently because of rapid economic change or improvements in data collection by national statistical offices. Thus, value-added trends should be interpreted as broad and relatively internally consistent indicators of the changing distribution of where economic value is generated. Small differences and changes should be treated with caution.

Figure 6-1

Global KTI industries, by output and share of GDP: 2014



GDP = gross domestic product; HT = high technology; KI = knowledge intensive; KTI = knowledge and technology intensive.

NOTES: Output of KTI industries is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. KTI industries include KI services and HT manufacturing industries classified by the Organisation for Economic Co-operation and Development. KI services include business, financial, communications, education, and health. Commercial KI services include business, financial, and communications services. Public KI services include education and health. HT manufacturing industries include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix tables 6-3–6-7.

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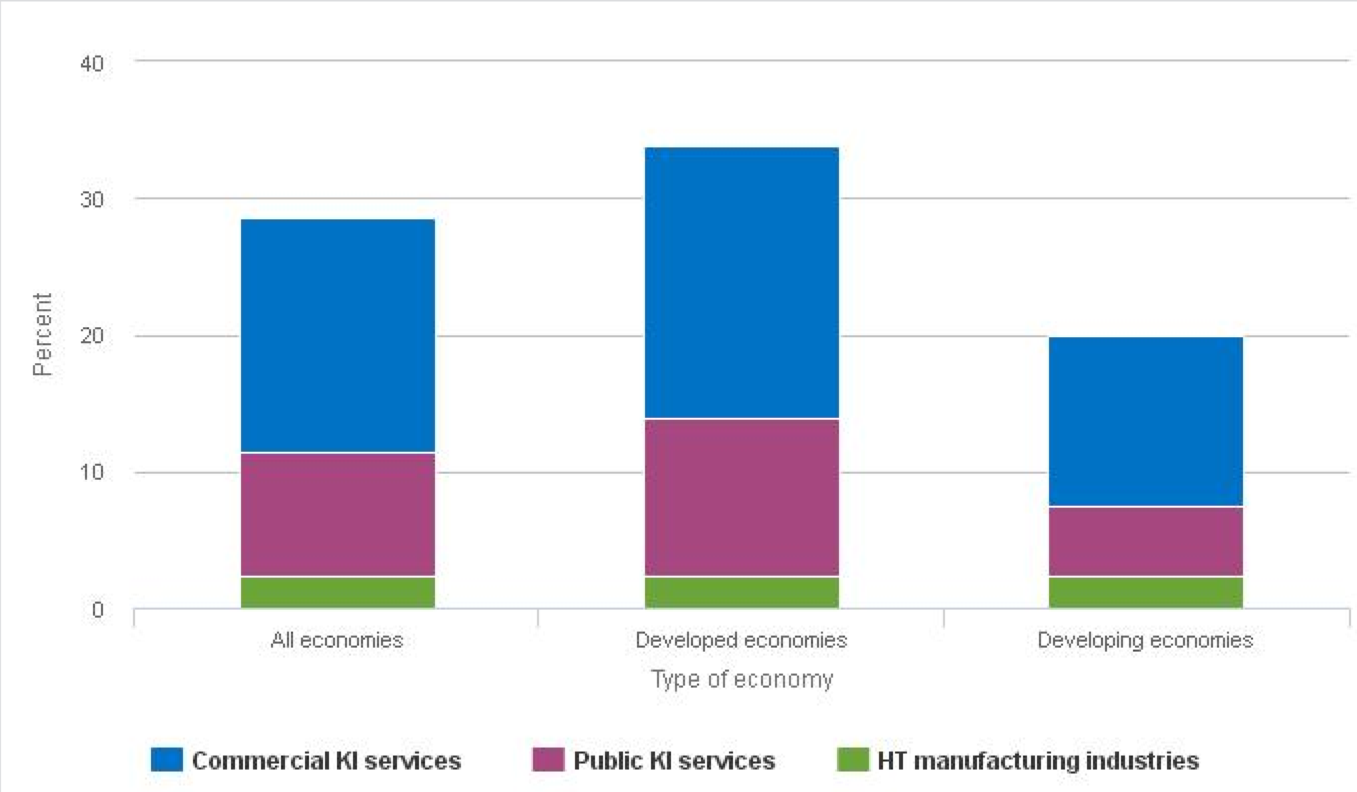
Knowledge- and Technology-Intensive Shares of Economies and Countries

The KTI share of developed economies is much higher than that of developing economies, largely because of their much larger share of KI services (Figure 6-2; Appendix Table 6-2 and Appendix Table 6-3). But KTI shares vary widely, even among developed economies:

Figure 6-2

Selected industry category share of GDP of developed and developing economies: 2014



GDP = gross domestic product; HT = high technology; KI = knowledge intensive.

NOTES: Output of knowledge- and technology-intensive (KTI) industries is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. KTI industries include KI services and HT manufacturing industries classified by the Organisation for Economic Co-operation and Development. KI services include business, financial, communications, education, and health. Commercial KI services include business, financial, and communications services. HT manufacturing industries include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. Public KI services include education and health. Developed economies are those classified as advanced by the International Monetary Fund (IMF). Developing economies are those classified as emerging by IMF.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix tables 6-3–6-7.

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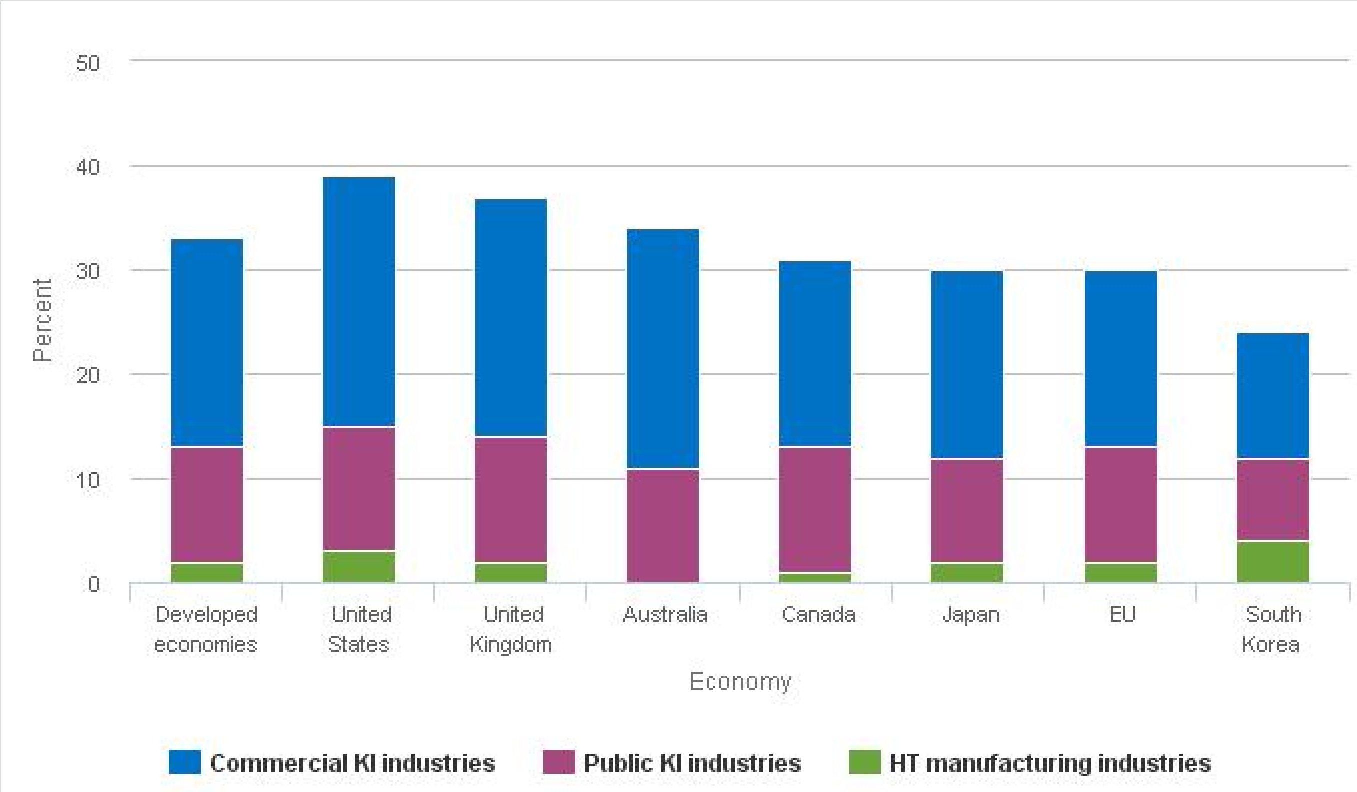
- The KTI shares of the United States (39%) and the United Kingdom (37%) are higher than the average for developed economies (34%) (Figure 6-3), reflecting higher-than-average shares in commercial KI services (23%–24% versus 20% average for developed economies). These two countries have a higher-than-average share of business services (14% versus 11% average for developed economies) (Appendix Table 6-3 and Appendix Table 6-8).
- The EU, Canada, and Japan have KTI shares of 30%–31%, which are close to the average for developed economies. Their shares of commercial KI services (17%–18%) are considerably smaller than that of the United States (24%) (Figure 6-3).
- Spain, Italy, and South Korea have KTI shares below the developed country average.

Figure 6-3

Output of KTI industries as a share of the GDP of selected developed economies: 2014



EU = European Union; GDP = gross domestic product; HT = high technology; KI = knowledge intensive; KTI = knowledge and technology intensive.

NOTES: Output of KTI industries is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. KTI industries include KI industries and HT manufacturing industries classified by the Organisation for Economic Co-operation and Development. KI industries include business, financial, communications, education, and health. Commercial KI industries include business, financial, and communications services. Public KI industries include education and health. HT manufacturing industries include aerospace; communications and semiconductors; computers and office machinery; pharmaceuticals; and testing, measuring, and control instruments. Developed economies are those classified as advanced by the International Monetary Fund.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix tables 6-3–6-7.

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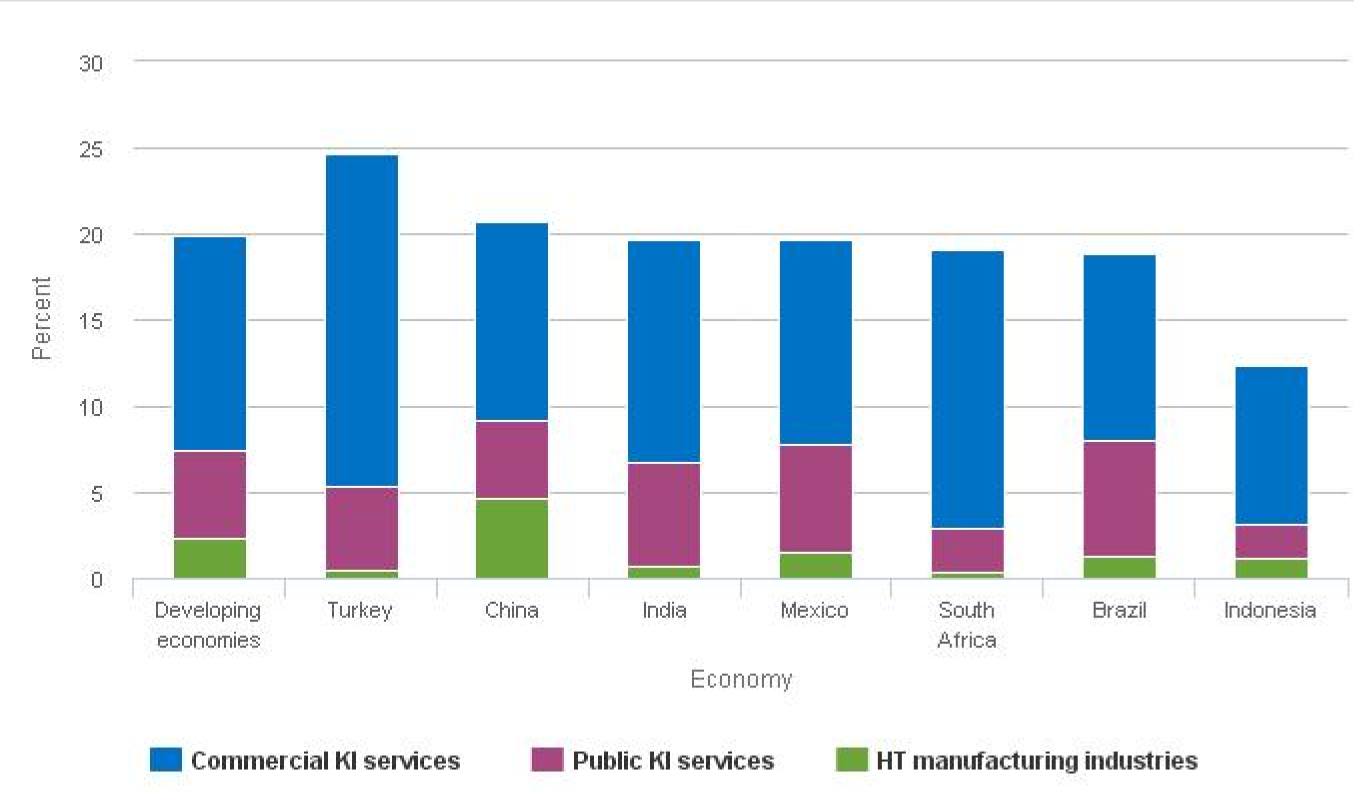
The KTI shares of individual developing countries vary widely, in part reflecting differences in their stage of development and level of per capita income (Figure 6-4; Appendix Table 6-2 and Appendix Table 6-3). Among the larger developing countries, Turkey, with a relatively high per capita income, has the highest KTI share (25%). Five other countries—Brazil, China, India, Mexico, and South Africa—have comparable KTI shares of 19%–21%. Indonesia has the lowest KTI share of any large developing country (12%).

Figure 6-4

Output of KTI industries as a share of GDP of selected developing economies: 2014



GDP = gross domestic product; HT = high technology; KI = knowledge intensive; KTI = knowledge and technology intensive.

NOTES: Output of KTI industries is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. KTI industries include KI services and HT manufacturing industries classified by the Organisation for Economic Co-operation and Development. KI services include business, financial, communications, education, and health. Commercial KI services include business, financial, and communications services. Public KI services include education and health. HT manufacturing industries include aerospace; communications and semiconductors; computers and office machinery; pharmaceuticals; and testing, measuring, and control instruments. Developing economies are those classified as emerging by the International Monetary Fund.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix tables 6-3–6-7.

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Education Infrastructure

Education has long been viewed as an important determinant of economic well-being and development. Research literature suggests that education fosters economic growth through three channels:

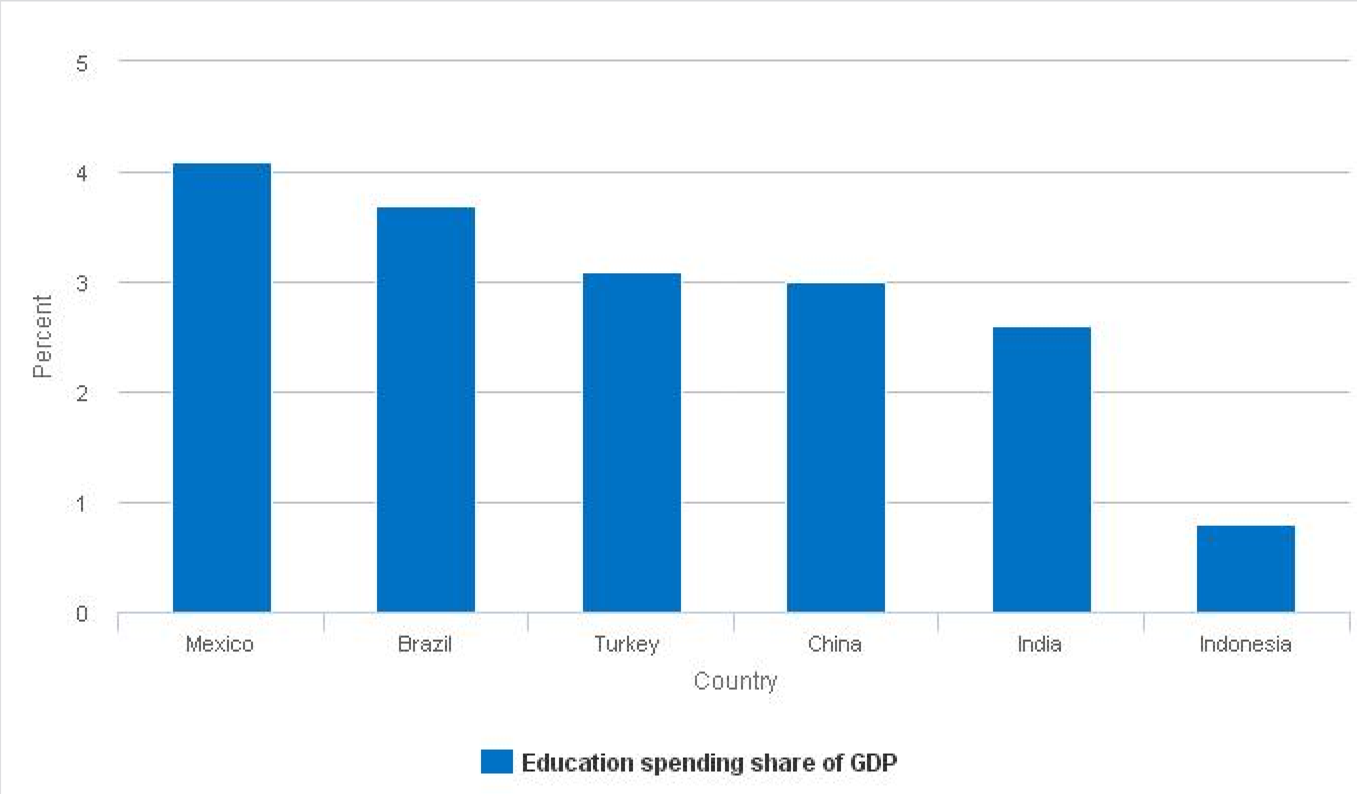
- Raised quality of human capital in the labor force, which lifts labor productivity
- Increased innovative capacity of the economy, which leads to new technologies, products, and processes
- More efficient and effective diffusion and transmission of knowledge needed to understand and process new information and to implement technologies devised by others

This section will examine the education share of GDP, which provides an approximate indication of the size and prominence of the education sector. Chapter 2 has data on international comparisons of S&E degree attainment, an indicator that may be relevant for KTI industries and innovation.

The education spending share of GDP varies widely among the larger developing countries, ranging from 0.8% in Indonesia to 4.1% in Mexico (Figure 6-5). Developed countries also have fairly wide variations in their education spending shares of GDP, ranging from 3.3% in Japan to 5.1% in the United States to 5.7% in the United Kingdom (Figure 6-6).

Figure 6-5

Education spending share of GDP for selected developing countries: 2014



GDP = gross domestic product.

SOURCES: IHS Global Insight, World Industry Service database (2014); World Bank, Education Statistics (2014), http://data.worldbank.org/data-catalog/ed-stats, accessed 15 January 2015. See appendix tables 6-3 and 6-5.

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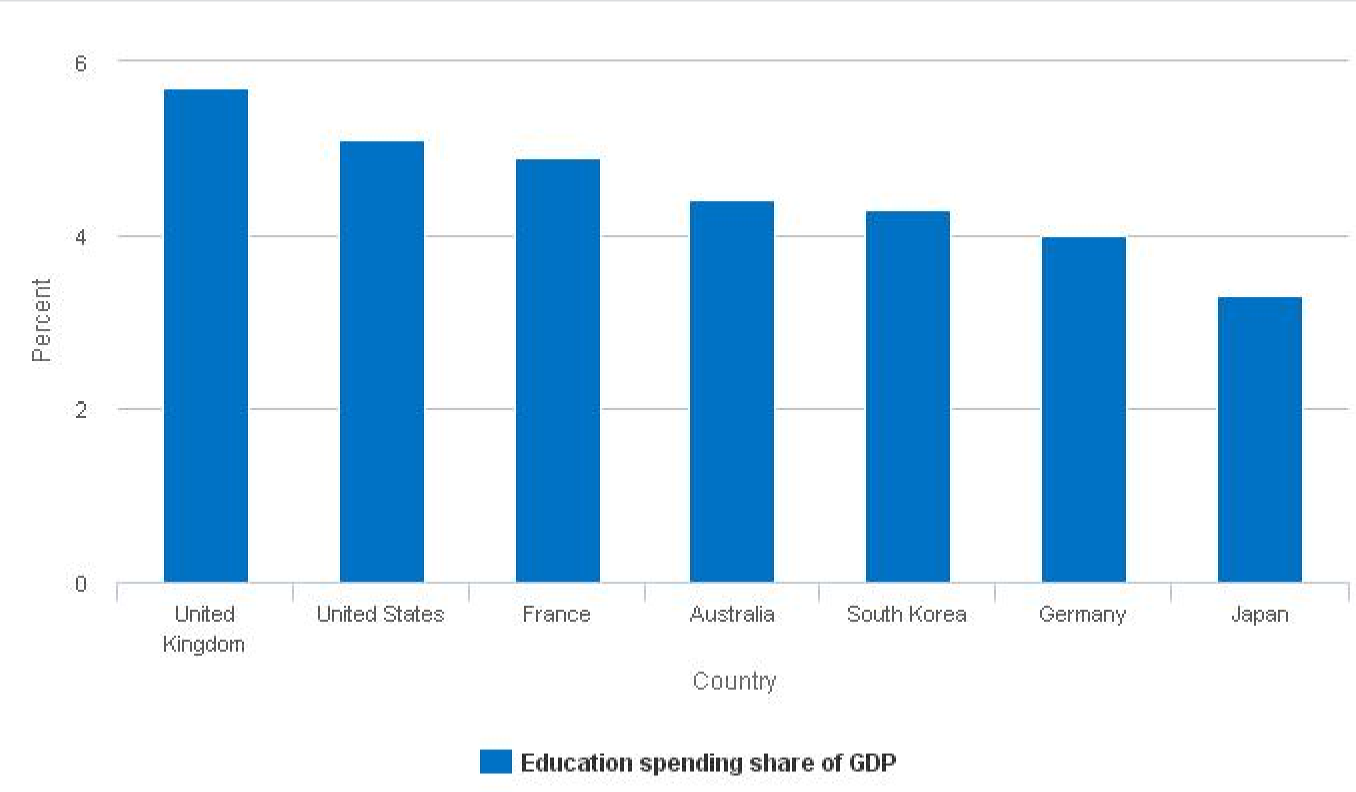
Figure 6-6

Education spending share of GDP for selected developed countries: 2014



GDP = gross domestic product.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix tables 6-3 and 6-5.

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Information and Communications Technology Infrastructure

Many economists regard ICT as a general-purpose platform technology that fundamentally changes how and where economic activity is carried out in today's knowledge-based countries, much as earlier general-purpose technologies (e.g., the steam engine, automatic machinery) propelled growth during the Industrial Revolution.[i] ICT infrastructure can be as important as or more important than physical infrastructure for raising living standards and economic competitiveness.[ii] This section examines ICT spending by consumers and businesses as a share of GDP.

Among developed countries, the United States, the United Kingdom, Germany, and France have among the highest ICT spending of consumers as a share of their GDP (Figure 6-7). Australia, Japan, and South Korea have slightly lower shares.

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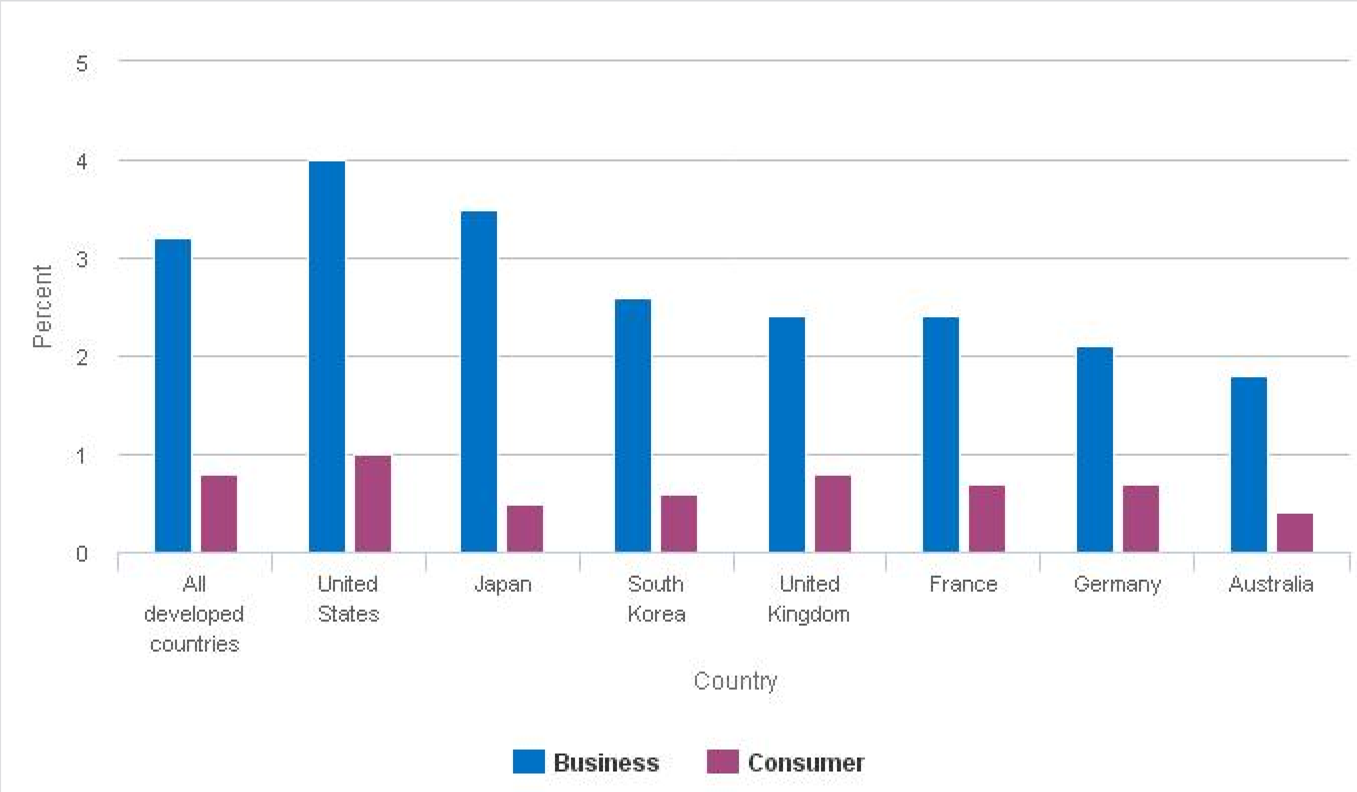
[i] See Bresnahan and Trajtenberg (1995) and DeLong and Summers (2001) for discussions of ICT and general-purpose technologies.

[ii] A World Bank study of developed and developing countries estimated that a 10 percentage point increase in broadband penetration raises economic growth by 1.2–1.4 percentage points (World Bank 2009:45).

Figure 6-7

ICT business and consumer spending as a share of GDP for selected developed countries: 2012–14



GDP = gross domestic product; ICT = information and communications technology.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) from IHS Global Insight ICT Global Navigator.

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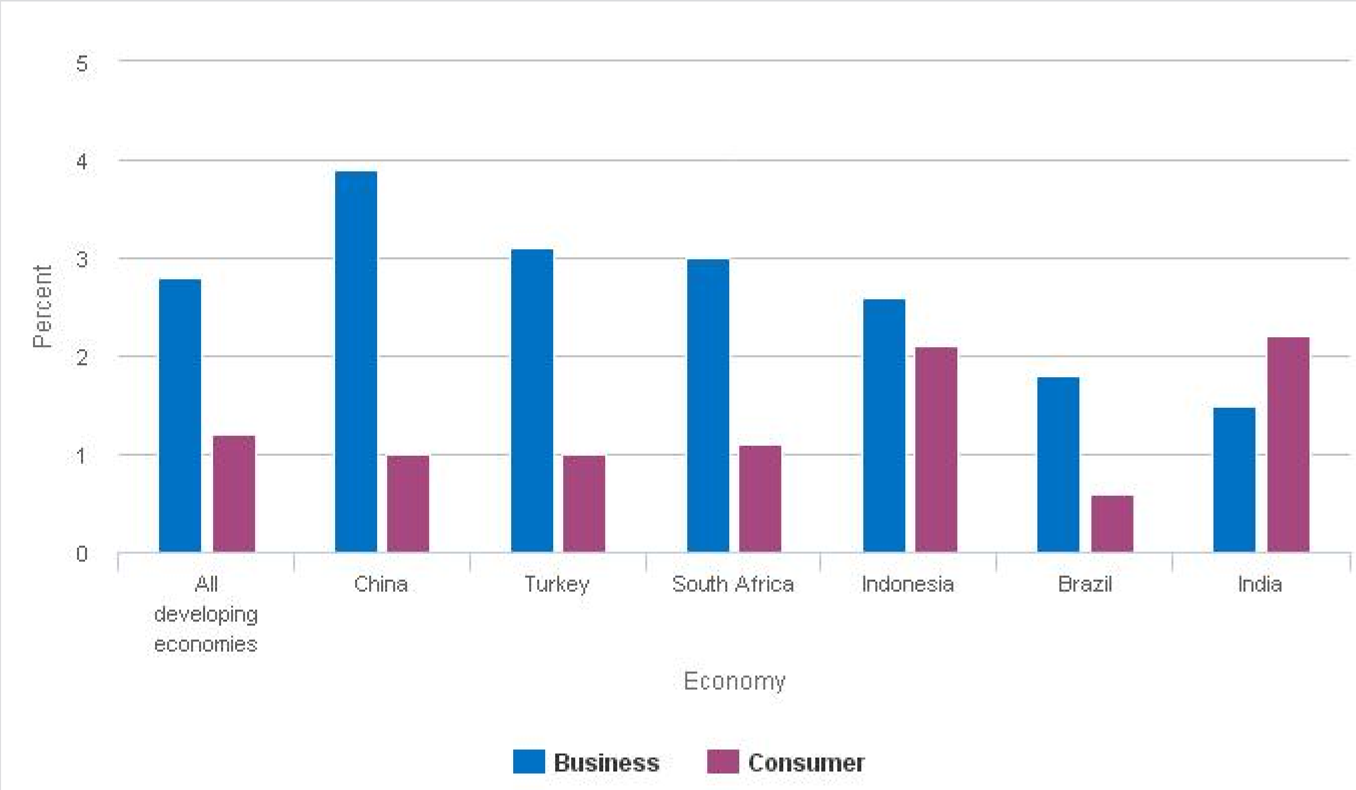
The ICT business spending share is important because of the large impact that businesses have on overall economic growth, employment, and productivity. The United States has the highest share of ICT business spending (4.0%), followed by Japan (3.5%). Australia (1.8%) and Germany (2.1%) have some of the lowest shares in ICT business spending (Figure 6-7).

Many developing countries have ICT spending shares that are comparable with or even higher than those of developed countries (Figure 6-8). China, which leads most of the larger developed economies in the ICT business share, matches the United States in both its ICT business and consumer shares. Turkey, South Africa, and Indonesia have ICT business spending shares between 2.6% and 3.1%.

Figure 6-8

ICT business and consumer spending as a share of GDP for selected developing economies: 2012–14



GDP = gross domestic product; ICT = information and communications technology.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) from IHS Global Insight ICT Global Navigator.

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Worldwide Distribution of Knowledge- and Technology-Intensive Industries

This section will examine the positions of the United States and other major economies in KTI industries, as measured by their shares of global KTI activity (Appendix Table 6-1). (For an explanation of KTI industries, please see "Chapter Overview.")

Public Knowledge-Intensive Services Industries

Public KI services—health and education—account for about $7 trillion in global value added (Figure 6-1). These sectors are major sources of knowledge and innovation of great benefit to national economies. Although they are far less market driven than other KTI industries in the global marketplace, competition in education and health appears to be increasing.[i] Education trains students for future work in science, technology, and other fields, and research universities are an important source of knowledge and innovation for other economic sectors. The health sector trains and employs highly skilled workers, conducts research, and generates innovation.

International comparison of both health and education sectors is complicated by variations in the size and distribution of each country's population, market structure, and the degree of government involvement and regulation. As a result, differences in market-generated value added may not accurately reflect differences in the relative value of these services.

The United States and the EU are the world's largest providers of education services, with world spending shares of 28%–30% (Figure 6-9; and Appendix Table 6-5). China is the third-largest provider, followed by Japan. Country and regional shares are similar in health care, except that Japan is ahead of China (Appendix Table 6-6).

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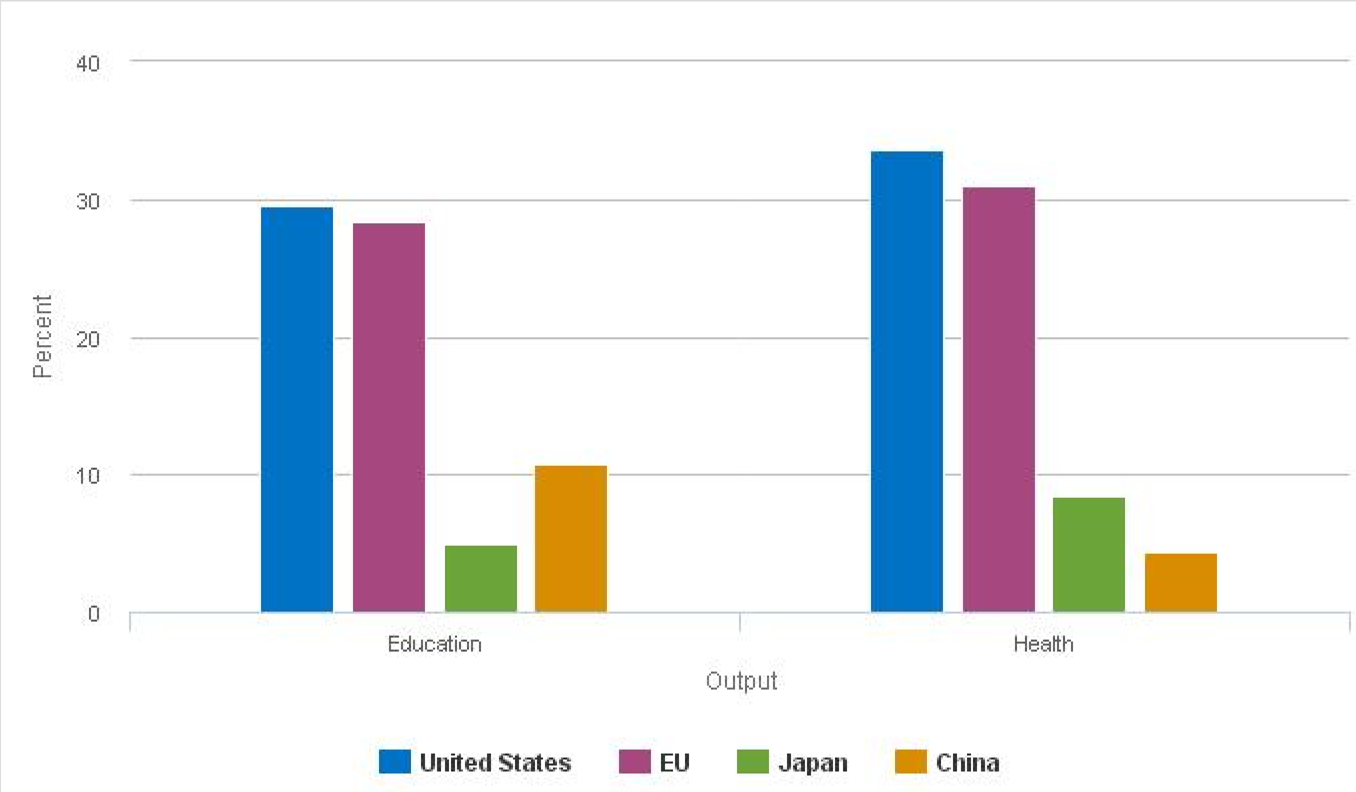
[i] In the education sector, countries compete to attract foreign students to study and train. In the health sector, some countries promote "medical tourism" to attract foreigners to obtain medical care that is often cheaper than that provided in their home country.

Figure 6-9

Output of education and health for selected regions/countries/economies: 2014



EU = European Union.

NOTES: Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. China includes Hong Kong. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Developed countries are those classified as advanced by the International Monetary Fund (IMF). Developing countries are those classified as emerging by IMF.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix tables 6-5 and 6-6.

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The U.S. and EU global shares of education and health fell modestly between 2003 and 2014 (Appendix Table 6-3, Appendix Table 6-5, and Appendix Table 6-6). Japan's share fell more sharply. China's global share of education and health services more than doubled during this period, in line with its rapid economic growth, emphasis on education, and focused efforts to improve the health care system. Brazil, India, and Indonesia showed a similar expansion in their global shares. The growth of education in China and India coincided with increases in both of these countries in earned higher education degrees and, particularly, doctorates in the natural science and engineering fields (see chapter 2).

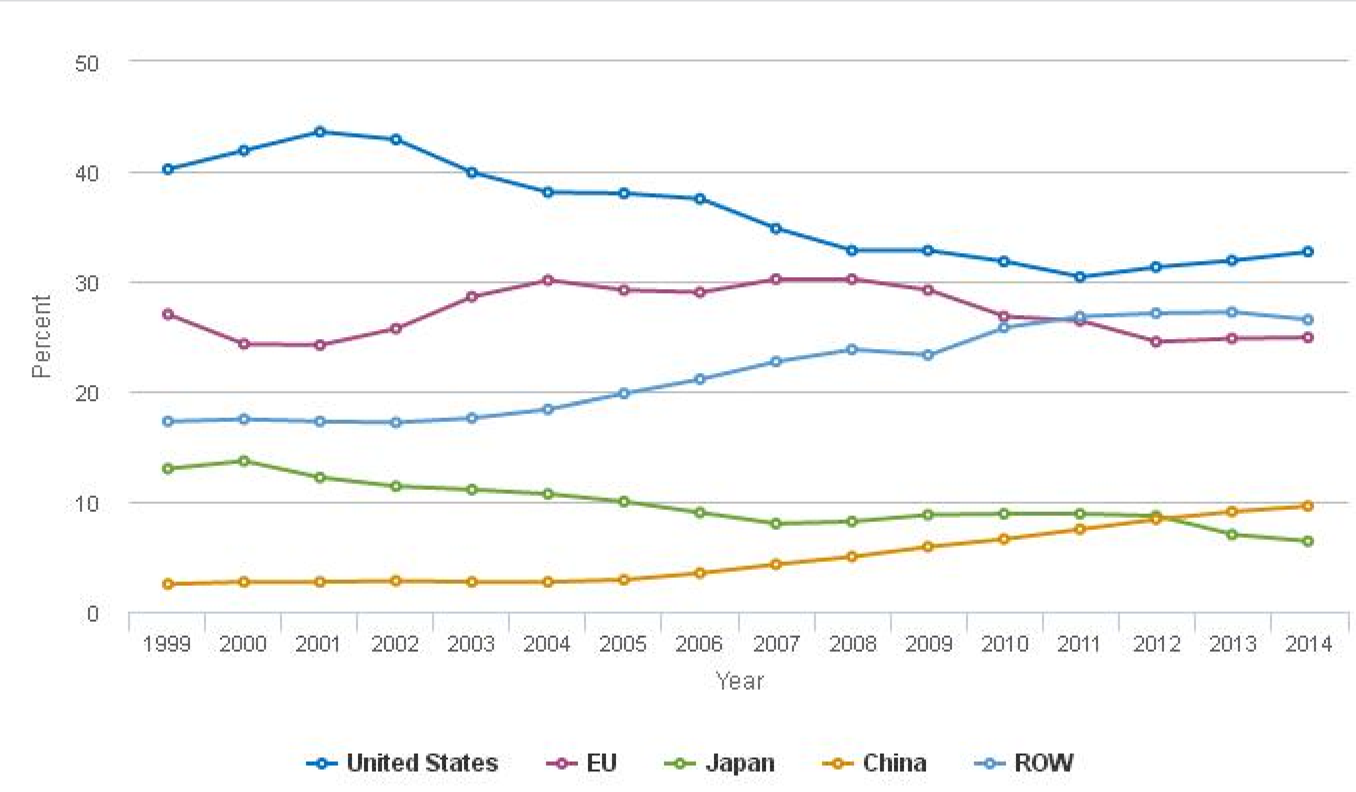
Commercial Knowledge-Intensive Services Industries

The global value added of commercial KI services—business, financial, and information—was $12.7 trillion in 2014 (Figure 6-1; Appendix Table 6-4). Business services, which includes the technologically advanced industries of computer programming and R&D services, is the largest service industry ($6.6 trillion). The large size of business services reflects the widespread practice of businesses and other organizations to purchase various services rather than provide them in-house, particularly in developed countries. The second-largest service industry is financial services ($4.5 trillion), with information far smaller ($1.6 trillion) (Appendix Table 6-8, Appendix Table 6-9, and Appendix Table 6-10).

The United States alone accounted for a third (33%) of global commercial KI services in 2014 (Figure 6-10). U.S. commercial KI services industries employ 19.7 million workers, 14% of the U.S. labor force, and pay higher-than-average wages (Table 6-1; Figure 6-11). In addition, these industries have a much higher concentration of skilled workers as measured by the proportion of those in S&E occupations. These industries perform 29% of U.S. industrial R&D (Table 6-1).

Figure 6-10

Output of commercial KI services for selected regions/countries/economies: 1999–2014



EU = European Union; KI = knowledge intensive; ROW = rest of world.

NOTES: Output of commercial KI services is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Developed countries are those classified as advanced by the International Monetary Fund (IMF). Developing countries are those classified as emerging by IMF.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix table 6-4.

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Table 6-1 Employment and R&D for selected U.S. industries: 2012 or most recent year

Industry	Employment (2014) (millions of jobs)	S&E share	Average salary (actual $)	Business R&D (2013) ($ billions)
All industries	139.0	4.4	45,000	322.5
Commercial KI services	19.7	15.8	68,000	92.5
HT manufacturing	1.8	26.4	70,000	146.7

HT = high technology; KI = knowledge intensive.

NOTES: Business R&D consists of domestic funding by companies' own internal funds and funds from other sources. Employment consists of the nonagricultural workforce. HT manufacturing industries and KI services are classified by the Organisation for Economic Co-operation and Development. HT manufacturing includes computers, communications, semiconductors, electronic and measuring instruments, aircraft and space vehicles, and pharmaceuticals. KI services include health, education, business, information, and financial services. Commercial KI services include business, information, and financial services. Business R&D of commercial KI services consists of professional and technical services and information. Coverage of some industries may vary among data sources because of differences in classification of industries. Salaries are rounded to the nearest thousand.

SOURCES: Bureau of Labor Statistics, Current Employment Statistics, http://www.bls.gov/ces/; Bureau of Labor Statistics, Occupational Employment Statistics, special tabulations; National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey (2015), http://www.nsf.gov/statistics/srvyindustry/.

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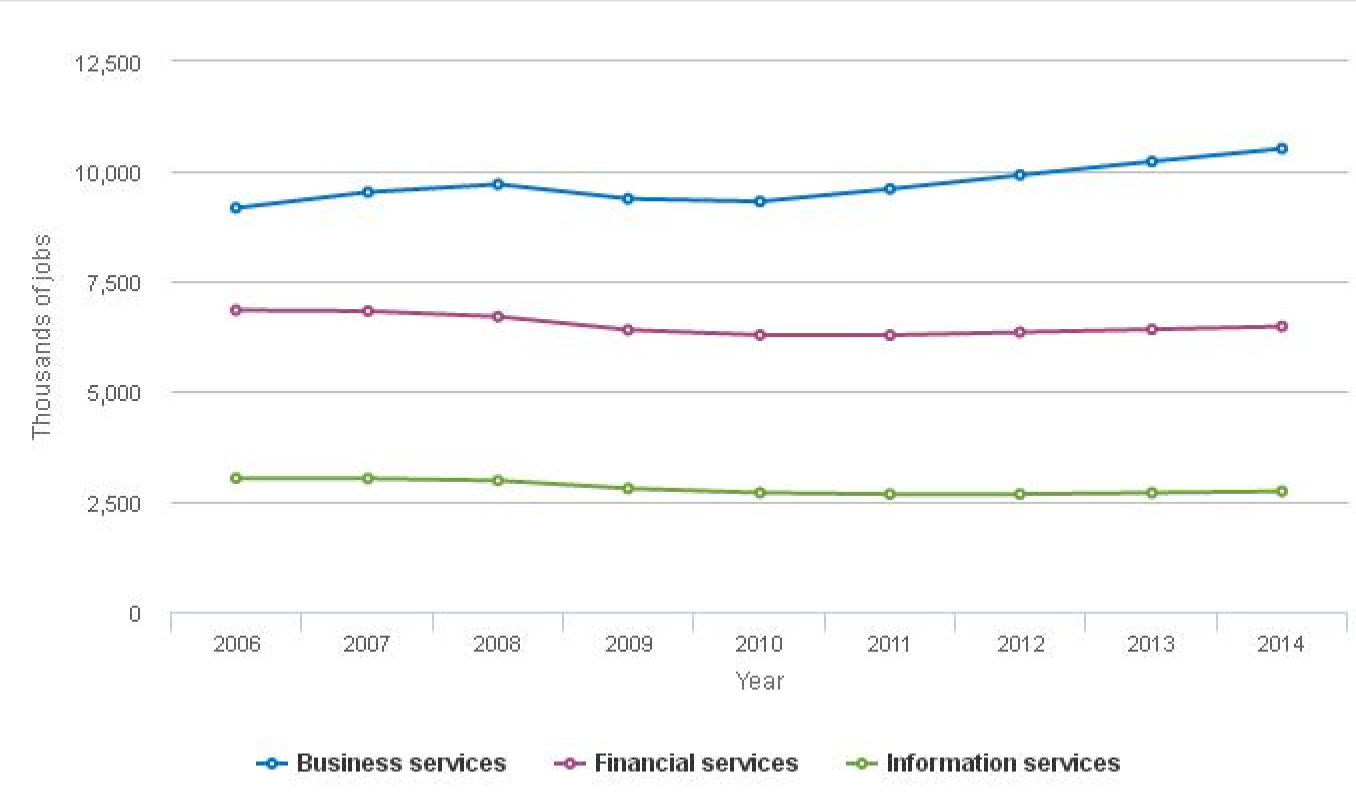
Figure 6-11

U.S. employment in commercial KI services: 2006–14



KI = knowledge intensive.

NOTES: KI services are classified by the Organisation for Economic Co-operation and Development. Commercial KI services include business, financial, and information services. Financial services include finance and insurance and rental and leasing. Business services include professional and technical services and management of companies and enterprises.

SOURCE: Bureau of Labor Statistics, Current Employment Statistics (2014), http://www.bls.gov/ces/, accessed 24 August 2015.

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The EU is the second-largest global provider (25% share) of commercial KI services. China is third (10%) and Japan is fourth (6%) (Figure 6-10).

Trends in Major Economies: U.S. commercial KI services recovered from the global recession bolstered by the strengthening U.S. economy. Value-added output in 2014 was 23% higher than its level in 2008 (Appendix Table 6-4). Business and financial services drove the recovery of commercial KI services, growing 20% and 44%, respectively (Appendix Table 6-8 and Appendix Table 6-9). Output of information services fell slightly (Appendix Table 6-10).

Since 2003, the U.S. global share of commercial KI services has dropped from 40% to less than 31% in 2011 before rising slightly to reach 33% in 2014 (Figure 6-10). These changes have been largely due to much faster growth in China and other developing countries. However, the United States continues to be the dominant provider of commercial KI services. The United States has a particularly strong position in business services (36% global share). Business services led the growth of U.S. commercial KI industries between 2003 and 2014 (Figure 6-12; Appendix Table 6-8). One source of growth of U.S. business services has been the infrastructure boom in developing countries, which has employed U.S. firms in areas including architecture, engineering, and consulting.[i]

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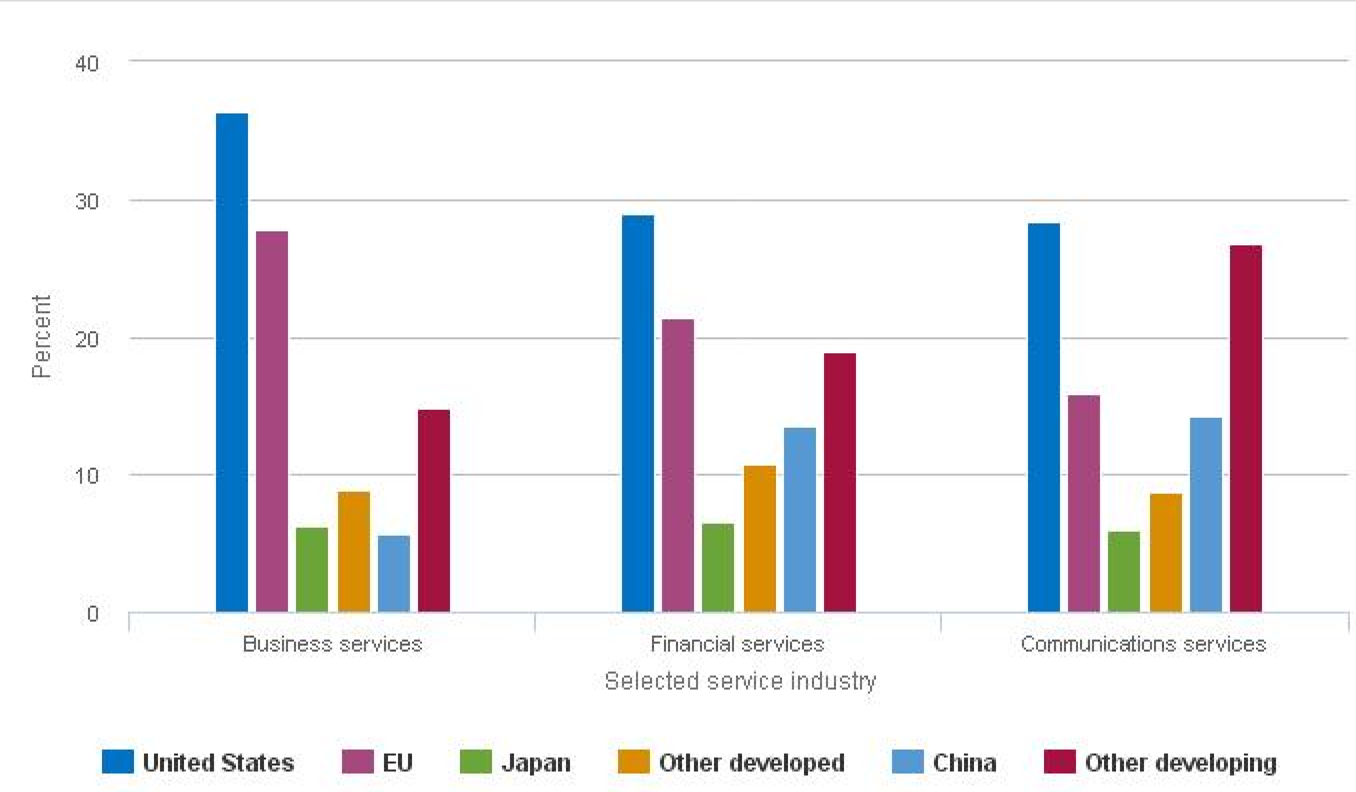
[i] See Jensen (2012) for a discussion of U.S. business services firms helping to build infrastructure in developing countries.

Figure 6-12

Output of selected service industries for selected regions/countries/economies: 2014



EU = European Union.

NOTES: Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. Business services include computer programming, R&D, and other business services. Data on computer programming, a component of business services, are provided separately. Financial services include leasing. China includes Hong Kong. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Developed countries are those classified as advanced by the International Monetary Fund (IMF). Developing countries are those classified as emerging by IMF.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix tables 6-8–6-12.

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Employment in U.S. commercial KI services has had a weak recovery (Figure 6-11), reaching 19.7 million in 2014, a gain of 344,000 jobs over 2008. Business services added about 800,000 jobs, but financial and information services each lost more than 200,000 jobs. The high growth in output of U.S. commercial KI services relative to weak job growth is consistent with historical trends (National Science Foundation, National Center for Science and Engineering Statistics [NSF/NCSES] 2014).

Commercial KI services in the EU have not recovered from the global recession because of member countries' stagnant economies. Output of the EU's commercial KI services was stagnant between 2008 and 2014 in contrast to U.S. industries growing more than 20% (Figure 6-10; Appendix Table 6-4). Commercial KI services in a few EU countries fared better, including Poland (see sidebar, Robust Growth of Poland's Commercial Knowledge-Intensive Services).

Output of Japan's commercial KI services was also flat in the postrecession period (Appendix Table 6-4). Japan's recovery from the global recession has been weak. In addition, Japan's global position has weakened over the last decade because of the lengthy stagnation of the Japanese economy (Figure 6-10).

The modest depreciation of the euro and yen relative to the dollar in 2009–14 may have slightly overstated the weakness of the EU's and Japan's commercial KI services industries (see sidebar, Currency Exchange Rates of Major Economies).

China's commercial KI services rebounded quickly from the global recession with output more than doubling in the postrecession period. China surpassed Japan in 2013 to become the world's third-largest provider (Figure 6-10). Over the last decade, China has grown at an average annual rate of nearly 20%, resulting in its global share more than tripling to reach 10% (Appendix Table 6-4). Business services and financial services led the growth of commercial KI services (Appendix Table 6-8 and Appendix Table 6-9). The rapid growth of financial services reflects the substantial role of public-owned or public-supported financial institutions.

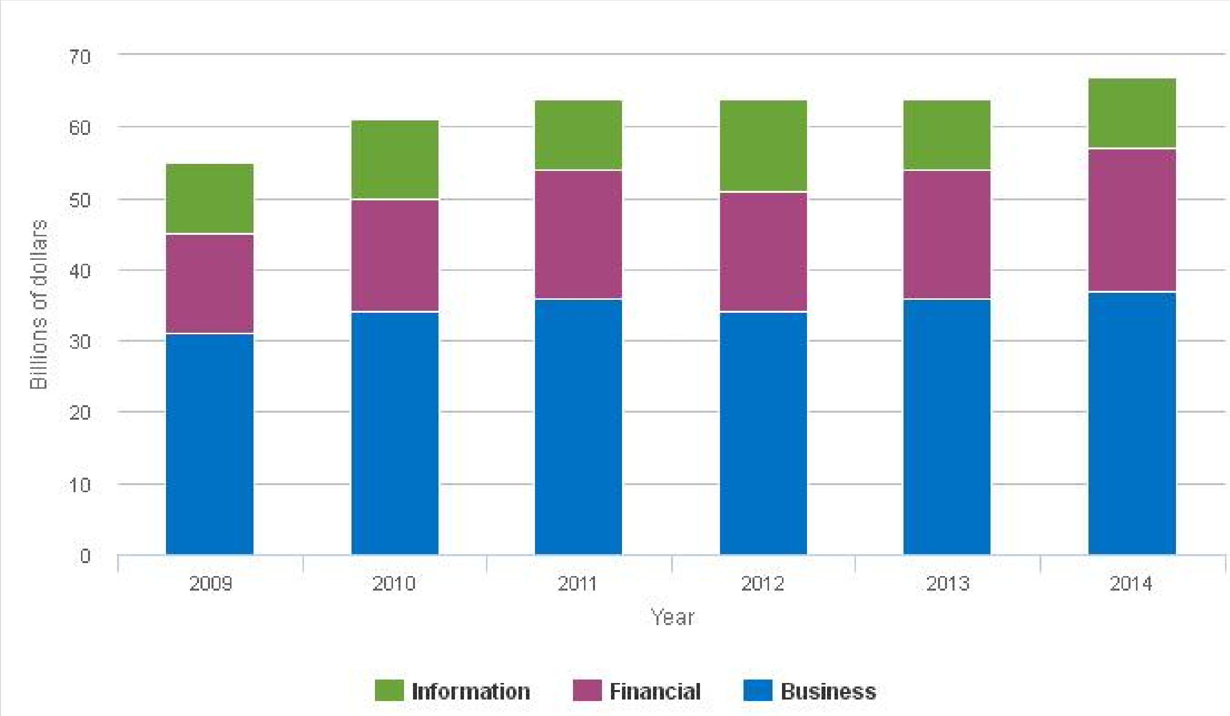
The developing economies of Brazil, India, and Russia also had sizable gains in commercial KI services, with each reaching global shares of 2% (Appendix Table 6-4). Brazil's expansion was led by financial services and information (Appendix Table 6-9 and Appendix Table 6-10). India gained the most in business services, particularly in computer programming, reflecting, in part, the success of Indian firms providing information technology (IT), accounting, legal, and other services to developed countries (Appendix Table 6-8 and Appendix Table 6-12). Russia's gain occurred from growth in its business and financial services.

Robust Growth of Poland's Commercial Knowledge-Intensive Services

Poland, a newer member of the EU, has sidestepped many of its neighbors' recent financial and economic difficulties. Poland's stable and growing economy has been attributed to its not adopting the euro and to its relatively low wage levels. Poland's service sector has grown rapidly over the last decade, with commercial KI services expanding from $56 billion in 2009 to $67 billion in 2014 (Figure 6-A). Business services have grown the fastest among the commercial KI services, reaching $37 billion in 2014. Outsourcing is a major and growing component of business services. Many foreign firms, including Infosys, have established sites in Poland that perform back office work such as finance and information technology for major corporations. Outsourcing companies are attracted to Poland's well educated and often multilingual work force. The business services industry is estimated to employ 110,000 workers, nearly as much as its automotive industry (140,000) (Ewing 2013).

Figure 6-A

Output of commercial KI services industries of Poland: 2009–14



KI = knowledge intensive.

NOTES: Output is on a value-added basis. Value added is the amount contributed by a country, firm, or entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix tables 6-15–6-20.

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Currency Exchange Rates of Major Economies

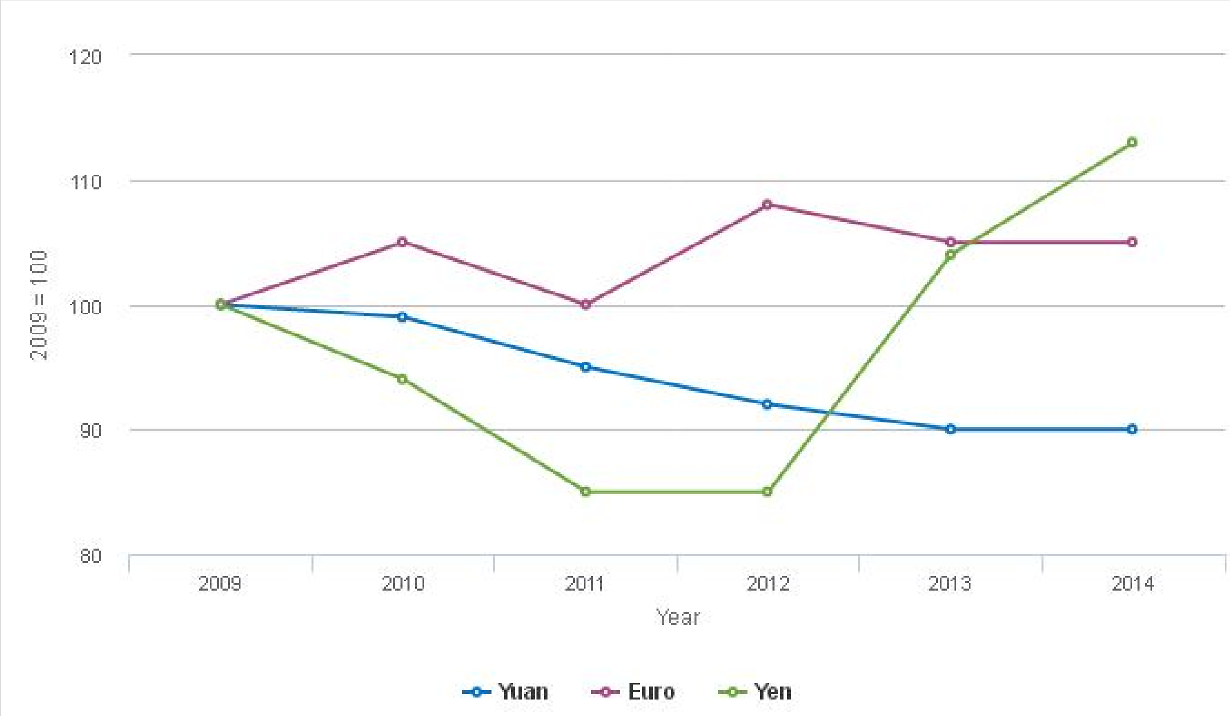
International comparisons of industry, trade, investment, and other global economic activities often use current dollars at market exchange rates. Most global economic activities are dollar denominated, which facilitates comparison. In addition, many economists believe that market exchange rates reflect, at least to some degree, differences in economic performance among various countries (Balke, Ma, and Wohar 2013:2).

However, fluctuations in exchange rates may also reflect factors other than economic performance. Governments can and do take action to influence the level of their exchange rates, ranging from intervening in currency exchange markets so as to exercise almost complete control of rates to using macroeconomic policies and other mechanisms so as to exercise more limited and indirect influence on markets. In addition, factors such as political instability or the short-term effects of global financial events on a country's economy can cause currency fluctuations that are unrelated to enduring differences in national economic performance. Factors such as these should remind the reader that comparing economic data from different countries in current dollar terms provides a mostly broadly indicative but rarely precise reflection of a country's relative economic performance.

Between 2009 and 2014, the exchange rates of the world's four largest economies—China, the EU member countries that use the euro (the eurozone), Japan, and the United States—exhibited some fluctuations (Figure 6-B). The euro and Japanese yen depreciated 5% and 13%, respectively, against the dollar. The yuan's exchange rate, which is controlled by China's government, modestly appreciated against the dollar.

Figure 6-B

U.S. dollar exchange rate with selected currencies: 2009–14



SOURCE: Federal Reserve, Economic and Research and Data, Foreign Exchange Rates, http://www.federalreserve.gov/releases/h10/current/, accessed 15 February 2015.

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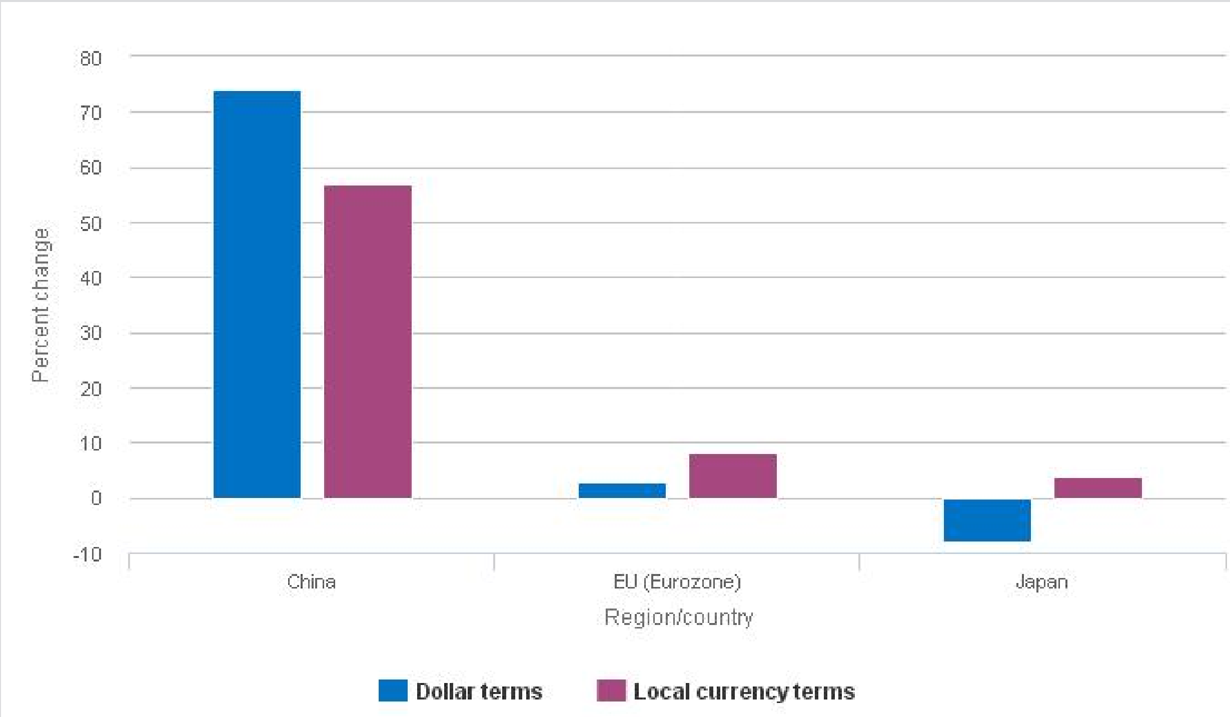
The depreciation of the euro and yen against the dollar from 2009 to 2014 made the eurozone's and Japan's positions in economic activities—denominated in current U.S. dollars—appear somewhat weaker during this period. Denominated in local currency terms, their economic performance looked stronger. For example, the value added of Japan's commercial KI services in current dollars declined 8% from 2009 to 2014 (Figure 6-C). The value added in yen increased 4%. The EU's commercial KI services increased 3% in dollar terms and 8% on a euro basis.

Figure 6-C

Output of commercial KI services industries, by selected region/country/economy: 2009–14



EU = European Union; KI = knowledge intensive.

NOTES: Output of commercial KI services is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. KI services include education, health, and business, financial, and communications services and are classified by Organisation for Economic Co-operation and Development. Commercial KI services consist of financial services, information, and business. EU (Eurozone) consists of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Slovakia, Spain, and Sweden.

SOURCES: Federal Reserve, Economic Research and Data, Foreign Exchange Rates, http://www.federalreserve.gov/releases/h10/current/, accessed 15 February 2015; IHS Global Insight, World Industry Service database (2014). See appendix table 6-7.

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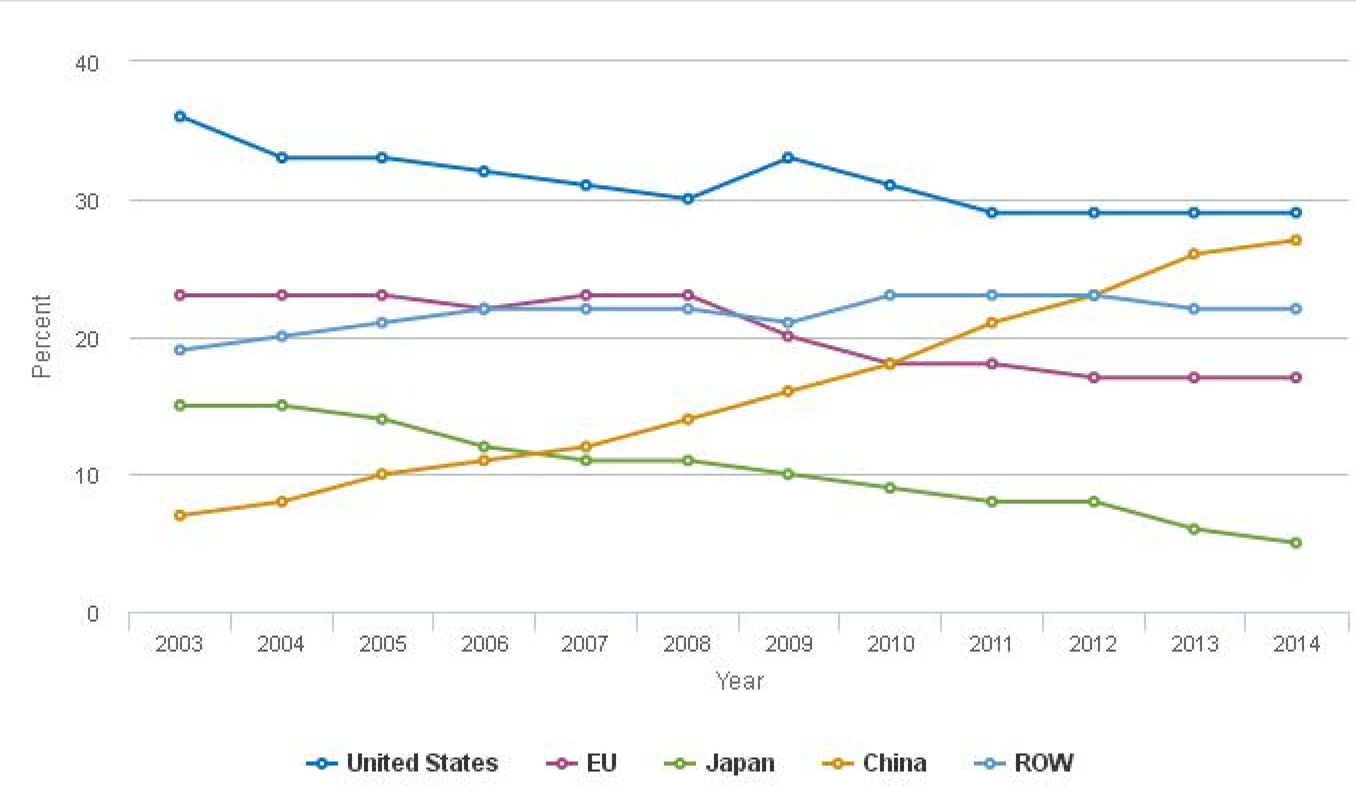
High-Technology Manufacturing Industries

Global value added of HT manufacturing was $1.8 trillion in 2014, making up 15% of the manufacturing sector (Figure 6-1; Appendix Table 6-7 and Appendix Table 6-11). The three ICT manufacturing industries—semiconductors, computers, and communications—made up a collective $0.7 trillion in global value added (Appendix Table 6-13, Appendix Table 6-14, and Appendix Table 6-15). The three remaining industries are pharmaceuticals ($500 billion); testing, measuring, and control instruments ($360 billion); and aircraft and spacecraft ($200 billion) (Appendix Table 6-16, Appendix Table 6-17, and Appendix Table 6-18).

The United States and China are the largest global producers (29% and 27% global share, respectively) (Figure 6-13) of HT manufacturing industries. U.S. HT manufacturing industries employ 1.8 million workers and pay higher-than-average wages due, in part, to their high concentration of highly skilled S&E workers (Table 6-1; Figure 6-14). Although a small part of the U.S. economy (3% of GDP), U.S. HT manufacturing industries fund about one-half of U.S. business R&D.

Figure 6-13

Output of HT manufacturing industries for selected regions/countries/economies: 2003–14



EU = European Union; HT = high technology; ROW = rest of world.

NOTES: Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. HT manufacturing industries are classified by the Organisation for Economic Co-operation and Development and include aircraft and spacecraft; communications; computers; pharmaceuticals; semiconductors; and testing, measuring, and control instruments. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Developed countries are those classified as advanced by the International Monetary Fund (IMF). Developing countries are those classified as emerging by IMF.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix table 6-7.

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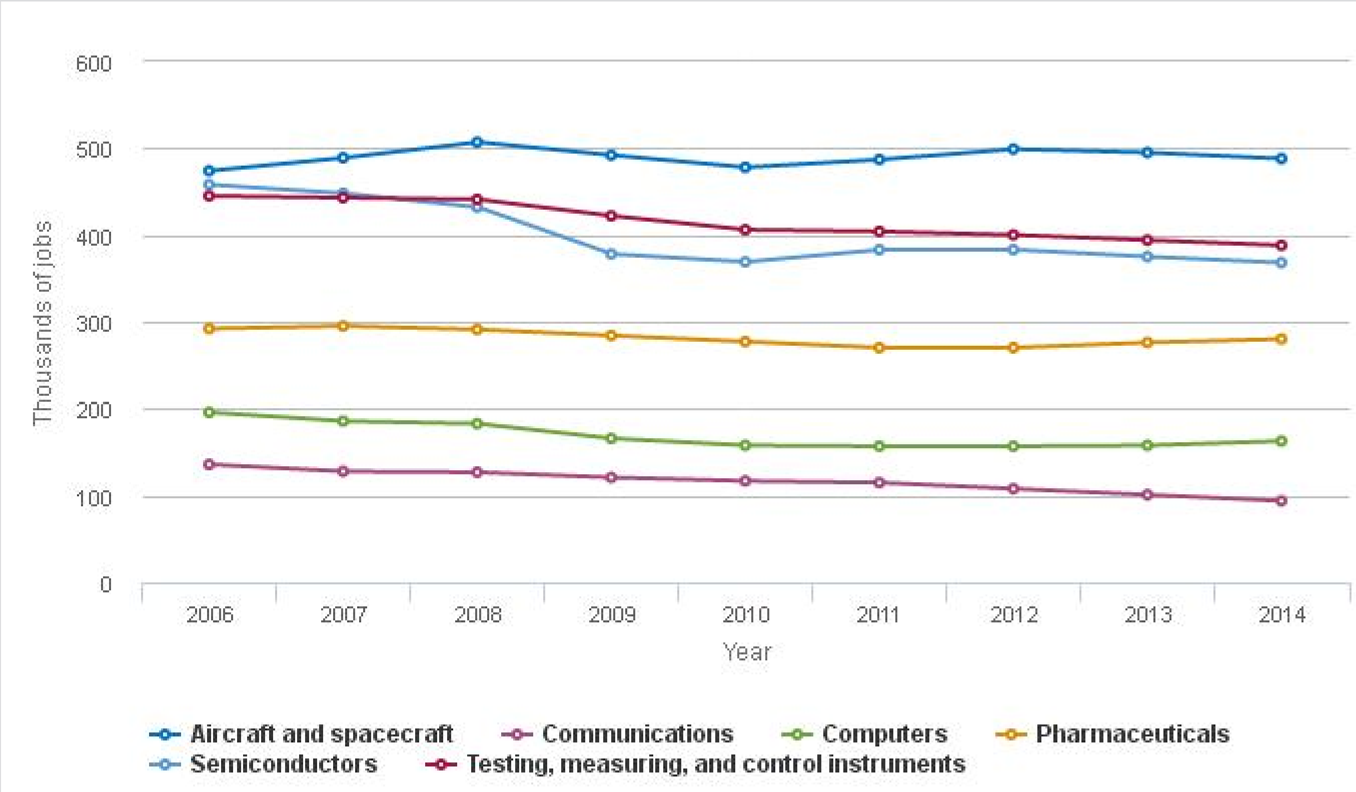
Figure 6-14

U.S. employment in HT manufacturing industries: 2006–14



HT = high technology.

NOTES: HT manufacturing industries are classified by the Organisation for Economic Co-operation and Development. HT manufacturing industries include aircraft and spacecraft; communications; computers; pharmaceuticals; semiconductors; and testing, measuring, and control instruments.

SOURCE: Bureau of Labor Statistics, Current Employment Statistics (2014), http://www.bls.gov/ces/, accessed 15 February 2015.

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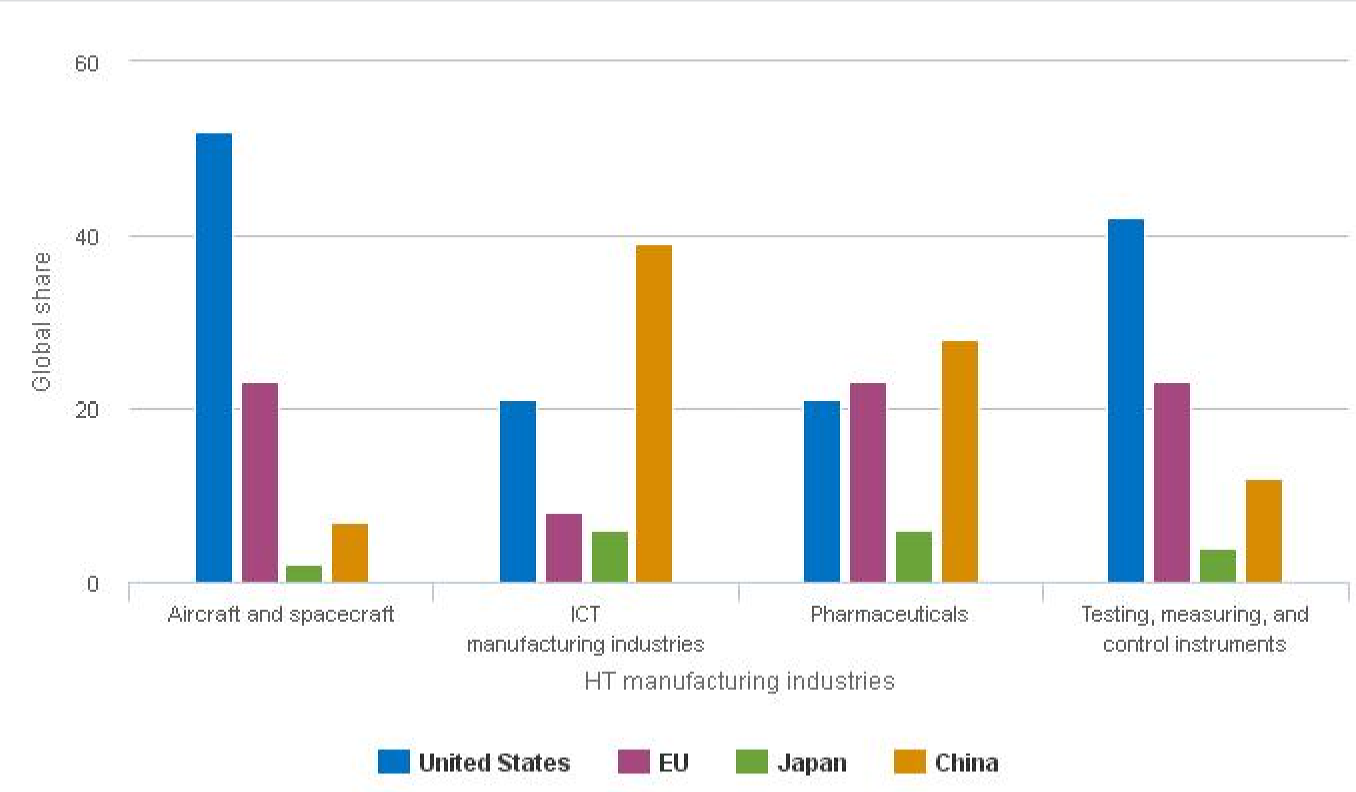
China is the largest global producer of the ICT manufacturing industries (39% global share), functioning as the final assembly location for these goods produced in "Factory Asia"—the electronics goods production network centered in East Asia (World Trade Organization and Institute of Developing Economies 2011:14–15) (Figure 6-15).

Figure 6-15

HT manufacturing industries of selected regions/countries/economies: 2014



EU = European Union; HT = high technology; ICT = information and communications technology.

NOTES: HT manufacturing industries are classified by the Organisation for Economic Co-operation and Development and include aircraft and spacecraft; communications; computers; pharmaceuticals; semiconductors; and testing, measuring, and control instruments. ICT manufacturing industries consist of computers, communications, and semiconductors. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. China includes Hong Kong. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Developed countries are those classified as advanced by the International Monetary Fund (IMF). Developing countries are those classified as emerging by IMF.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix tables 6-20 and 6-27–6-33.

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The EU and Japan are the third- and fourth-largest global producers with shares of 17% and 5%, respectively (Figure 6-13; Appendix Table 6-7).

Trends of the United States

U.S. HT manufacturing has recovered from the global recession with the strengthening U.S. economy. In 2014, U.S. HT manufacturing output was 18% higher than in 2008 (Appendix Table 6-7). Four HT manufacturing industries have driven postrecession growth: semiconductors; pharmaceuticals; testing, measuring, and control instruments; and aircraft and spacecraft (Appendix Table 6-13 and Appendix Table 6-16, Appendix Table 6-17, and Appendix Table 6-18). The United States continues to have a dominant position in aircraft (52% global share) and testing, measuring, and control instruments (42%).

Over the last decade, the U.S. global share of HT manufacturing has slipped from 33% to level off at 29% starting in 2011, largely due to much faster growth in China. Despite the decline in the U.S. global share, U.S. HT manufacturing output grew by more than 40% over the last decade. The four industries that led the postrecession recovery have also been the drivers of growth over the last decade (Appendix Table 6-13 and Appendix Table 6-16, Appendix Table 6-17, and Appendix Table 6-18). Growth of the ICT manufacturing industries of computers and communications has been stagnant because of the relocation of final production to China and other countries and the intensification of global competition (Appendix Table 6-14 and Appendix Table 6-15).

Despite a recovery in output, U.S. employment in HT manufacturing has not increased. Employment fell from 2.0 million jobs in 2008 to 1.8 million in 2014 (Figure 6-14). The lack of employment growth reflects the relocation of production to China and other countries, as well as the rapid productivity growth of U.S. HT manufacturing industries, which have eliminated some jobs, particularly those in routine tasks (see sidebar, U.S. Manufacturing and Employment). Some researchers and policymakers have concluded that the location of HT manufacturing and R&D activities may lead to the migration of higher-value activities abroad (Fuchs and Kirchain 2010:2344).

Trends of Other Major Producers

HT manufacturing industries in the EU and Japan have not recovered from the global recession. In the EU, output contracted by 7% between 2008 and 2014 because of the EU's weak economy. Because of the EU's lack of growth, its global share slipped from 23% to 17% during this period (Appendix Table 6-7). Among individual industries, the output of the ICT manufacturing industries shrank by a third. Pharmaceuticals grew slightly (5%), and aircraft and spacecraft grew by 16% (Appendix Table 6-16 and Appendix Table 6-18).

Japan's HT manufacturing industries contracted by 41% between 2008 and 2014 because of its weak recovery from the global recession. In addition, Japan's deep decline is likely due to its decade-long stagnant economy, the loss of competitiveness of Japanese electronics firms, and the transfer of production to China and other countries (Appendix Table 6-7). Over the last decade, value-added output contracted by 44%, resulting in Japan's global share dropping from 15% to 5%. Output of ICT industries alone fell by more than half.

After output growth slowed greatly in 2009 during the global recession, China's HT manufacturing industries rebounded strongly. China's value-added output in 2014 was more than double its level in 2008 (Appendix Table 6-7). Over the last decade, value-added output rose more than fivefold, pushing China's global share from 8% to 27%. China's rapid gain has been attributed to many factors, including policies and subsidies to encourage MNCs to invest in China, low wages, adequate infrastructure, and the global scale of China's manufacturing plants.

China became the world's largest producer in the ICT manufacturing industries with a 39% global share in 2014 (Figure 6-15; Appendix Table 6-13, Appendix Table 6-14, and Appendix Table 6-15). China also became the world's largest producer of pharmaceuticals, with a 28% share (Appendix Table 6-16), helped by production of generic drugs by China-based firms and the establishment of production facilities controlled by U.S. and EU multinationals. Output has grown rapidly in testing, measuring, and control instruments, although from a low base (Appendix Table 6-17).

Notwithstanding these rapid advances, HT manufacturing in China continues to be limited to lower value-added activities, such as final assembly.[i] For example, although Chinese semiconductor companies have gained global market share, China remains very reliant on semiconductors supplied by foreign firms for most of its production of smartphones and other electronic products (PricewaterhouseCoopers 2014). Many MNCs continue to conduct their higher value-added activities in developed countries because of the greater availability of skilled workers and stronger intellectual property protection. In addition, Chinese-owned HT companies have not met many of the ambitious targets and goals of the Chinese government's indigenous innovation program.

Anecdotal reports suggest that some multinationals are relocating their facilities from China to other developing countries with lower labor costs or returning production to developed countries in response to increases in transportation costs and in China's manufacturing wages.[ii] However, China remains an attractive location for foreign MNCs because of its well-developed manufacturing infrastructure that can supply the global market. In addition, China's growing and potentially huge domestic market is prompting some foreign HT firms to expand their production facilities and establish R&D laboratories to develop products for China's rapidly growing consumer market.

Other major Asian producers—Singapore, South Korea, and Taiwan—showed little change in their global shares during this period (Appendix Table 6-7). Over the last decade, companies based in these economies have moved up the value chain to become producers of semiconductors and other sophisticated components that are supplied to China and other countries.

Other Asian countries that grew rapidly include the Philippines and Vietnam (Appendix Table 6-7) (see sidebar, High-Technology Manufacturing Industries Take Off in the Philippines).

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[i] See Williamson and Raman (2011) for a discussion of China's acquisition of foreign companies.

[ii] See *Economist* (2013) for a discussion of multinational firms choosing to have more of their manufacturing take place in developed countries.

U.S. Manufacturing and Employment

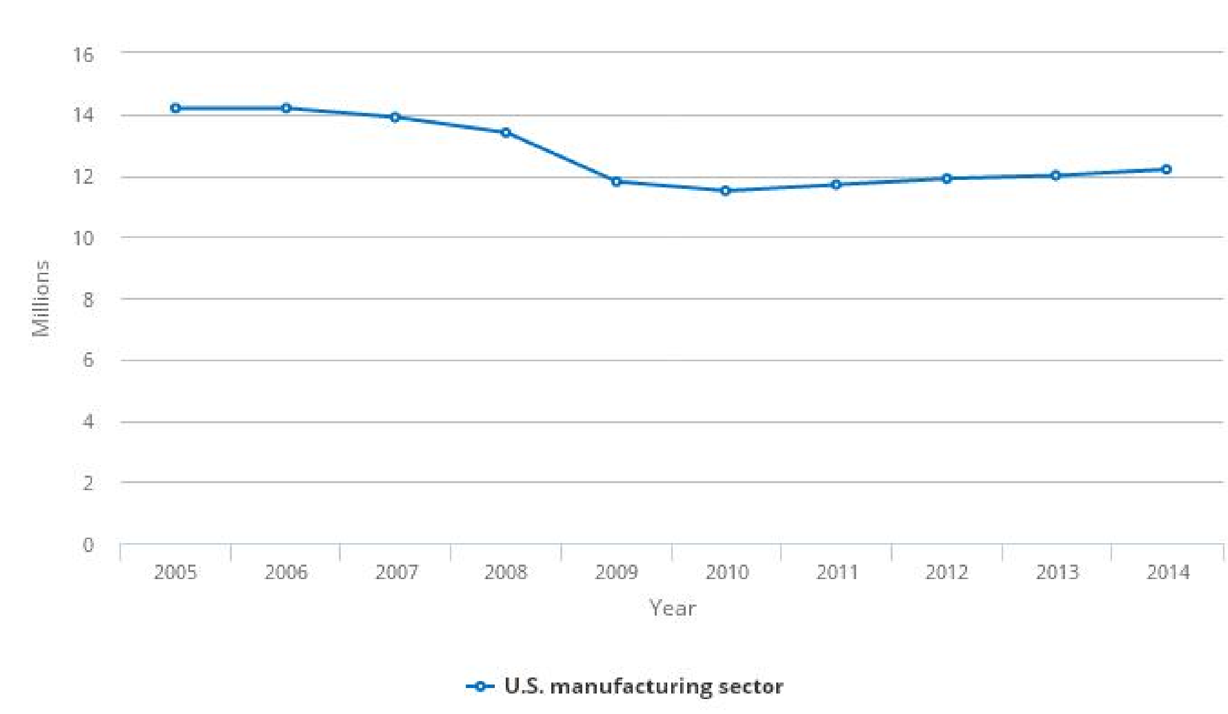
Several signs point to an increase in U.S. manufacturing activity after years of decline. After falling continuously in the previous decade, employment in the U.S. manufacturing sector increased somewhat in 2011–14, coinciding with a rebound in this sector's output after the 2008–09 global recession (Figure 6-D). However, employment in 2014 remains well below its pre-recession level. According to press reports, several firms, including Apple, General Electric, and Lenovo, are building new manufacturing facilities in the United States (Booth 2013:1). Some analysts and researchers predict a resurgence in U.S. manufacturing production, pointing to low transportation and energy costs, modest U.S. labor costs, and favorable currency exchange rates as factors conducive to manufacturing growth (PricewaterhouseCoopers 2012:3).

However, others doubt that there will be a large-scale relocation of manufacturing facilities in the United States or installation of new facilities. Even if there is significant increase in manufacturing production from relocation or new plants, some doubt that this will be accompanied by large-scale increases in employment. Many U.S. manufacturing industries are highly productive, which allows them to increase output substantially without increasing employment much. Although manufacturers in the United States and other high-income economies will continue to hire more high-skilled workers, manufacturing employment is likely to continue to decline over the next several decades due to further advances in productivity and global competitive pressures (McKinsey Global Institute 2012:4).

In interpreting recent trends in manufacturing production and employment, it is helpful to take into account that manufacturing's share of gross domestic product and the labor force has steadily declined in the United States and other advanced countries over the past several decades (Shipp et al. 2012:61). Even as its share of output and employment has declined, manufacturing continues to play a key role in innovation, productivity, and exports in developed countries.

Figure 6-D

U.S. manufacturing employment: 2005–14



SOURCE: U.S. Bureau of Labor Statistics, Current Employment Statistics, http://www.bls.gov/ces/.

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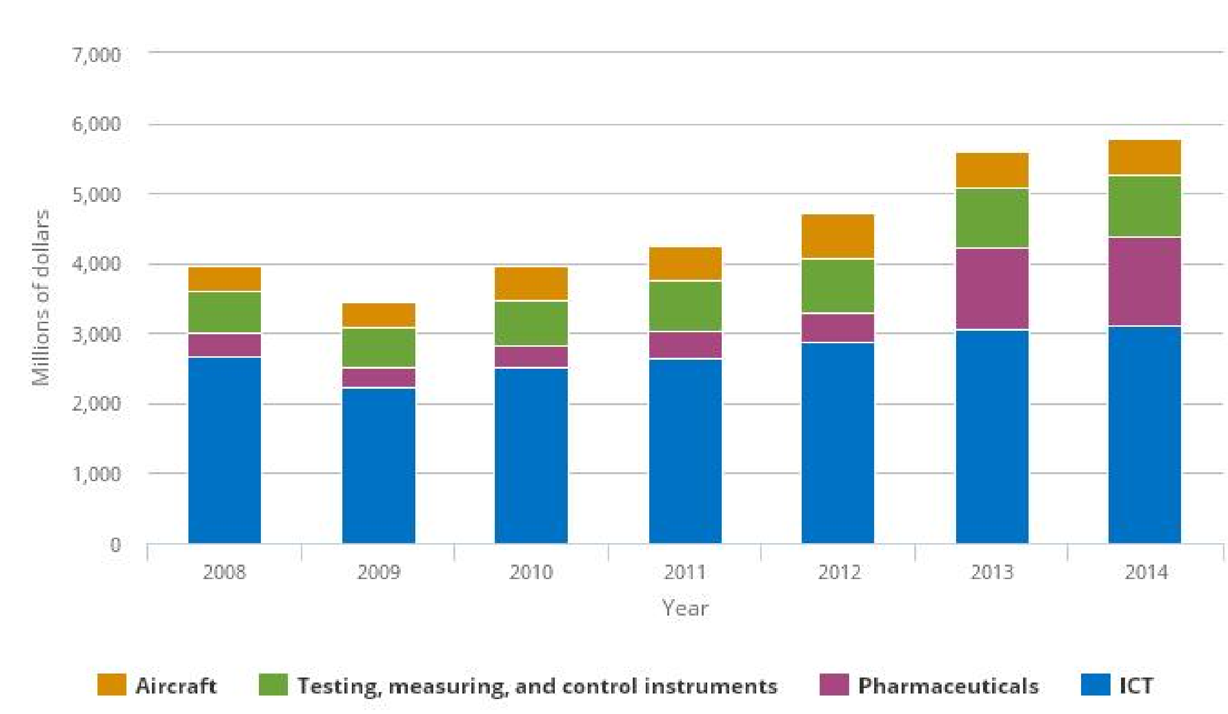
High-Technology Manufacturing Industries Take Off in the Philippines

The Philippines is a rapidly growing emerging economy that is transitioning from being primarily based on agriculture to being based more on services and trade. The value added of the Philippines' HT manufacturing industries expanded from $4.0 billion in 2008 to $5.8 billion in 2014, largely due to gains in communication goods and pharmaceuticals (Figure 6-E). The Philippines' market for pharmaceuticals is growing quickly because of rapid growing demand for health care, domestic manufacturing capability, and extensive involvement of foreign pharmaceutical companies. Multinationals have chosen to invest in the Philippines to capitalize on the growing domestic market and to use the Philippines as a launching pad into other Southeast Asian markets. Most multinationals import or distribute their finished drug products or outsource their production to local manufacturers. Production of communication goods has also risen rapidly because the Philippines has become a substantial producer of finished goods and supplier of intermediate inputs to "Factory Asia," the production network of electronics in East Asian countries (World Trade Organization and Institute of Developing Economies 2011:14–15).

Figure 6-E

HT manufacturing output of the Philippines: 2008–14



HT = high technology; ICT = information and communications technologies.

NOTES: Output is on a value-added basis. Value added is the amount contributed by a country, firm, or entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. ICT manufacturing industries consist of communications, computers, and semiconductors.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix tables 6-15–6-20.

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Trade and Other Globalization Indicators

The third section of this chapter examines several trade and globalization measures associated with KTI industries in the United States and other economies. (For an explanation of KTI industries, please see Chapter Overview.) In the modern world economy, production is more often *globalized* (i.e., value is added to a product or service in more than one nation) and less often *vertically integrated* (i.e., conducted under the auspices of a single company and its subsidiaries) than in the past. These trends have affected all industries, but their impact has been pronounced in many commercial KTI industries. The broader context is the rapid expansion of these industrial and service capabilities in many developing countries, both for export and internal consumption, accompanied by an increasing supply of skilled, internationally mobile workers. (See Chapter 3 for a discussion on the migration of highly skilled labor.)

This section focuses on cross-border trade of international KI services and HT trade. It also examines direct investment and other globalization measures of U.S. multinationals in KTI industries. Trade data are a useful though imperfect indicator of globalization (for a discussion, see sidebar, Measurement and Limitations of Trade Data).

This discussion of trade trends in KI services and HT manufactured products focuses on (1) the trading zones of the North American Free Trade Agreement (NAFTA), with a particular focus on the United States, and the EU; (2) China, which is rapidly taking on an increasingly important role in KTI trade; (3) Japan and other Asian economies; and (4) large developing countries, including Brazil and India.

The EU, East Asia, and NAFTA have substantial volumes of intraregional trade. This section treats trade within these three regions in different ways. Intra-EU and NAFTA exports are not counted because they are integrated trading zones with common external trade tariffs and few restrictions on intraregional trade. This kind of trade is treated as essentially equivalent to trade between China and Hong Kong, which is excluded because it is essentially intra-economy trade. (Data on trade in commercial KI services between China and Hong Kong are not available.) Intra-Asian trade is counted for other Asian countries because they have a far smaller degree of political and trade integration.

Measurement and Limitations of Trade Data

Trade data are based on a classification of goods or services themselves, rather than industry sectors. In the case of product trade, trade is assigned one product code according to the Harmonized Commodity Description and Coding System, or Harmonized System (HS).* The product classification of trade is fundamentally different from the industry classification used in the last section, which is based on the primary activity of the industry that produced a product and not on the characteristics of the product itself. Thus, the two classifications cannot be mapped onto each other. For example, an export classified as a computer service in the product-based system may be considered computer manufacturing in the industrial classification because it originated from a firm in that industry.

Data on exports and imports represent the market value of products and services in international trade. Exports of products are assigned by the importing country’s port of entry to a single country of origin. For goods manufactured in multiple countries, the country of origin is determined by where the product was “substantially transformed” into its final form.

The value of product trade entering or exiting a country's ports may include the value of components, inputs, or services classified in different product categories or originating from countries other than the country of origin. For example, China is credited with the full value (i.e., factory price plus shipping cost) of a smartphone when it is assembled in China, though made with components imported from other countries. In these data, countries whose firms provide high-value services such as design, marketing, and software development are typically not credited for these contributions.

* HS is used to classify goods traded internationally and was developed under the auspices of the Customs Co-operation Council. Beginning on 1 January 1989, HS numbers replaced schedules previously adhered to in more than 50 countries, including the United States. For more information, see http://www.census.gov /foreign-trade/guide/sec2.html#htsusa.

Global Trade in Commercial Knowledge- and Technology-Intensive Goods and Services

Exported goods and services to other countries are one measure of a country's economic success in the global market because exports capture the country's products that compete in the world market. In addition, exports bring in income from external sources and do not consume the income of a nation's own residents.

Global trade in commercial KTI goods and services consists of four services—communications, computer and information, finance, and other business—and six HT products—aerospace; communications; computers; pharmaceuticals; semiconductors; and testing, measuring, and control instruments.[i] Global cross-border exports of commercial KTI goods and services were an estimated $4.0 trillion, consisting of $1.6 trillion of commercial KI services and $2.4 trillion of exports of HT products (Appendix Table 6-19, and Appendix Table 6-20).

Commercial Knowledge-Intensive Services

Global exports of commercial KI services make up 44% of all commercial services. The commercial KI services share of services exports has risen from 38% to 44% during the last decade, a rise that coincided with the growth of companies contracting these services to companies in other countries. Among the commercial KI services, the largest was other business services, which include R&D services, architectural, engineering, and other technical services ($944 billion). The other three services are finance (which includes insurance) ($321 billion), computer and information services ($192 billion), and communications ($86 billion) (Appendix Table 6-21, Appendix Table 6-22, Appendix Table 6-23, and Appendix Table 6-24).

The EU was the largest exporter of commercial KI services, with a global share of 31% in 2013 (Figure 6-16). The United States was the second largest at 17%. Both had surpluses in trade of commercial KI services, in contrast to their deficits in HT product trade (Table 6-2).[ii] China and India, tying for third place, each had a 7% global export share (Table 6-3; Figure 6-16). India had a substantial surplus in trade of commercial KI services.

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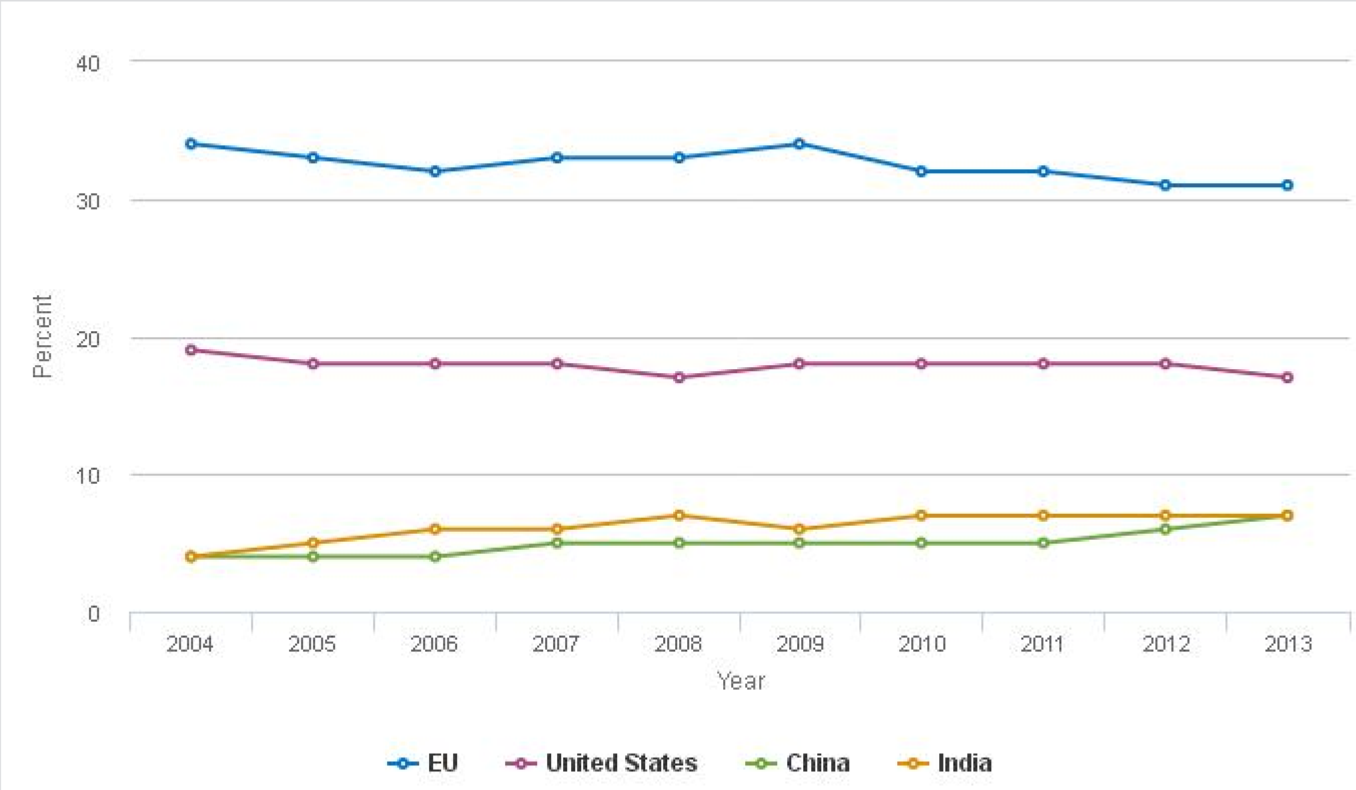
[i] Other business services includes trade-related services, operational leasing (rentals), and miscellaneous business; professional and technical services such as legal, accounting, management consulting, public relations services, advertising, market research and public opinion polling; R&D services; architectural, engineering, and other technical services; and agricultural, mining, and on-site processing.

[ii] A trade surplus occurs when exports exceed imports. A trade deficit occurs when imports exceed exports.

Figure 6-16

Commercial KI service exports, by selected region/country/economy: 2004–13



EU = European Union; KI = knowledge intensive.

NOTES: Commercial KI service exports consist of communications, business services, financial services, and computer and information services. Financial services includes finance and insurance services. EU exports do not include intra-EU exports.

SOURCE: World Trade Organization, International trade and tariff data, http://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 15 February 2015.

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Table 6-2 U.S. and EU commercial KI services trade, by category: 2013

(Billions of dollars)

	United States			EU		
Category	Exports	Imports	Balance	Exports	Imports	Balance
United States						
All commercial KI services	270.8	196.4	74.4	482.4	288.9	193.5
Computer and information services	18.2	26.3	-8.1	62.5	25.9	36.6
Financial services	99.5	68.5	31.0	103.9	41.3	62.6
Other business services	138.2	93.0	45.2	283.9	195.9	88.0

	United States			EU		
Category	Exports	Imports	Balance	Exports	Imports	Balance
Communications services	14.8	8.6	6.2	32.0	25.7	6.3

NOTES: EU = European Union; KI = knowledge intensive.
Commercial KI services trade consists of communications, other business services, financial services, and computer and information services. Financial services includes finance and insurance. EU trade does not include intra-EU trade.

SOURCE: World Trade Organization, International trade and tariff data, http://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 15 February 2015.

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Table 6-3 **India's and China's trade in commercial KI services: 2013**

(Billions of dollars)

	India			China		
Category	Exports	Imports	Balance	Exports	Imports	Balance
All commercial KI services	111	43	67.5	104	81	23.0
Communications services	2.2	1.1	1.1	1.7	1.6	0.1
Computer information services	50	3	46.9	15	6	9.5
Financial services	8	11	-3.4	7	26	-18.6
Other business services	50.9	28.0	23.0	79.5	47.5	32.0

NOTES: KI = knowledge intensive.
Commercial KI services trade consists of communications, business services, financial services, computer and information services, and other business services. Financial services includes finance and insurance.

SOURCE: World Trade Organization, International trade and tariff data, http://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 15 February 2015.

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Trends of major exporters. From 2004 to 2013, the EU's exports of commercial KI services more than doubled to $482 billion (Table 6-2; Appendix Table 6-19). This was driven by growth of other business services exports (Appendix Table 6-24). The EU's trade surplus widened in all major components of commercial KI services.

Over the same period, U.S. exports of commercial KI services more than doubled to reach $271 billion (Table 6-2; Appendix Table 6-19). This was spurred by growth in financial and business services (Appendix Table 6-23 and Appendix Table 6-24). The U.S. trade surplus widened in other business, finance, and communications services (Appendix Table 6-22) (for U.S. exports of R&D services, see sidebar, U.S. Trade in R&D Services).

Growth of China's exports resulted in its global share rising to 7% (Table 6-3; Figure 6-16). Similar to China, India's exports reached 7% of the global total. India became the world's second-largest exporter of computer and information services (26% global share), behind the EU (Appendix Table 6-21).

U.S. Trade in R&D Services

Trade in R&D services, part of U.S. trade in business services, occurs mostly within multinational companies (MNCs). In 2013, companies located in the United States exported $30 billion in these services and imported $32 billion, based on U.S. Bureau of Economic Analysis statistics (Appendix Table 6-25).

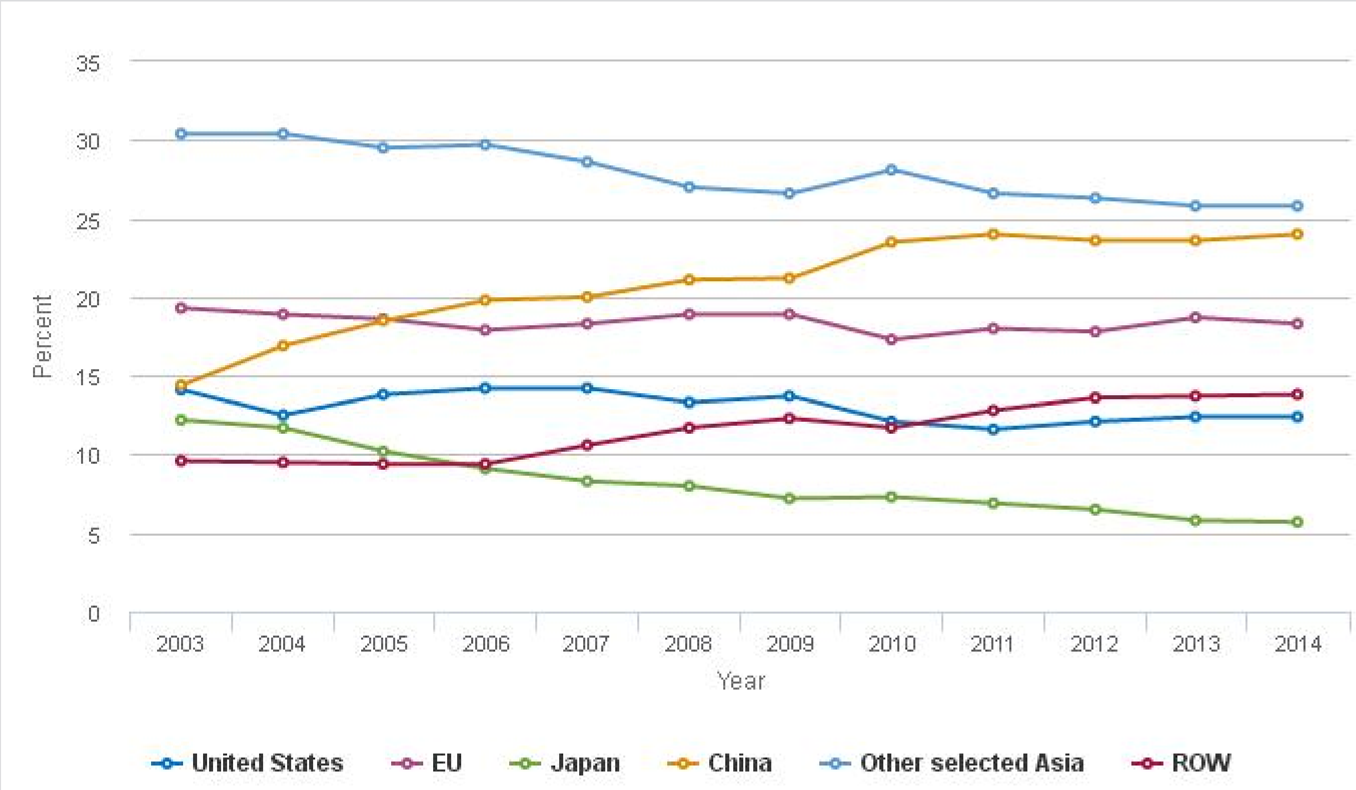
The European Union was the top destination for more than 40% of U.S. R&D services exports in 2013 and led U.S. imports (55%). Asia-Pacific was the second-largest destination for U.S. R&D services exports (16%) and provided 23% of U.S. imports. Among the Asian economies, Japan accounted for 10% of U.S. R&D services exports and 4% of U.S. imports. Although their shares of U.S. exports were negligible, China and India each provided 6% and 8%, respectively, of U.S. imports (see the "Cross-National Comparisons of R&D Performance" and "R&D by Multinational Enterprises" sections in chapter 4).

High-Technology Products

The global HT product export volume ($2.4 trillion in 2014) was dominated by ICT products—communications, computers, and semiconductors—with a collective value of $1.3 trillion, more than half of the total in this category. Aircraft and spacecraft; pharmaceuticals; and testing, measuring, and control instruments combined added about $1.1 trillion in 2014. HT product exports accounted for just 12% of the $20.0 trillion in total manufactured goods exports (Figure 6-17; Appendix Table 6-20 and Appendix Table 6-26, Appendix Table 6-27, Appendix Table 6-28, Appendix Table 6-29, Appendix Table 6-30, Appendix Table 6-31, Appendix Table 6-32, and Appendix Table 6-33).

Figure 6-17

Exports of HT products, by selected region/country/economy: 2003–14



EU = European Union; HT = high technology; ROW = rest of world.

NOTES: HT products include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. China includes Hong Kong. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Exports of the United States exclude exports to Canada and Mexico. Exports of the EU exclude intra-EU exports. Exports of China exclude exports between China and Hong Kong. Other selected Asia consists of Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand.

SOURCE: IHS Global Insight, World Trade Service database (2014). See appendix table 6-20.

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China is the world's largest exporter of HT goods and has a substantial surplus (Table 6-4; Figure 6-17 and Figure 6-18; Appendix Table 6-20). The EU and the United States are the second- and third-largest global exporters; they both have trade deficits. Taiwan, Japan, and South Korea are the next-largest exporters, each with a global share between 6% and 9%. For a list of regions and countries/economies in world trade data, see Appendix Table 6-34.

Table 6-4 Exports and trade balance of HT products, by selected product and region/country/economy: 2014

(Billions of dollars)

Region/country /economy	ICT products		Pharmaceuticals		Testing, measuring, and control instruments		Aircraft and spacecraft	
	Exports	Balance	Exports	Balance	Exports	Balance	Exports	Balance
United States	69.1	-108.3	47.7	-21.2	65.3	9.2	119.7	79.4
EU	82.4	-133.6	151.8	70.3	97.1	21.7	115.2	60.1
Japan	74.7	-8.1	5.3	-17.5	49.5	19.1	10.0	-2.0
China	497.5	201.2	14.9	0.3	69.1	-37.7	5.6	-34.5
Other selected Asia	501.3	245.0	18.5	1.3	98.3	39.4	10.7	-26.2

EU = European Union; HT = high technology; ICT = information and communications technology.

NOTES: HT products include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. China includes Hong Kong. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Exports of the United States exclude exports to Canada and Mexico. Exports of the EU exclude intra-EU exports. Exports of China exclude exports between China and Hong Kong. Other selected Asia consists of Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand.

SOURCE: IHS Global Insight, World Trade Service database (2014). See appendix table 6-20.

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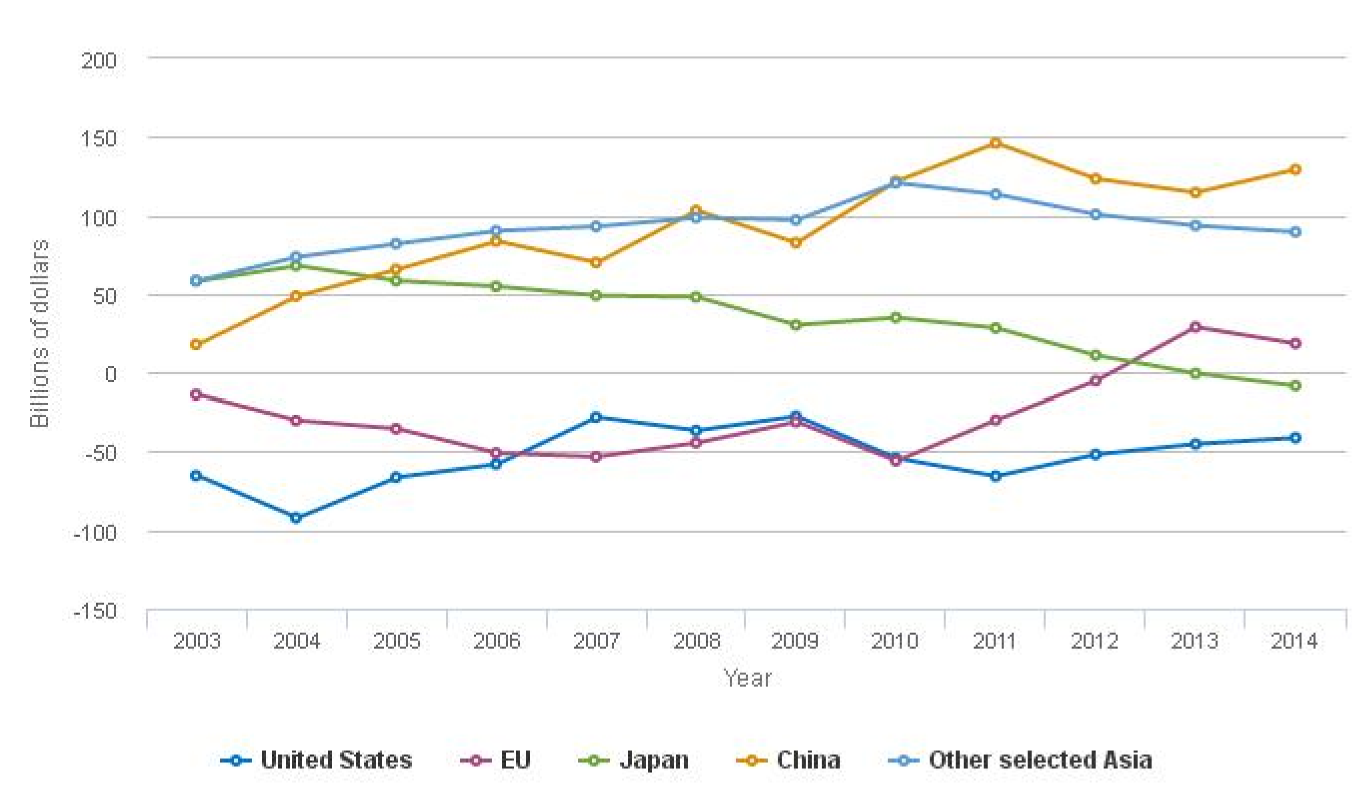
Figure 6-18

Trade balance of HT products, by selected region/country/economy: 2003–14



EU = European Union; HT = high technology.

NOTES: HT products include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. China includes Hong Kong. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Exports of the United States exclude exports to Canada and Mexico. Exports of the EU exclude intra-EU exports. Exports of China exclude exports between China and Hong Kong. Other selected Asia consists of Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand.

SOURCE: IHS Global Insight, World Trade Service database (2014). See appendix table 6-20.

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Trends of major exporters. China's HT products exports grew by more than threefold, pushing its global share from 14% in 2003 to 24% in 2014 (Figure 6-17; Appendix Table 6-20). However, because many of China's exports consist of inputs and components imported from other countries, China's exports and trade surplus are likely much less in value-added terms (see sidebar, International Initiative to Measure Trade in Value-Added Terms).

China's ICT exports, which dominate China's HT product exports, more than tripled to reach almost $500 billion over the last decade (Table 6-4; Appendix Table 6-27, Appendix Table 6-28, Appendix Table 6-29, and Appendix Table 6-30). China's ICT trade surplus expanded from almost $30 billion to more than $200 billion. Its exports of testing, measuring, and control instruments grew at the same pace to reach almost $70 billion (Appendix Table 6-31).

In the United States, HT product exports nearly doubled to reach $302 billion between 2003 and 2014 (Appendix Table 6-20). The U.S. global share slipped from 14% to 12%. The U.S. HT product trade deficit narrowed slightly (from $65 billion in 2003 to $41 billion in 2014) (Figure 6-18).[iii]

U.S. growth of HT product exports was led by pharmaceuticals and aircraft (Appendix Table 6-32 and Appendix Table 6-33). Exports of aircraft climbed to $120 billion, and the related trade surplus widened from $29 billion to $80 billion. Pharmaceutical exports nearly tripled in value to reach $48 billion. Growth of ICT product exports was stagnant between 2003 and 2014 as production of ICT goods migrated to China and other locations (Appendix Table 6-27, Appendix Table 6-28, Appendix Table 6-29, and Appendix Table 6-30). The U.S. trade deficit in ICT products widened from $79 billion to $108 billion (Table 6-4).

The EU's HT exports grew slightly faster than those of the United States over the last decade, and the EU's global share remained stable at 18%. Testing, measuring, and control instruments; pharmaceuticals; and aircraft drove the growth of the EU's HT exports (Table 6-4; Appendix Table 6-31, Appendix Table 6-32, and Appendix Table 6-33). The trade surpluses in these three products widened substantially. Exports of ICT products were flat, and the EU's trade deficit widened during this period (Appendix Table 6-27, Appendix Table 6-28, Appendix Table 6-29, and Appendix Table 6-30).

Japan's exports trailed the average for all developed countries, with its global share falling from 12% to 6%. Japan's decline from an export powerhouse in electronics reflects its lengthy economic stagnation, the financial difficulties of Japanese electronics firms, and Japanese companies moving their production to Taiwan, China, and other lower-cost locations.

Taiwan's HT exports more than doubled during this period, and it surpassed Japan in 2009 to become the largest developed Asian exporter of HT products. South Korea's HT exports nearly doubled, and it reached Japan's level in 2013. South Korea and Taiwan's rapid gains in HT exports were due to growth of ICT product exports (Appendix Table 6-27, Appendix Table 6-28, Appendix Table 6-29, and Appendix Table 6-30).

Vietnam grew the fastest of any developing country, with its HT exports increasing from less than $1 billion to $39 billion. Vietnam has become a low-cost location for assembly of cell phones and other ICT products, with some firms shifting production out of China, where labor costs are higher. India's exports rose sevenfold to reach $28 billion because of expansion in pharmaceuticals and ICT products.

[iii] The U.S. trade balance is affected by many factors, including currency fluctuations, differing fiscal and monetary policies, and export subsidies and trade restrictions between the United States and its trading partners.

International Initiative to Measure Trade in Value-Added Terms

Manufactured goods increasingly embody elements produced by global supply chains, and the conventional trade measures used here count the gross value of both intermediate and final goods upon crossing international borders. The Trade in Value Added joint initiative of the Organisation for Economic Co-operation and Development (OECD) and the World Trade Organization (WTO) aims to correct this shortcoming by recording only net value added at each crossing. This approach has two advantages: First, it provides more accurate measures of global trade volumes; and second, it makes possible better estimates of national contributions to the value of goods and services in international trade.

The iPhone offers a simple example. The conventional measures show a large trade deficit with China, the point of final assembly. The OECD's estimate, net of value added by supplier economies, shows a much smaller estimated trade deficit with China and larger trade deficits with countries that supply inputs to the iPhone (Table 6-D).

OECD/WTO estimates of trade in value-added terms are derived from OECD country-level input-output tables. Input-output tables track the interrelationships among domestic industries and between domestic industries and consumers—households, government, industry, and export customers.

The most recent version of the OECD/WTO database, released in October 2015, covers 61 economies (including all OECD countries, Brazil, China, India, Indonesia, Russia, and South Africa) and the years 1995, 2000, 2005, and 2008–2011. Trade in value-added indicators and additional information are available at http://www.oecd.org/industry/ind/measuringtradeinvalue-addedanoecd-wtojointinitiative.htm.

Table 6-D U.S. trade balance in iPhones, by selected country/economy

(Millions of dollars)

Type of trade	China	Germany	South Korea	Taiwan	ROW
Balance (gross)	-1,646	0	0	0	0
Balance (value added)	-65	-161	-800	-207	-413

ROW = rest of world.

SOURCE: Organisation for Economic Co-operation and Development, Trade in Value-Added: Concepts, Methodologies and Challenges, http://www.oecd.org/sti/ind/49894138.pdf, accessed 15 March 2013.

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Multinational Companies in U.S. Knowledge- and Technology-Intensive Industries

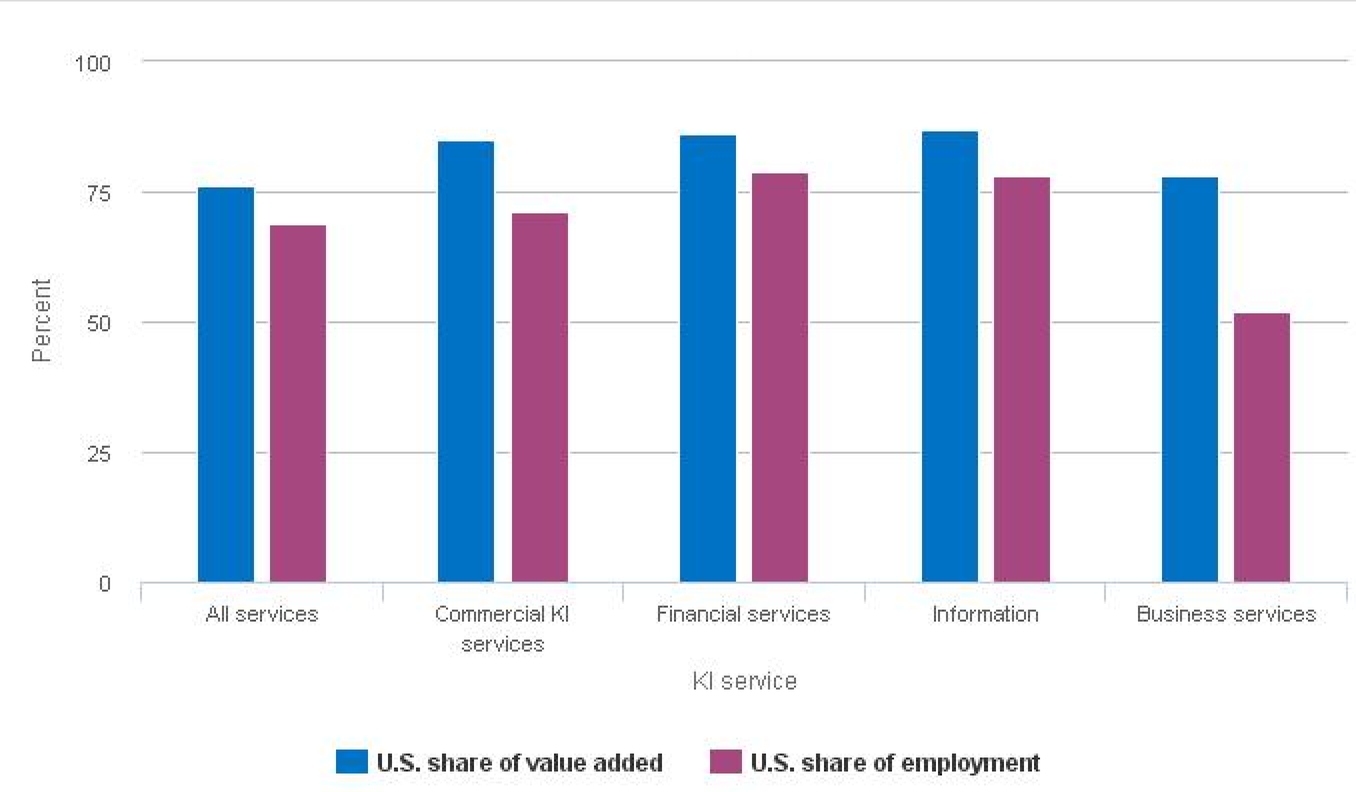
U.S. Bureau of Economic Analysis (BEA) data on multinational companies in KTI industries are not directly comparable with the world industry data used in the previous sections. However, BEA data provide additional information on the globalization of activity and employment and direct investment of MNCs operating in the United States and the activities of U.S. MNCs outside of the United States in these industries.

Commercial Knowledge-Intensive Services Industries

U.S. multinationals in commercial KI services industries—financial, business, and information services—generated $1.3 trillion in value added and employed 7.9 million workers worldwide in 2013 (Appendix Table 6-35). Production and employment are concentrated in the United States. The U.S. share of worldwide value added was highest in information services and financial services (86%–87% each) and accounted for 78% of business and financial services in 2013 (Figure 6-19; Appendix Table 6-35). Information and financial services also had the highest shares of U.S. employment (78%–79%). Business services had a considerably lower share (52%).

Figure 6-19

Globalization indicators of U.S. multinationals in commercial KI services: 2013



KI = knowledge intensive.

NOTES: Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. Commercial KI services are classified by the Organisation for Economic Co-operation and Development and include business, financial, and information. Internet and data processing are part of communications. Management, scientific, and technical and computer system design are part of business services.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, U.S. Direct Investment Abroad: Activities of U.S. Multinational Enterprises, Financial and Operating Data for U.S. Multinational Companies (2009–13), http://www.bea.gov /international/di1usdop.htm, accessed 15 February 2015. See appendix table 6-35.

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High-Technology Manufacturing Industries

U.S. multinationals in the HT manufacturing industries (excluding aircraft and spacecraft) generated nearly $500 billion and employed 2.2 million workers worldwide in 2013 (Figure 6-20; Appendix Table 6-35).[i] Production and employment of HT manufacturing industries is less concentrated in the United States than commercial KI services, especially in employment (Appendix Table 6-35). The U.S. share of value-added output is highest in semiconductors (84%), followed by pharmaceuticals (82%). The U.S. share of employment is less than half in navigational, measuring, and other instruments, and accounts for half of the communications workforce.

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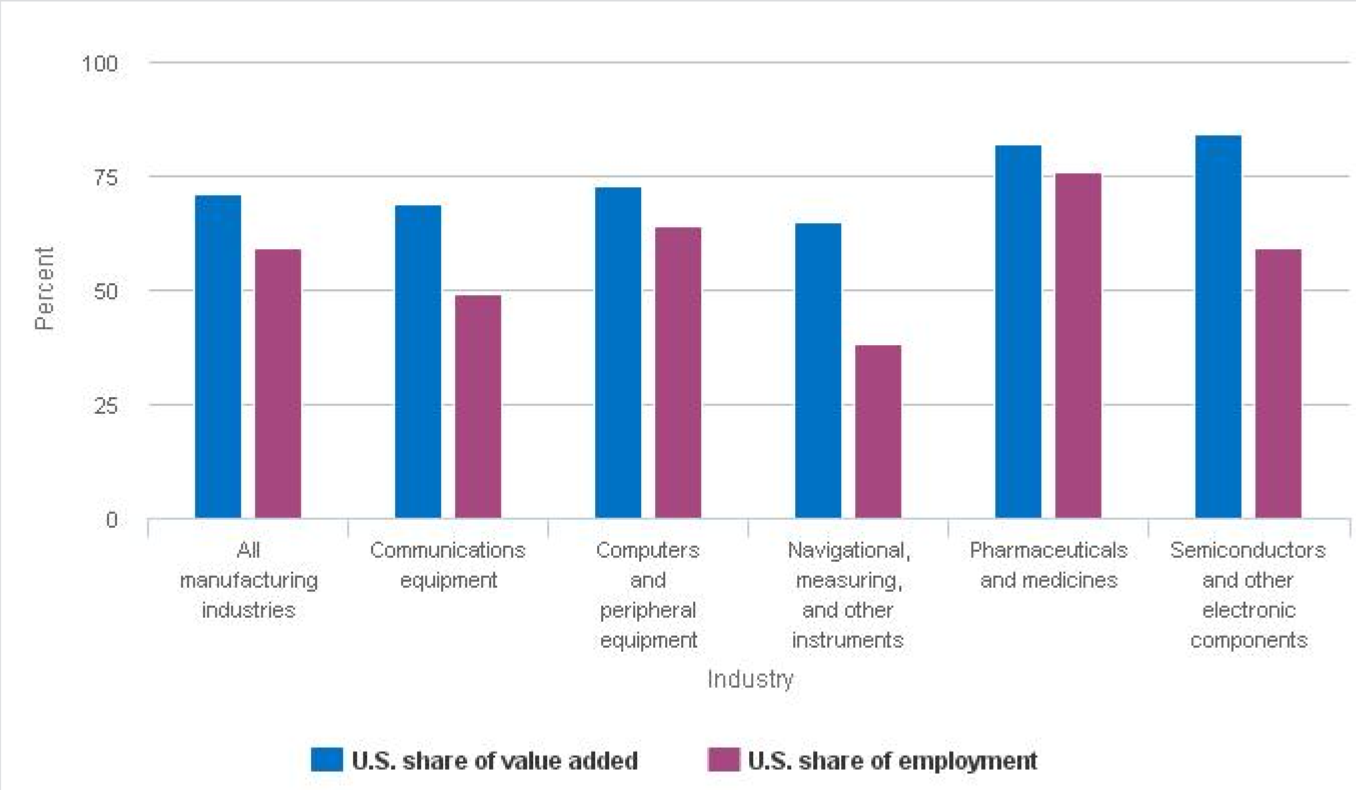
[i] Bureau of Economic Analysis data on inward and outward direct investment in aircraft and spacecraft are not available.

Figure 6-20

Globalization indicators of U.S. multinationals in selected manufacturing industries: 2013



NOTE: Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, U.S. Direct Investment Abroad: Activities of U.S. Multinational Enterprises, Financial and Operating Data for U.S. Multinational Companies (2009–13), http://www.bea.gov /international/di1usdop.htm, accessed 15 February 2015. See appendix table 6-35.

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U.S. Direct Investment Abroad

The stock of U.S. direct investment abroad in computer and electronic products, which includes the HT industries of communications; semiconductors; and testing, measuring, and control instruments, was $97 billion in 2013 (Table 6-5), with just over half going to the Asia and Pacific region.[ii] Singapore was the largest recipient in this region (19%), followed by China (8%) and Japan (6%). The EU received about a third.

[ii] The Asia and Pacific region includes Australia, China, Hong Kong, India, Indonesia, Japan, Malaysia, New Zealand, the Philippines, Singapore, South Korea, Taiwan, and Thailand.

Table 6-5 **U.S. outward foreign direct investment in selected industries and regions /countries: 2013**

(Percent)

Region/country	Computers and electronic products	Information	Finance	Professional, scientific, and technical services
All countries total ($billions)	96.9	157.5	767.2	98.8
Selected regions/countries (share of total)				
EU	31.9	55.1	41.9	52.3
Asia and Pacific	51.5	21.3	16.9	28.7
China	8.1	5.7	1.4	3.2
India	0.4	-1.0	0.4	11.2
Japan	5.8	4.0	9.4	2.1
Singapore	19.4	3.3	2.1	0.9
South Korea	3.2	0.1	0.7	0.6
All others	14.6	9.2	2.9	10.7

EU = European Union.

NOTES: Data are preliminary. Outward foreign investment is on a historical cost-position basis. Finance excludes depository institutions. All others includes Australia, Indonesia, Malaysia, New Zealand, Philippines, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, U.S. Direct Investment Abroad: Activities of U.S. Multinational Enterprises, Financial and Operating Data for U.S. Multinational Companies (2009–13), http://www.bea.gov/international/di1usdop.htm, accessed 15 February 2015.

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The stock of U.S. direct investment abroad in information; finance; and professional, scientific, and technical services, which comprise commercial KI services industries, was $1.0 trillion in 2013 (Table 6-5). Financial services accounted for most U.S. direct investment abroad, with far smaller stocks for information and professional, scientific, and technical services. The EU is the largest recipient in these three industries, with shares ranging from 42% to 55%. The Asia and Pacific region, including Japan, is the next largest, with shares of 17%–29% in these industries. India received a sizable amount of U.S. foreign direct investment (FDI) in professional, scientific, and technical services.

Foreign Direct Investment in the United States

The stock of inward FDI in U.S. computer electronics manufacturing industries was $49 billion in 2013, less than the amount the United States invested abroad in these industries (Table 6-5 and Table 6-6). Limited data on the geographic region show that the Asia and Pacific region is a major investor, with a share of 37%. Japan has a share of 20% in FDI in this industry.

Table 6-6 **Foreign direct investment in selected U.S. industries, by selected region/country: 2013**

(Percent)

Region/country	Computers and electronic products	Information	Finance	Professional, scientific, and technical services
All countries total ($billions)	49.4	148.6	364.7	104.2

Region/country	Computers and electronic products	Information	Finance	Professional, scientific, and technical services
Selected regions/countries (share of total)				
EU	na	na	63.0	80.0
Asia and Pacific	37.0	18.0	11.0	na
China	0.0	na	na	na
India	0.0	0.0	na	3.0
Japan	20.0	na	9.0	7.0
Singapore	na	0.0	na	0.3
South Korea	0.1	0.0	0.1	0.0
All others	na	na	na	na

NOTES: na = not applicable.
EU = European Union.
Data are preliminary. Foreign direct investment is on a historical cost-position basis. Finance excludes depository institutions. All others includes Australia, Indonesia, Malaysia, New Zealand, Philippines, Taiwan, and Thailand.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, Foreign Direct Investment in the U.S.: Balance of Payments and Direct Investment Position Data, http://www.bea.gov/international/di1fdibal.htm, accessed 15 February 2015.

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Similarly, the stock of inward FDI in U.S. commercial KI services, at $618 billion in 2013, was less than the amount the United States invested abroad in these industries (Table 6-5 and Table 6-6). The EU is the largest investor in finance and professional, scientific, and technical services. The Asia and Pacific region accounts for 18% of investment in information services.

Innovation-Related Indicators of the United States and Other Major Economies

The fourth section of this chapter examines several innovation-related measures in industry, with a focus on KTI industries. The OECD defines innovation as the "implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method" (OECD/Eurostat 2005:46–47). Innovation is widely recognized as instrumental to realizing commercial value in the marketplace and as a driver of economic growth. New ICT, for example, has stimulated the creation of new products, services, and industries that have transformed the world economy over the past several decades.

This section will present data on how innovation activity varies among U.S. industries, using information from NSF's Business R&D and Innovation Survey (BRDIS) (see sidebar, Data Sources).[i] The section also includes three indicators of activities that can facilitate innovation but do not themselves constitute innovation. Two of these, patents and trade in royalties and fees, are indicators of invention—they protect intellectual property in inventions that can have value for commercial innovations. The third indicator concerns venture capital financing for U.S. HT small businesses, which can help bring new products and services to market.

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[i] The NSF BRDIS definition of innovation is very similar to the OECD definition.

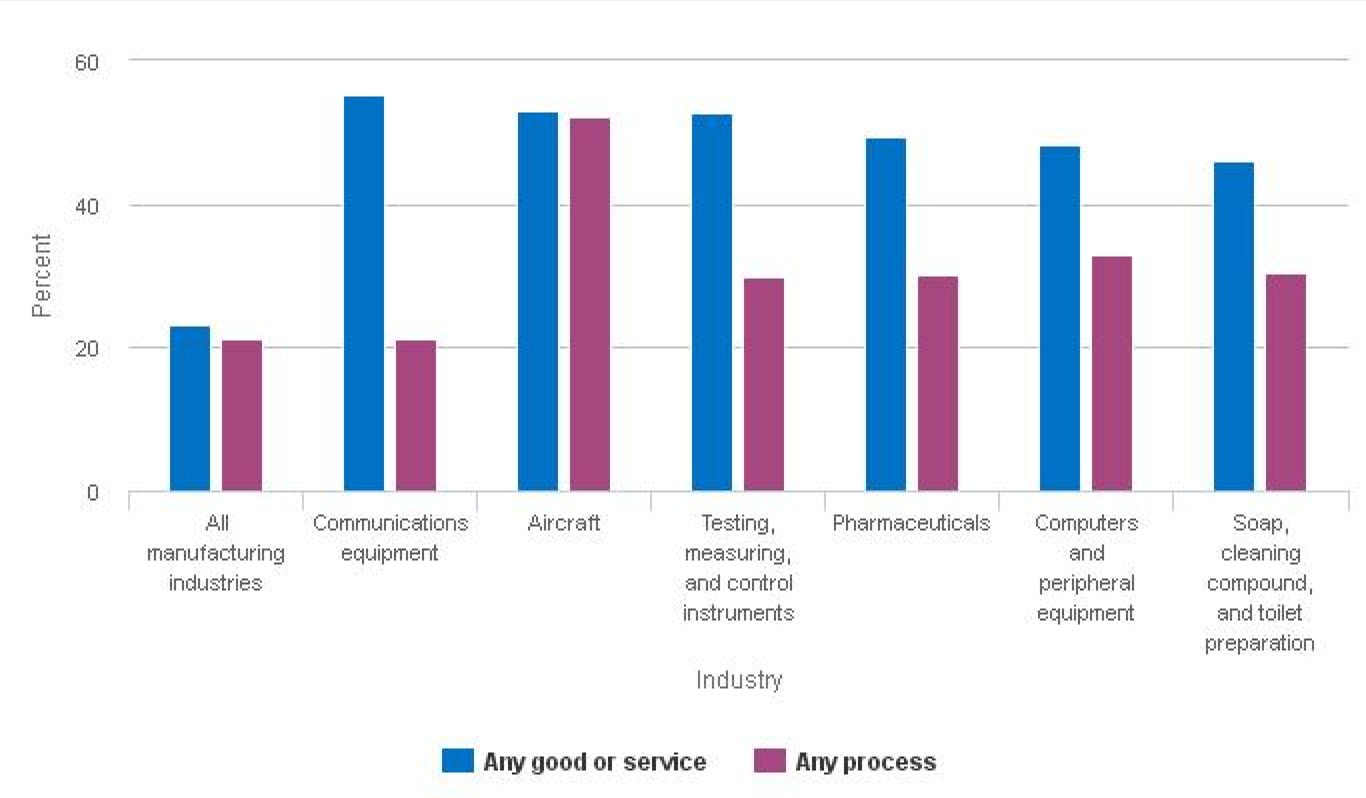
Innovation Activities by U.S. Businesses

U.S. KTI industries have a much higher incidence of innovation—introducing new products, services, or processes—than other industries.

The five U.S. HT manufacturing industries—aircraft; communications and semiconductors; computers; pharmaceuticals; and testing, measuring, and control instruments—reported rates of product innovation that were at least double the manufacturing sector average (Figure 6-21). Most of these industries reported significantly higher rates of innovation in both goods and services, suggesting that high rates of innovation by manufacturing companies go hand-in-hand with innovations in services. Most of these industries also reported higher-than-average rates of process innovations, particularly in production methods, logistics, and delivery methods.

Figure 6-21

Share of U.S. manufacturing companies reporting innovation activities, by selected industry: 2008–10



NOTES: The survey asked companies to identify innovations introduced from 2008 to 2010. Data may not be internationally comparable.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey (2010).

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Innovation is also higher in several commercial KI services industries in comparison with other nonmanufacturing industries (Figure 6-22).[i] Software firms lead in incidence of innovation, with 69% of companies reporting the introduction of a new product or service, compared with the 9% average for all nonmanufacturing industries. Innovation is also three to four times higher than the nonmanufacturing average in three other industries—computer systems design, data processing and hosting, and scientific R&D services.

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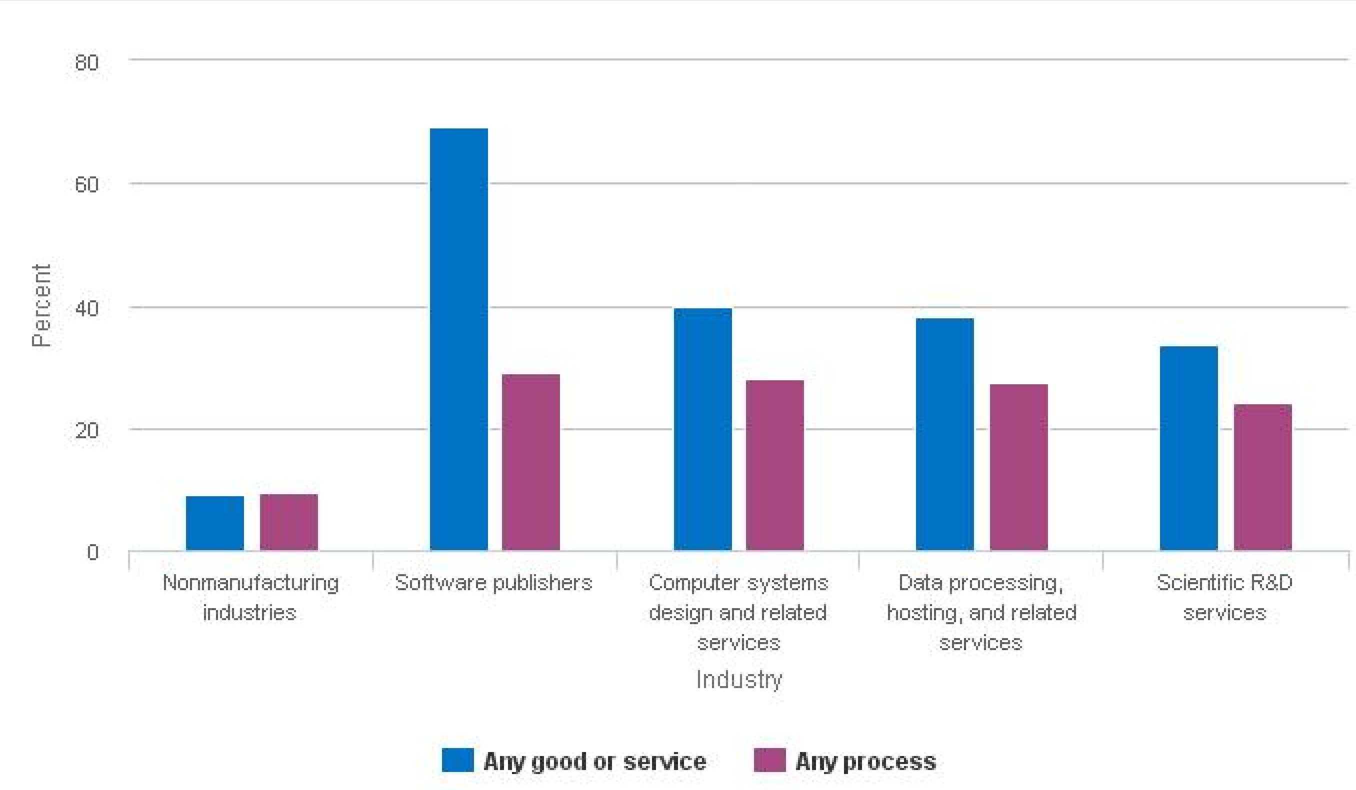
[i] BRDIS data are not available for the entire U.S. service sector.

Figure 6-22

Share of U.S. nonmanufacturing companies reporting innovation activities, by selected industry: 2008–10



NOTES: The survey asked companies to identify innovations introduced from 2008 to 2010. The sum of yes plus no percentages may not add to 100% because of item nonresponse to some innovation question items. Figures are preliminary and may later be revised. Data may not be internationally comparable.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey (2010).

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Global Trends in Patenting

Nations assign patents to inventors to exclude others from making, using, or selling the invention for a limited period in exchange for publicly disclosing details and licensing the use of the invention.

Patents are a rough and incomplete indicator of innovation. Although patents of commercialized inventions provide important information on innovation, most patented inventions are never commercialized. Conversely, many products, services, and processes that are commercialized are not patented. Companies may choose different means to protect their intellectual property and innovation activities; for example, using trade secrets or copyrights (Figure 6-23). In addition, technical standards are considered important for innovation and may have greater impact on economic growth than patents (see sidebar, Technical Standards, Innovation, and Economic Growth).

Technical Standards, Innovation, and Economic Growth

A technical standard is "a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose."* Standards are widely used in industries and firms that produce, use, or rely on information and communications technologies.

One example of a technical standard is Apple's operating system for the iPhone, which governs the interface and function of the large number of iPhone applications (apps). Apple's technical standards allow a large number of companies and developers to provide apps that increase the utility, value, and desirability of the iPhone.

The number of standards is proliferating in the global economy, coinciding with the globalization of HT value chains and the complexity and persuasiveness of technologies embedded in products and services. For example, the semiconductor industry is estimated to have at least 1,000 standards.

Standards increase industry growth and productivity, which can increase a country's economic growth. The wide-ranging impacts of standards include the following (Tassey 2015:189–90):

- Raising the efficiency of R&D
- Expanding existing markets and creating new markets for an industry's products and services
- Increasing the growth and productivity of incumbent firms
- Facilitating the entry of small and medium-sized firms, which can increase innovation and growth of the entire industry

Standards consist of two types: product and nonproduct. Product standards govern the performance and function of components used in HT products and prescribe procedures to test product development, production, and market transactions. In the United States, businesses have typically developed product standards by reaching voluntary consensus with relevant stakeholders, including firms in the industry, suppliers, and R&D laboratories.

Nonproduct standards have more general and broader functions than product standards. These standards generally govern the efficiency, operation, and performance of the entire industry. Examples include measurement and test methods, interface standards, scientific and engineering databases, and standard reference materials (Tassey 2015:192). Nonproduct standards have become increasingly important because many HT products are a complex mix of goods and services.

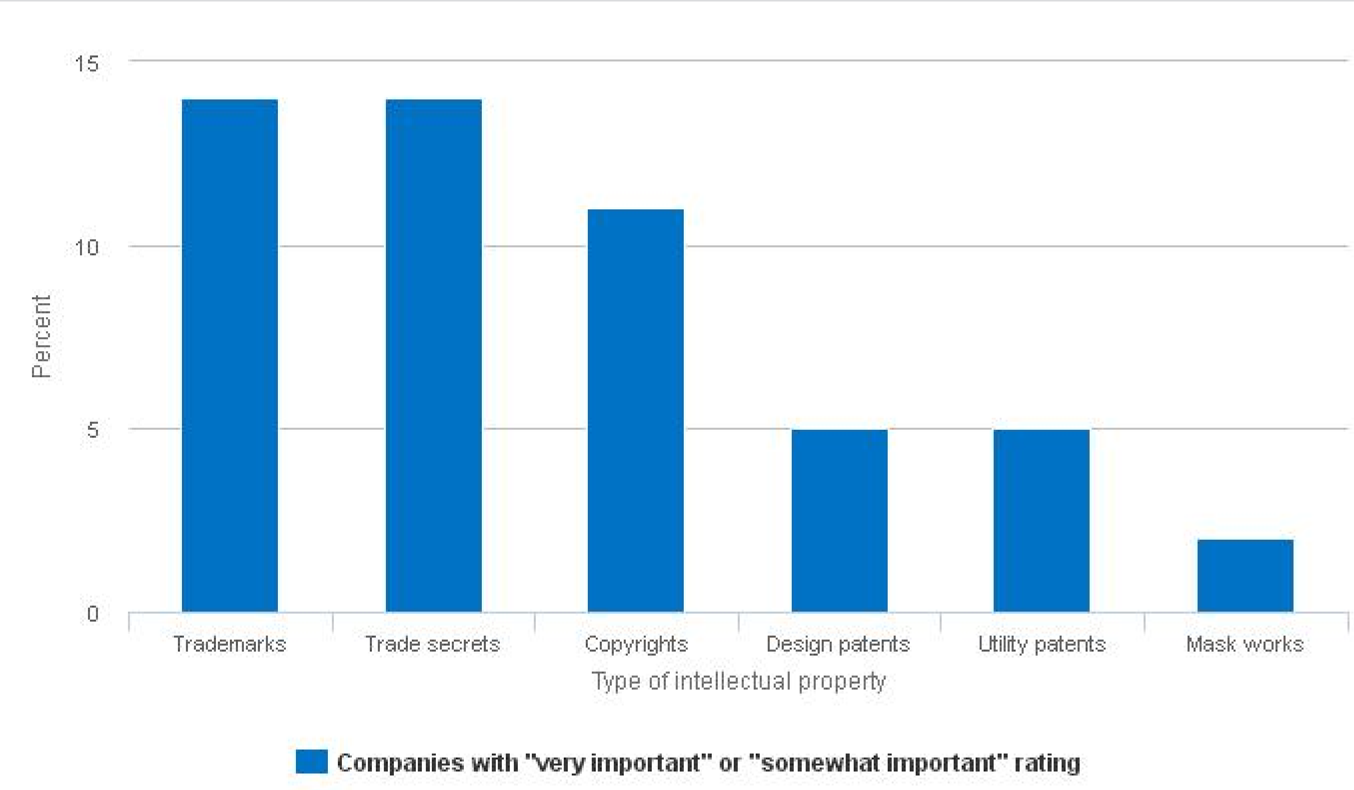
The two types of nonproduct standards are technical and basic. Technical nonproduct standards are operational, applied functions and guidelines that govern the performance, function, and interaction of services and products. U.S. industries have also developed technical nonproduct standards through a voluntary consensus approach. The second type is basic nonproduct standards that include generic measurement and test methods that are typically derived from fundamental scientific principles, such as laws of physics. Although these standards have wide applications in industry, firms and even industries tend to underinvest because they are expensive and require an extensive and specialized scientific infrastructure. Therefore, basic standards are considered a public good and usually have some degree of public involvement in many developed countries. The National Institute of Standards and Technology provides this function for the United States.

Researchers and policymakers are increasingly interested in standards because they appear to play an important role in facilitating technological development, innovation, and increasing economic growth. Several studies have found that standards are significantly associated with economic growth through greater diffusion of knowledge. However, the impact of standards on innovation and economic growth is not fully understood because of their complexity and the limited amount of research in this area. Furthermore, the existing research has mostly focused on developed countries with few studies on China and other developing countries (Ernst 2013:5).

* The source of this definition is the International Organization for Standardization (http://www.iso.org/iso/home/standards.htm).

Figure 6-23

Companies rating intellectual property as being very or somewhat important: 2011



SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey (2011).

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Patents may provide important information for subsequent inventions and technological advances. However, patents may be obtained to block rivals and negotiate with competitors, to use in lawsuits, or to build “thickets” of patents to impede or raise others’ cost of R&D and innovation (Noel and Schankerman 2009:2). Research suggests that some organizations and countries pursue “strategic patenting” to block competitors and to monetize patents through licensing and other activities (Ernst 2013:1–9). The globalization of production has coincided with a rise in patent protection across multiple countries that is sometimes used as a tool for corporate transfer pricing and tax planning.

This discussion focuses largely on patent activity at the U.S. Patent and Trademark Office (USPTO). It is one of the largest patent offices in the world and has a significant share of applications and grants from foreign inventors because of the size and openness of the U.S. market.[i] Although U.S. patents are naturally skewed toward U.S. inventions, these market attributes make U.S. patent data useful for identifying trends in global inventiveness.

This section also deals with patents filed in the world’s three largest patenting centers: the United States, the EU, and Japan. Because of the high costs associated with patent filing and maintenance in these three patent offices, inventions covered by these patents are likely to be valuable.

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[i] The Japan Patent Office is also a major patent office but has a much smaller share of foreign patents than the USPTO and the European Patent Office.

U.S. Patent and Trademark Office Grants

The USPTO granted almost 300,000 patents worldwide in 2014 (Appendix Table 6-36 and Appendix Table 6-37). The United States received nearly half (48%) of them (Figure 6-24). Japan, the next largest, accounted for 18%, followed by the EU (15%).

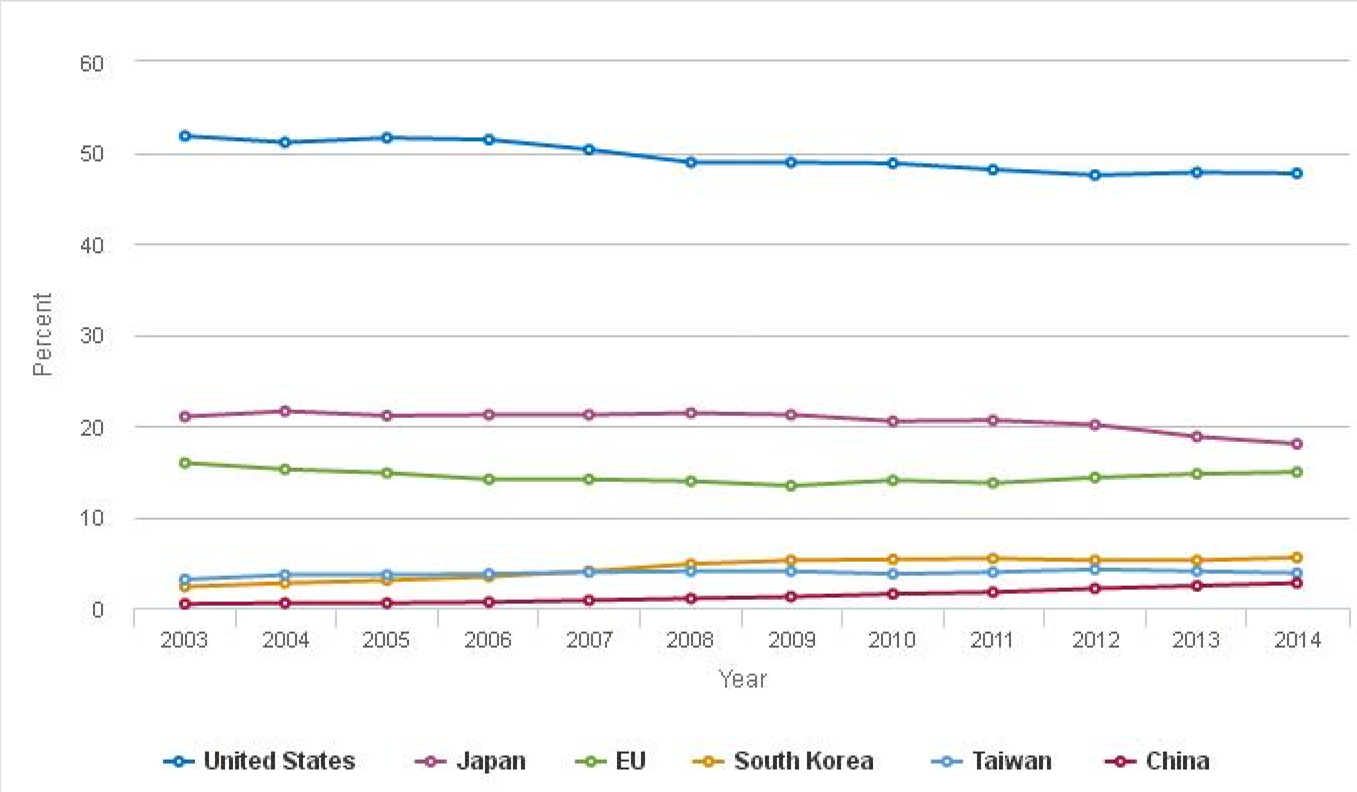
After flat growth earlier in the decade, the number of USPTO patents nearly doubled between 2008 and 2014 (Appendix Table 6-37). The rapid growth likely reflects the globalization of KTI and other industries that are patent intensive, particularly in developed and developing Asian economies. In addition, growth may be due to the recovery from the global recession, along with USPTO efforts to decrease its backlog of patent applications.[ii]

Faster growth of patents granted to non-U.S. inventors reduced the U.S. share from 52% in 2003 to 48% in 2014 (Figure 6-24). The decline in the U.S. share likely indicates increased technological capabilities abroad, globalization that makes patent protection in foreign countries more important, and patenting by U.S.-based inventors located abroad, such as patents granted to inventors located in subsidiaries of U.S. MNCs.

[ii] The United States enacted the Leahy–Smith America Invents Act in 2011, a comprehensive reform of U.S. patent law. The Act included a new fast track option by the USPTO to review patent applications from start-up companies and the provision of additional resources to the USPTO to reduce its backlog of patent applications. For more information, see https://www.whitehouse.gov/the-press-office/2011/09/16/president-obama-signs-america-invents-act-overhauling-patent-system-stim.

Figure 6-24

USPTO patents granted, by selected region/country/economy of inventor: 2003–14



EU = European Union; USPTO = U.S. Patent and Trademark Office.

NOTES: China includes Hong Kong. Patent grants are fractionally allocated among regions/countries/economies based on the proportion of the residences of all named inventors.

SOURCES: Science-Metrix, LexisNexis, and SRI International. See appendix table 6-37.

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Japan's share fell slightly, and the EU's share remained steady between 2008 and 2014 (Figure 6-24). USPTO patenting by Japan and the EU may indicate economic factors or an increased preference to patent in their home patent offices.

Patenting activity in the Asian economies of South Korea, Taiwan, China, and India increased strongly over the last decade. South Korea's share more than doubled to reach 5.5% (Figure 6-24). Taiwan's share increased to 3.8%. China grew the fastest of any economy, although from a low base, resulting in its share rising from 0.4% to 2.7%. India also grew from a low base with its share reaching 1.0% (Appendix Table 6-37).

U.S. Patent and Trademark Office Patenting Activity by U.S. Companies

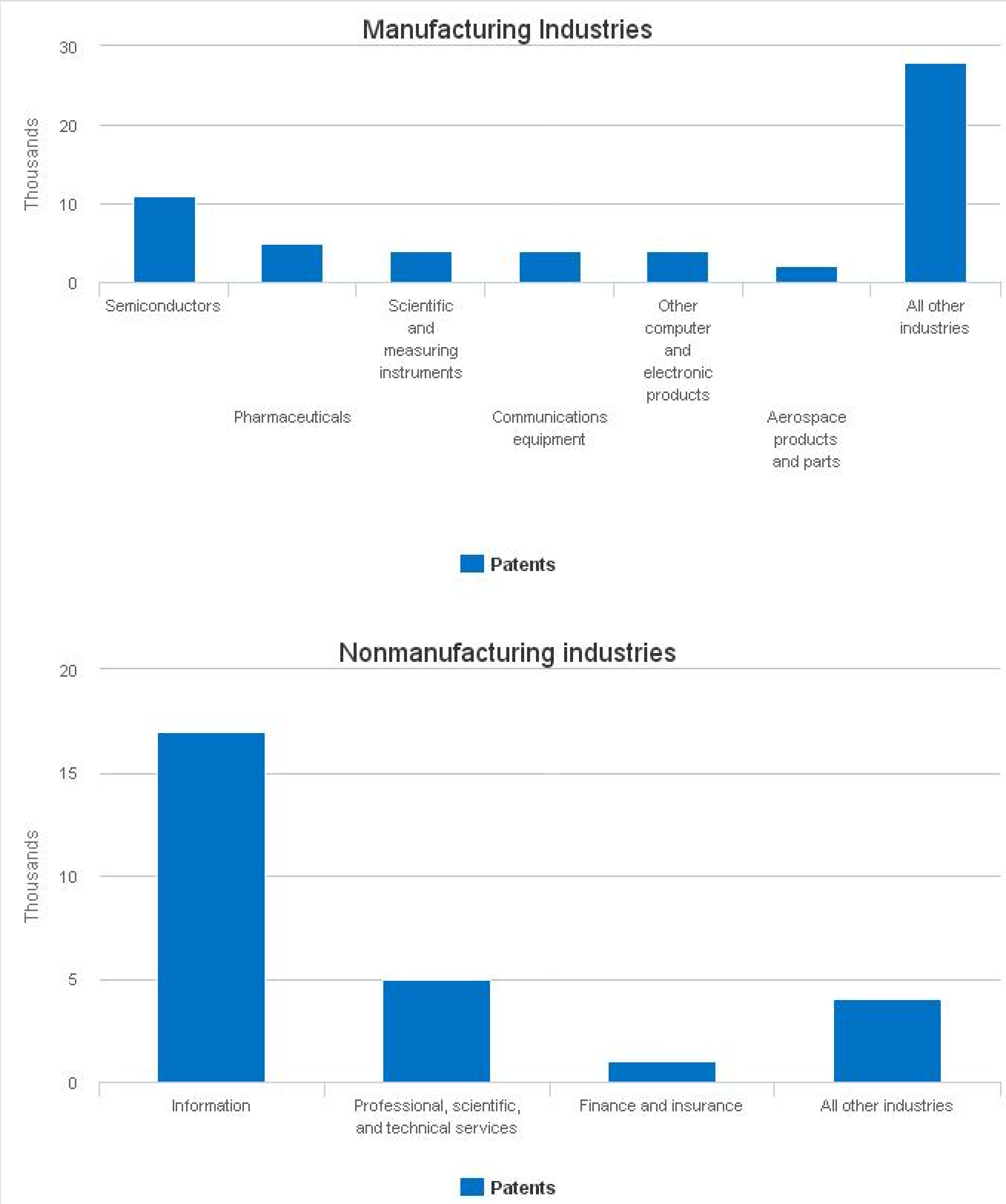
U.S. KTI industries are far more active in patenting than other industries because patenting is relatively more important for their intellectual property protection than that of non-KTI industries (Figure 6-25). (The BRDIS data on USPTO patents are not comparable with the USPTO patent data presented in the previous and following sections. [iii]) U.S. HT industries received about half of the 58,000 patents granted to all U.S. manufacturing industries in

2012 (Figure 6-25), compared with its one-fourth share of value added of all manufacturing industries. The U.S. semiconductor industry was issued the largest number of patents (11,000) among these HT industries, followed by 2,000–5,000 each for the other four.

[iii] The BRDIS data are collected from a sample of U.S. firms, whereas the USPTO data are from administrative records of all U.S. inventors, including individuals and nonprofits.

Figure 6-25

USPTO patents granted, by selected U.S. industry: 2012



USPTO = U.S. Patent and Trademark Office.

NOTES: Detail may not add to total because of rounding. Industry classification is based on the dominant business code for domestic R&D performance, where available. For companies that did not report business codes, the classification used for sampling was assigned. Statistics are based on companies in the United States that reported to the survey, regardless of whether they did or did not perform or fund R&D. These statistics do not include an adjustment to the weight to account for unit nonresponse. For a small number of companies that were issued more than 100 patents by USPTO, counts from USPTO.gov were used to supplement survey data.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey (2012).

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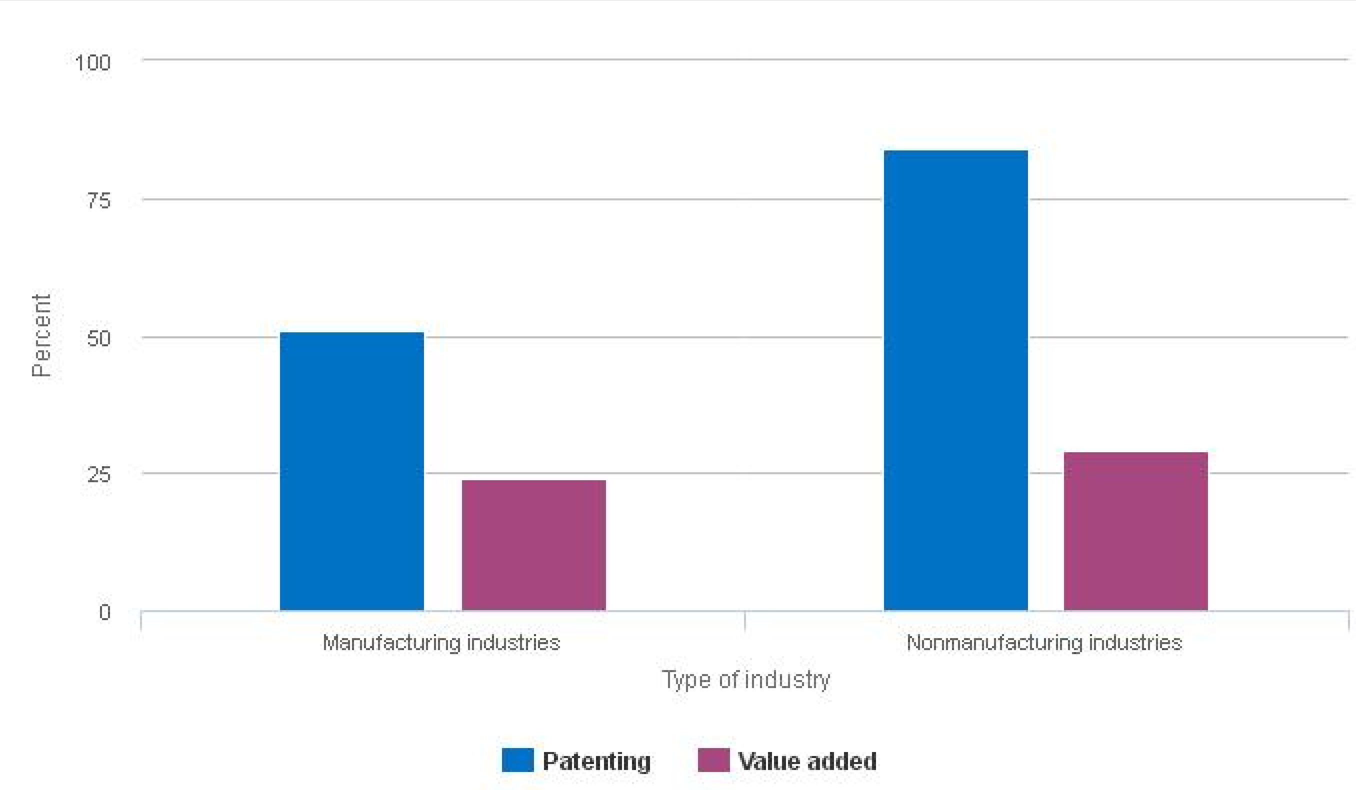
U.S. commercial KI services received 84% of the 27,000 patents issued to nonmanufacturing industries in 2012 (Figure 6-26). These industries' share of patents is much higher than their value-added share of all nonmanufacturing industries (29%), similar to the position of HT manufacturing industries. The information services industry accounted for 17,000 patents, three-fourths of the patents issued to commercial KI services; professional, scientific, and technical services were ranked second with 5,000 patents.

Figure 6-26

Selected industry category share of value-added and USPTO patents granted, by manufacturing and nonmanufacturing industries: 2012



USPTO = U.S. Patent and Trademark Office.

NOTES: Detail may not add to total because of rounding. Industry classification is based on the dominant business code for domestic R&D performance, where available. For companies that did not report business codes, the classification used for sampling was assigned. Statistics are based on companies in the United States that reported to the survey, regardless of whether they did or did not perform or fund R&D. These statistics do not include an adjustment to the weight to account for unit nonresponse. For a small number of companies that were issued more than 100 patents by USPTO, counts from USPTO.gov were used to supplement survey data.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey (2012).

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U.S. Patent and Trademark Office Patents Granted, by Technology Area

This section discusses patterns and trends of technologies that are closely linked to science or KTI industries. The ICT category consists of six technologies—basic communication processes, computer technology, digital communications, IT methods for management, semiconductors, and telecommunications. The instruments category consists of five technologies—analysis of biological materials, control, measurement, medical technology, and optics. The three remaining technologies are microstructural and nanotechnology, biotechnology, and pharmaceuticals. The classification used in this section was developed by the World Intellectual Property Organization and is therefore not compatible with the NSF technology classification used in previous editions (see sidebar, New Technology Classification of U.S. Patent and Trademark Office Patents).

ICT accounted for 38% of all USPTO patents in 2014 led by computer technology (17%), followed by semiconductors, telecommunications, and digital communications, each with shares of 5%–6% (Figure 6-27; Appendix Table 6-38, Appendix Table 6-39, Appendix Table 6-40, Appendix Table 6-41, Appendix Table 6-42, and Appendix Table 6-43). The ICT share grew from 26% to 38% since 2003, consistent with the growing use of ICT by a wide variety of industries. The propensity to patent ICT may also have increased. Computer technology led the growth of ICT patents with its share climbing from 9% to 17%.

New Technology Classification of U.S. Patent and Trademark Office Patents

Science and Engineering Indicators 2016 uses a slightly different technology classification of patents compared with *SEI 2012* and *SEI 2014*. The classification system used in *SEI 2016* was developed by the World Intellectual Property Organization (WIPO) (Schmoch 2008:1–15). The WIPO classification has several desirable features for international comparability of patenting activity in technologies:

- The WIPO classification is designed for country comparison and covers 35 technology fields, including HT and science-based technologies (e.g., information and communications technologies [ICT], biotechnology, pharmaceuticals) (Table 6-E).
- The WIPO classification of patents is based on International Patent Classification (IPC) codes, which are used by all major patent offices. The use of IPC codes permits international comparison of patent offices.
- WIPO has updated the classification over time to reflect changes in patent activity and technologies, including adding more ICT fields.

Table 6-E **WIPO patent classification of technologies**

WIPO patent classification of technologies	
Analysis of biological materials	Macromolecular chemistry and polymers
Audiovisual technology	Materials and metallurgy
Basic communication processes	Measurement
Basic materials chemistry	Mechanical elements
Biotechnology	Medical technology
Chemical engineering	Microstructural and nanotechnology
Civil engineering	Optics
Computer technology	Organic fine chemistry
Control	Other consumer goods

WIPO patent classification of technologies

Digital communication	Other special machines
Electrical machinery, apparatus, and energy	Pharmaceuticals
Engines, pumps, and turbines	Semiconductors
Environmental technology	Surface technology and coating
Food chemistry	Telecommunications
Furniture and games	Textile and paper machines
Handling	Thermal processes and apparatus
IT methods for management	Transport
Machine tools	

IT = information technology; WIPO = World Intellectual Property Organization.

SOURCE: Schmoch U. 2008. Concept of a technology classification for country comparisons: Final report to the World Intellectual Property Organization. Karlsruhe, Germany: Fraunhofer Institute for Systems and Innovation Research, http://www.wipo.int/export/sites/www/ipstats/en/statistics/patents/pdf/wipo_ipc_technology.pdf, accessed 5 September 2015.

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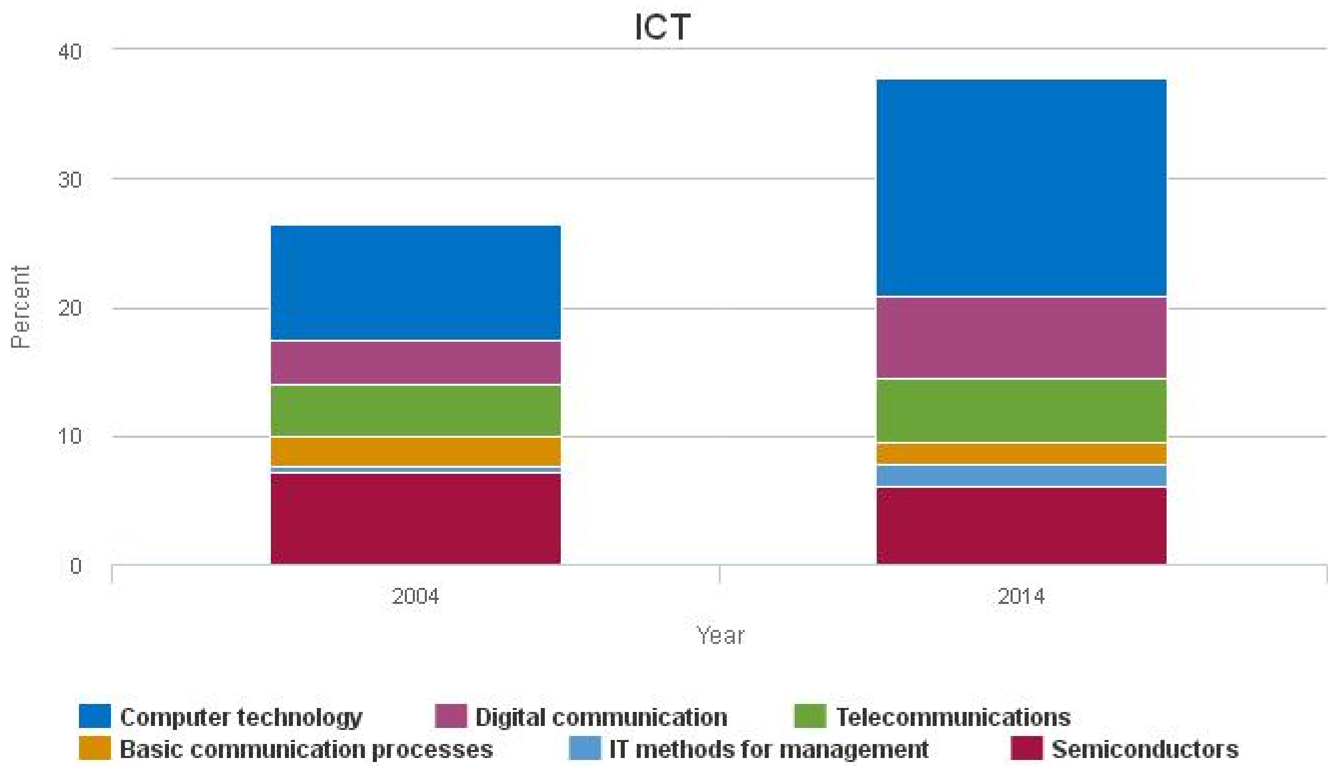
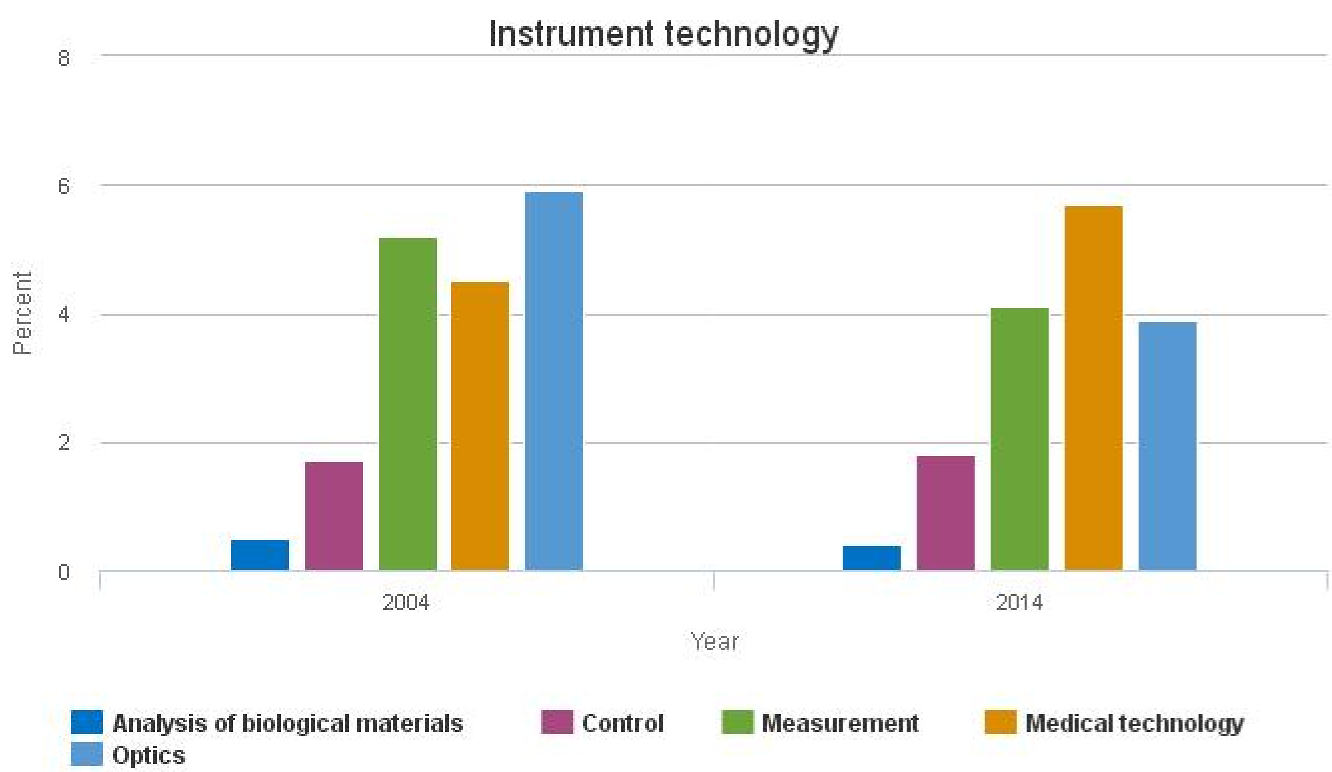
The WIPO classification is similar to The Patent Board™ classification that was used in *SEI 2012* and *SEI 2014*: Each classification has 35 technology fields, and some fields are the same, including biotechnology, pharmaceuticals, and semiconductors. They have some differences, particularly for ICT fields. The WIPO classification has six ICT technology fields—basic communication processes, computer technology, digital communication, information technology methods for management, semiconductors, and telecommunications. The Patent Board™ classification has five fields—computer systems, information processing, networking, semiconductors, and telecommunications. Importantly, the WIPO classification is freely available to researchers, policymakers, and others who wish to independently verify results or conduct their own research.

Figure 6-27

USPTO patents granted in selected technology categories: 2004 and 2014





ICT = information and communications technology; IT = information technology; USPTO = U.S. Patent and Trademark Office.

NOTES: Patents are classified by the World Intellectual Property Organization's (WIPO's) classification of patents, which classifies International Patent Classification (IPC) codes under 35 technical fields. IPC reformed codes, which take into account changes that were made to the WIPO classification in 2006 under the eighth version of the classification, were used to prepare these data. Fractional counts of patents were assigned to each IPC code on patents to assign the proper weight of a patent to the corresponding IPC codes and their associated technical fields under the classification. Patents are fractionally allocated among regions/countries/economies based on the proportion of residences of all named inventors.

SOURCES: Science-Metrix, LexisNexis, and SRI International. See appendix tables 6-37–6-48.

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The instruments category also has a significant share of USPTO patents (16%) (Figure 6-27; Appendix Table 6-44, Appendix Table 6-45, Appendix Table 6-46, Appendix Table 6-47, and Appendix Table 6-48). Medical technology has the largest share (6%), followed by measurement and optics, which each have a 4% share.

Biotechnology and pharmaceuticals each have a 2%–3% share (Appendix Table 6-49 and Appendix Table 6-50).

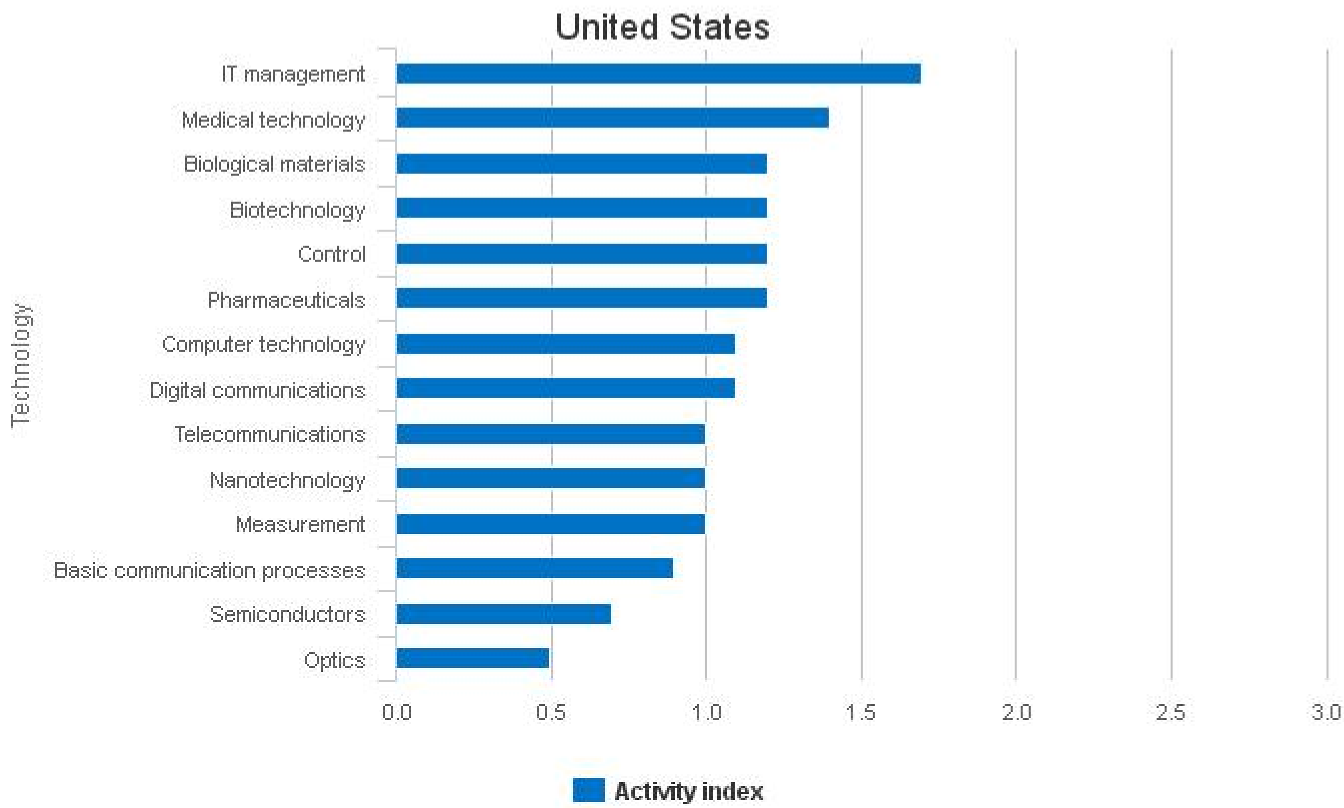
Activity of Major Patenting Regions and Countries in Selected Technology Areas

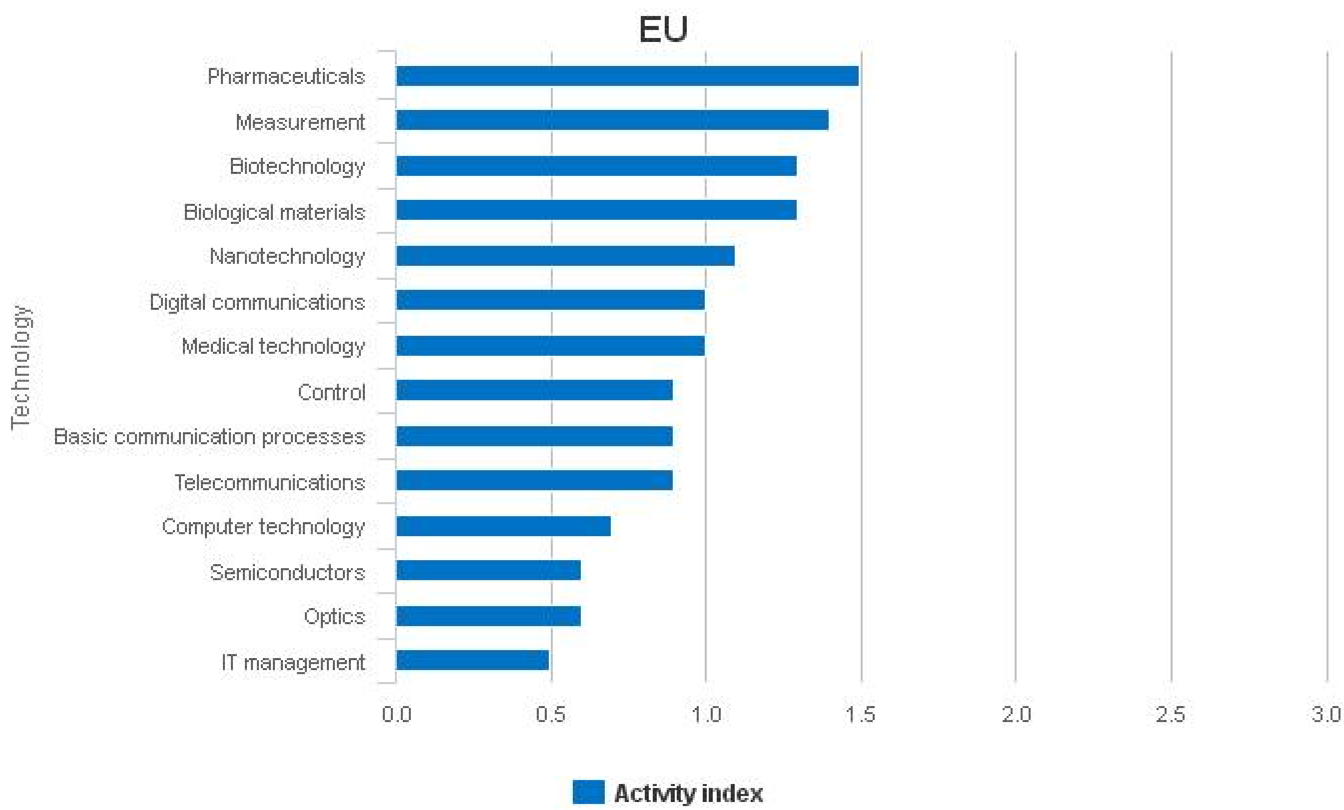
This section presents the *patent activity indexes* of the United States, the EU, and several Asian countries in these technology areas averaged for 2012–14. A patent activity index is the ratio of a country's share of a technology to its share of all patents. A patent activity index greater than one indicates that the country is relatively more active in the technology area.

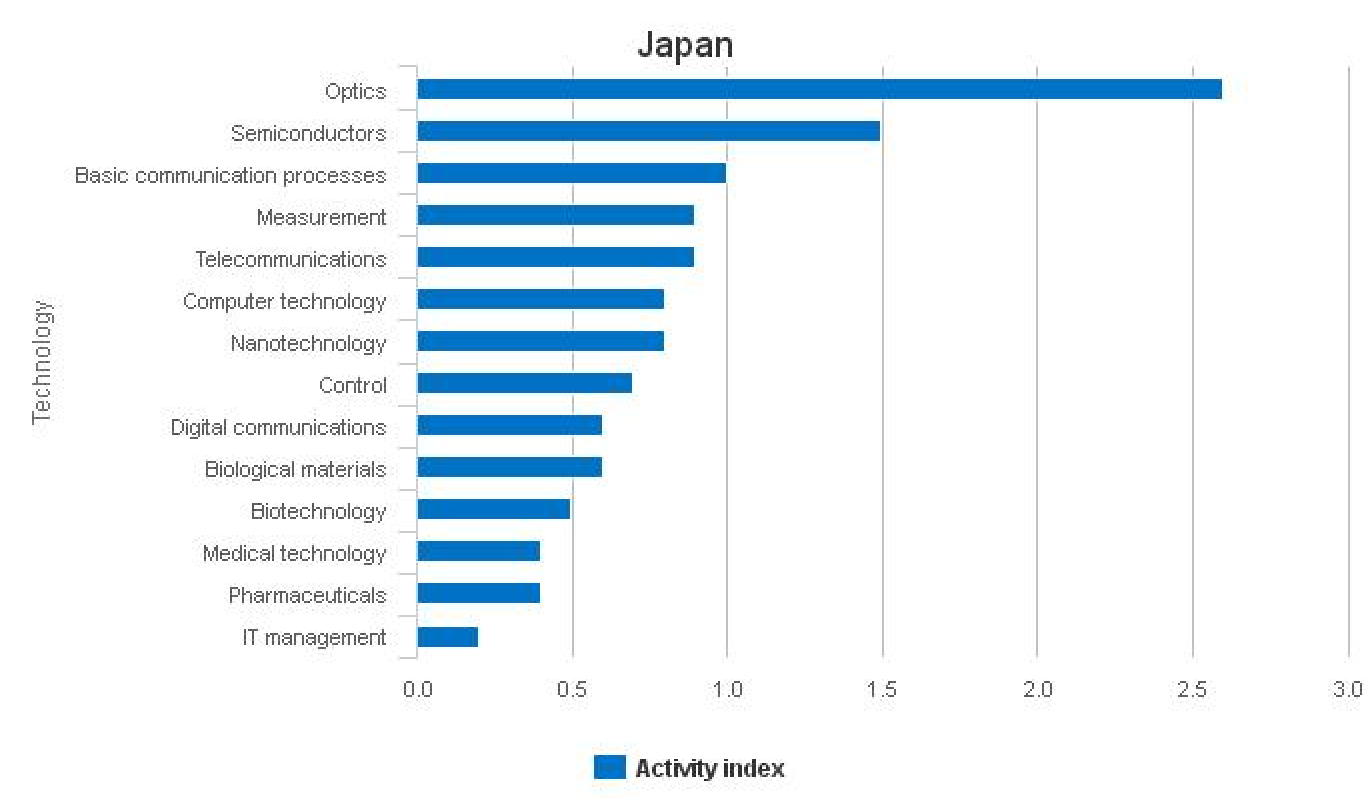
The United States is relatively more active in three ICTs: IT management, computer technology, and digital communications (Figure 6-28). It is particularly active in IT management with an index of 1.7. In the instruments category, the United Sates is relatively more active in medical technology, biological materials, and control, which may reflect its strong market position in the HT manufacturing industry of scientific instruments and measuring equipment. The United States also has greater-than-average activity in biotechnology and pharmaceuticals, consistent with its strong market position in the pharmaceuticals industry. The United States has relatively weaker activity in semiconductors and basic communications processes. Its index is very low in optics, which is part of the instruments technology category.

Figure 6-28

Patent activity index of selected technologies for the United States, the EU, and Japan: 2012–14







EU = European Union; IT = information technology.

NOTES: A patent activity index is the ratio of a country's share of a technology area to its share of all patents. A patent activity index greater (less) than 1.0 indicates that the country is relatively more (less) active in the technology area. Patents are classified by the World Intellectual Property Organization's (WIPO's) classification of patents, which classifies International Patent Classification (IPC) codes under 35 technical fields. IPC reformed codes, which take into account changes that were made to the WIPO classification in 2006 under the eighth version of the classification, were used to prepare these data. Fractional counts of patents were assigned to each IPC code on patents to assign the proper weight of a patent to the corresponding IPC codes and their associated technical fields under the classification. Patents are fractionally allocated among regions/countries/economies based on the proportion of residences of all named inventors.

SOURCES: Science-Metrix, LexisNexis, and SRI International.

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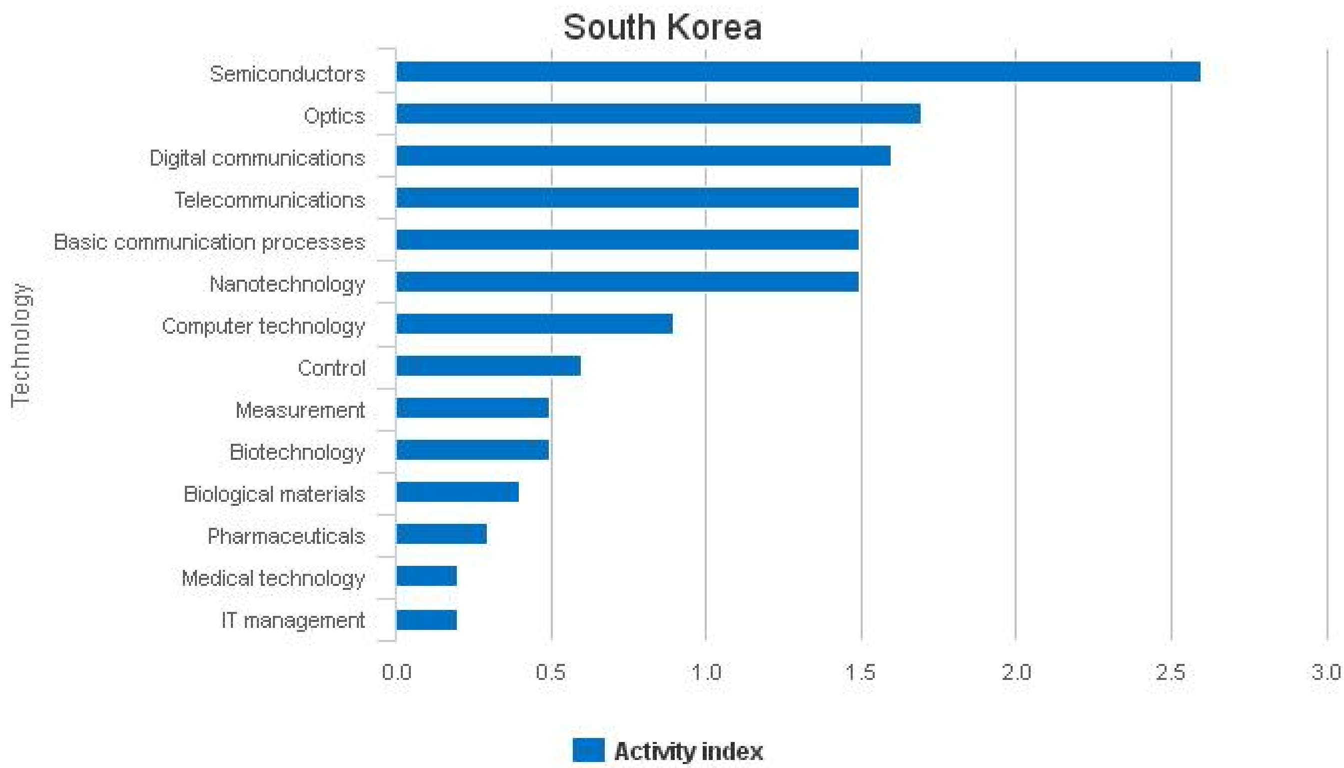
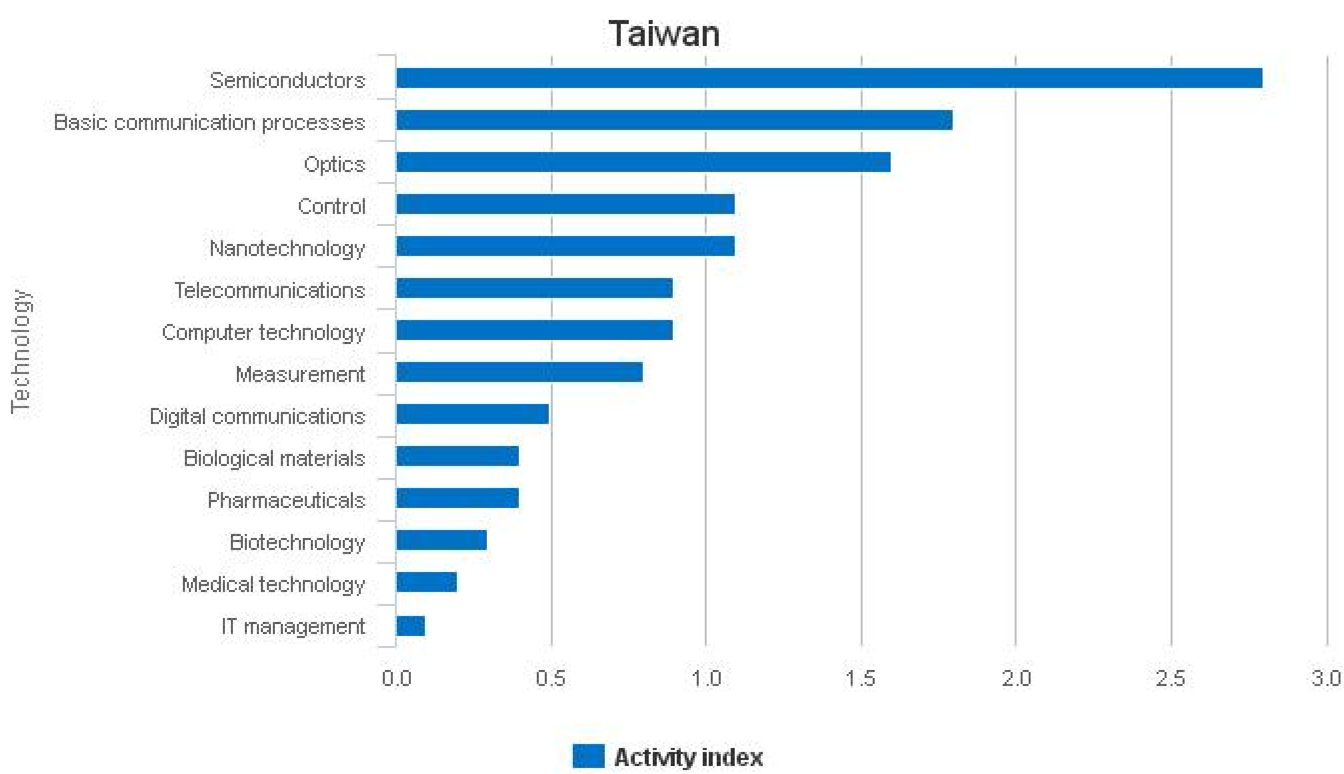
The EU's patenting is average or relatively less active in most technologies (Figure 6-28). It is relatively more active in two instrument technologies—measurement and biological materials—which may reflect its strong market position in the scientific measuring and instruments industry. The EU also is very active in pharmaceuticals (1.5) and biotechnology (1.3), which likely reflect its strong market position in pharmaceuticals.

Japan has a similar profile to the EU with average or relatively less patenting activity in most technologies (Figure 6-28). Japan has very high activity in optics and is high in semiconductors. South Korea and Taiwan have very high activity indexes in semiconductors and optics (Figure 6-29). They also have high relative activity in basic communication processes. South Korea is also active in telecommunications.

Figure 6-29

Patent activity index of selected technologies for South Korea and Taiwan: 2012–14





IT = information technology.

NOTES: A patent activity index is the ratio of a country's share of a technology area to its share of all patents. A patent activity index greater (less) than 1.0 indicates that the country is relatively more (less) active in the technology area. Patents are classified by the World Intellectual Property Organization's (WIPO's) classification of patents, which classifies International Patent Classification (IPC) codes under 35 technical fields. IPC reformed codes, which take into account changes that were made to the WIPO classification in 2006 under the eighth version of the classification, were used to prepare these data. Fractional counts of patents were assigned to each IPC code on patents to assign the proper weight of a patent to the corresponding IPC codes and their associated technical fields under the classification. Patents are fractionally allocated among regions/countries/economies based on the proportion of residences of all named inventors.

SOURCES: Science-Metrix, LexisNexis, and SRI International.

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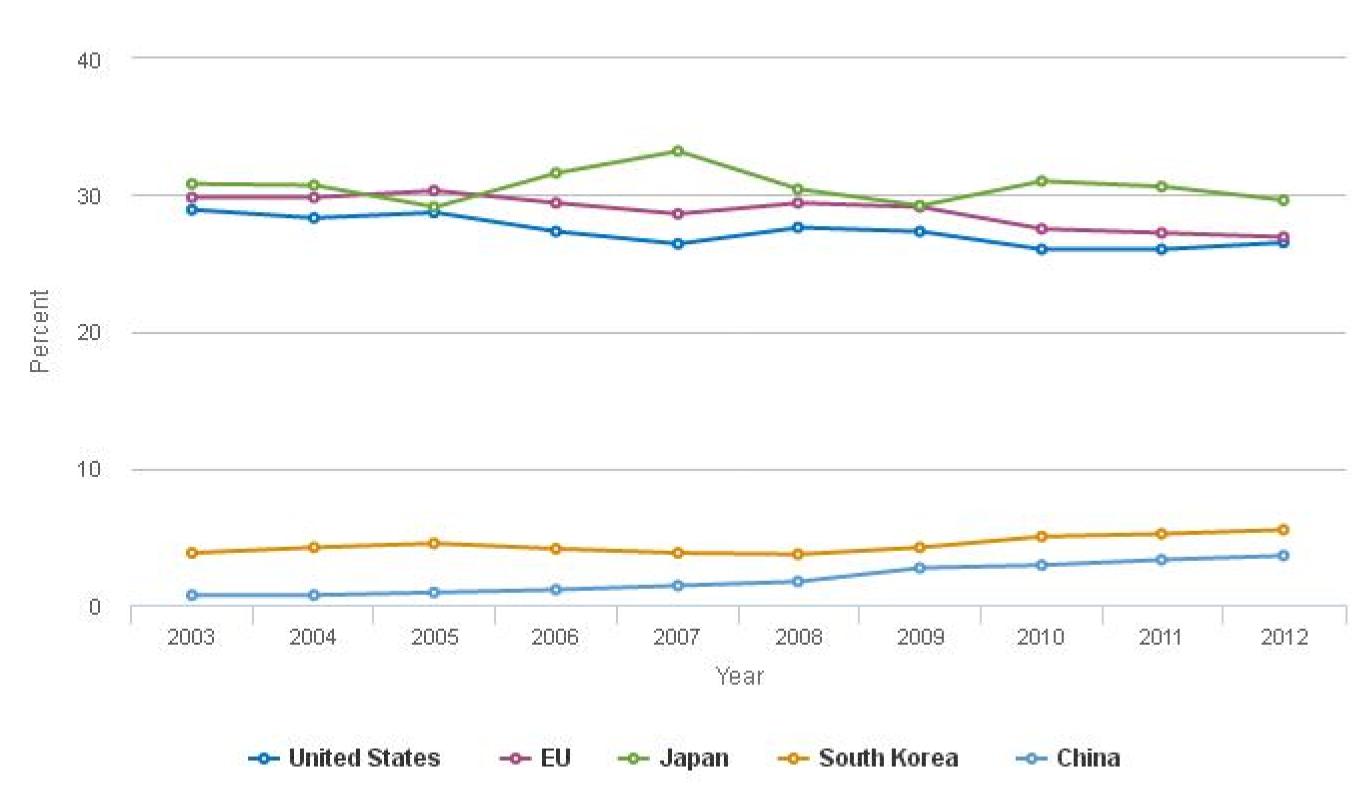
Patenting Valuable Inventions: Triadic Patents

Using counts from a national patent office as an indicator of inventive activity may not differentiate between inventions of minor and substantial economic potential. Inventions for which patent protection is sought in three of the world's largest markets—the United States, Europe, and Japan—are likely to be viewed by their owners as justifying the high costs of filing and maintaining these patents in three markets. These *triadic patents* serve as an indicator of higher-value inventions, although growing patent activity in China, India, South Korea, and other locations may limit the utility of this measure. The number of triadic patents is strongly correlated with expenditures on industry R&D, suggesting that countries with higher patenting activity make greater investments to foster innovation (OECD 2009:36).

Japan is the leading recipient of triadic patents with a share of 30% (Figure 6-30; Appendix Table 6-51). The EU and United States are tied at second with shares each of 26%–27%.

Figure 6-30

Global triadic patent families, by selected region/country/economy: 2003–12



EU = European Union.

NOTES: Triadic patent families include patents all filed together at the European Patent Office and Japan Patent Office and granted at the U.S. Patent and Trademark Office, protecting the same set of inventions. Patent families are fractionally allocated among regions/countries/economies based on the proportion of residences of all named inventors. China includes Hong Kong.

SOURCES: Science-Metrix; SRI International; and Organisation for Economic Co-operation and Development, Patent Statistics, Patents by Technology database, http://stats.oecd.org/Index.aspx?DatasetCode=PATS_IPC, accessed 12 March 2015.

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The shares of the United States and the EU fell slightly over the decade (Figure 6-30; Appendix Table 6-51). Japan's share remained unchanged. South Korea's share rose from 4% to 6%. China's share quadrupled to 4%, consistent with its rapid growth in USPTO patents during this period.

Trade in Royalties and Fees

Firms trade intellectual property, such as patented and unpatented techniques, processes, formulas, and other intangible assets and proprietary rights. These types of transactions generate revenues in the form of royalties and licensing fees. Trade in royalties and fees provides a broad indicator of technology flows across the global economy and the value of an economy's intellectual property in the international marketplace.[i]

Global exports of royalties and fees were $255 billion in 2013 (Figure 6-31; Appendix Table 6-52). The United States was the world's largest exporter of royalties and fees (50% global share) with a substantial trade surplus (Figure 6-31).[ii] The U.S. global export share fell slightly between 2004 and 2013.

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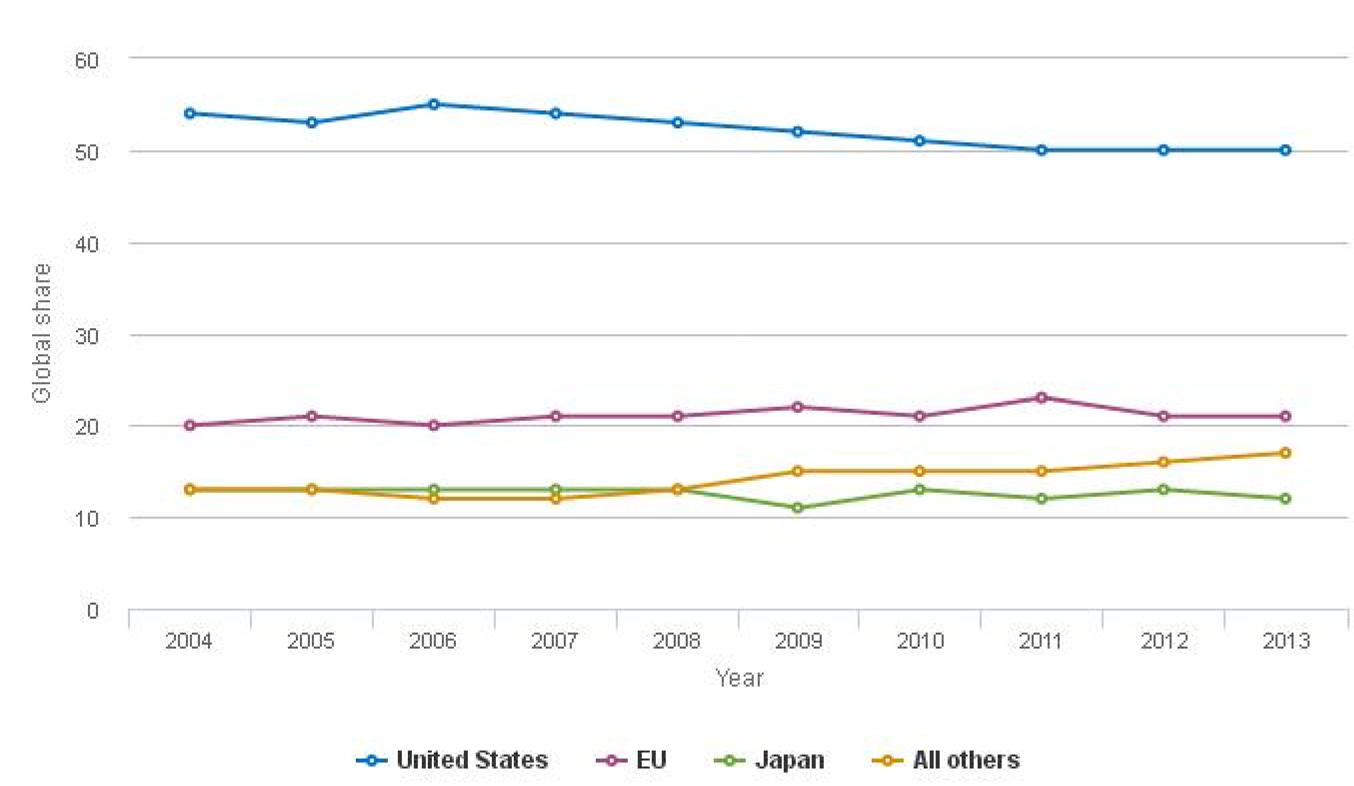
[i] Differences in tax policies and protection of intellectual property also likely influence the volume and geographic patterns of global trade in royalties and fees (Gravelle 2010:8; Mutti and Grubert 2007:112).

[ii] The volume and geographic patterns of U.S. trade in royalties and fees have been influenced by U.S.-based multinationals transferring their intellectual property to low-tax jurisdictions or their foreign subsidiaries to reduce their U.S. and foreign taxes (Gravelle 2010:8; Mutti and Grubert 2007:112).

Figure 6-31

Exports of royalties and fees, by selected region/country/economy: 2004–13



EU = European Union.

NOTE: EU exports do not include intra-EU exports.

SOURCE: World Trade Organization, International trade and tariff data, http://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 15 February 2015.

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The EU is the second largest, with a global share of 21%, but it has a small deficit in trade of royalties and fees. Japan, the third largest (12% share), has a substantial trade surplus. The global shares of the EU and Japan were stable over the last decade.

Exports of developing countries are very low; for example, the global shares of China and India were less than 1% in 2014.

Venture Capital and Small Business Innovation Research Investment

Entrepreneurs seeking to start or expand a small firm with new or unproven technology may not have access to public or credit-oriented institutional funding. Often, entrepreneurs rely on friends and family for financing. However, when they need or can get access to larger amounts of financing, venture capital investment is often critical to financing nascent and emerging HT businesses. This section will examine patterns and trends of venture capital financing in the United States and internationally and Small Business Innovation Research (SBIR) investment in the United States.[i]

Venture capital investment. Global venture capital investment was $79 billion in 2014. The United States attracted the most venture capital ($49 billion) of any region/country (Figure 6-32; Appendix Table 6-53). China was second ($13 billion), followed by Europe ($9 billion) and India ($5 billion) (Figure 6-33).

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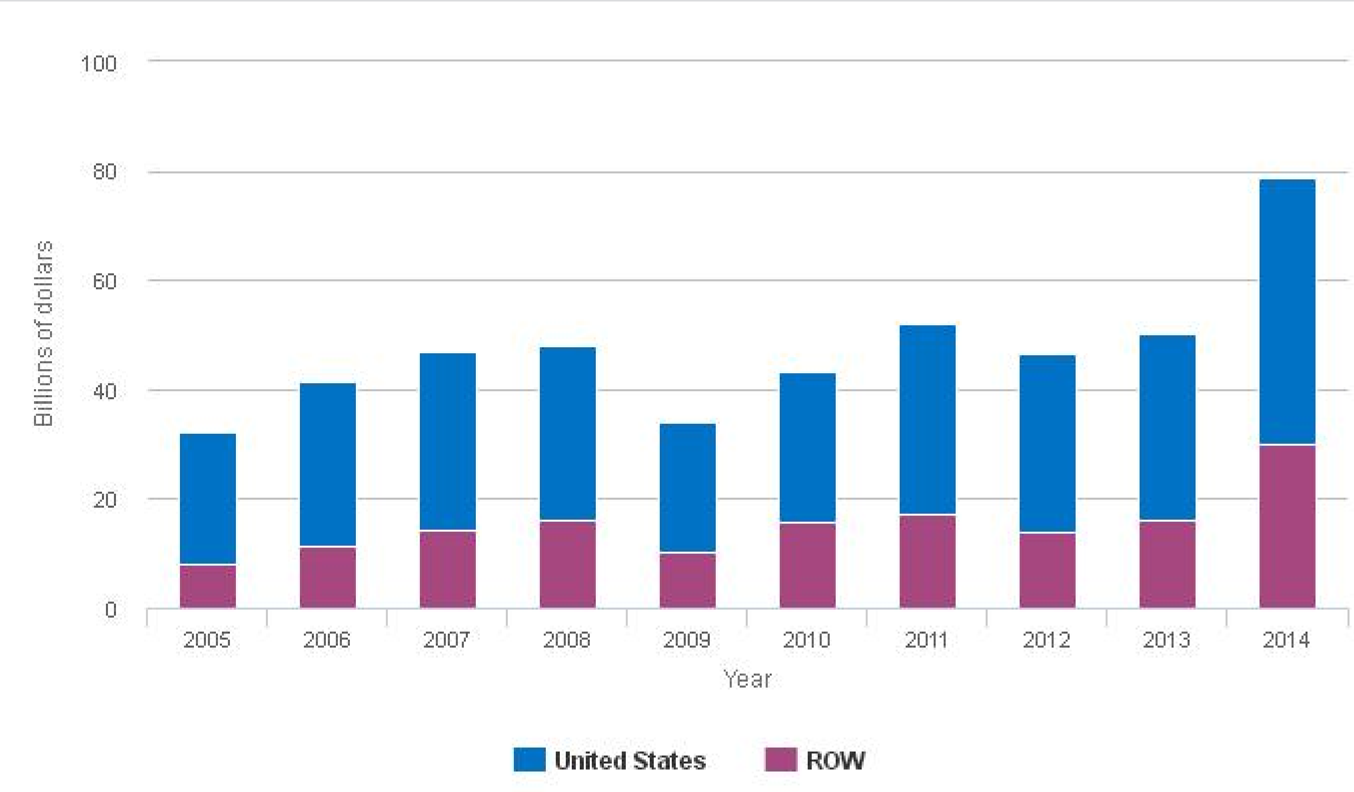
[i] In this section, business denotes anything from an entrepreneur with an idea to a legally established operating company.

Figure 6-32

Venture capital investment in the United States and the rest of the world: 2005–14



ROW = rest of world.

NOTE: ROW includes Canada, China, Europe, India, and Israel.

SOURCE: Dow Jones, special tabulations (2015) from VentureSource database, http://www.dowjones.com/info/venture-capital-data.asp, accessed 15 March 2015.

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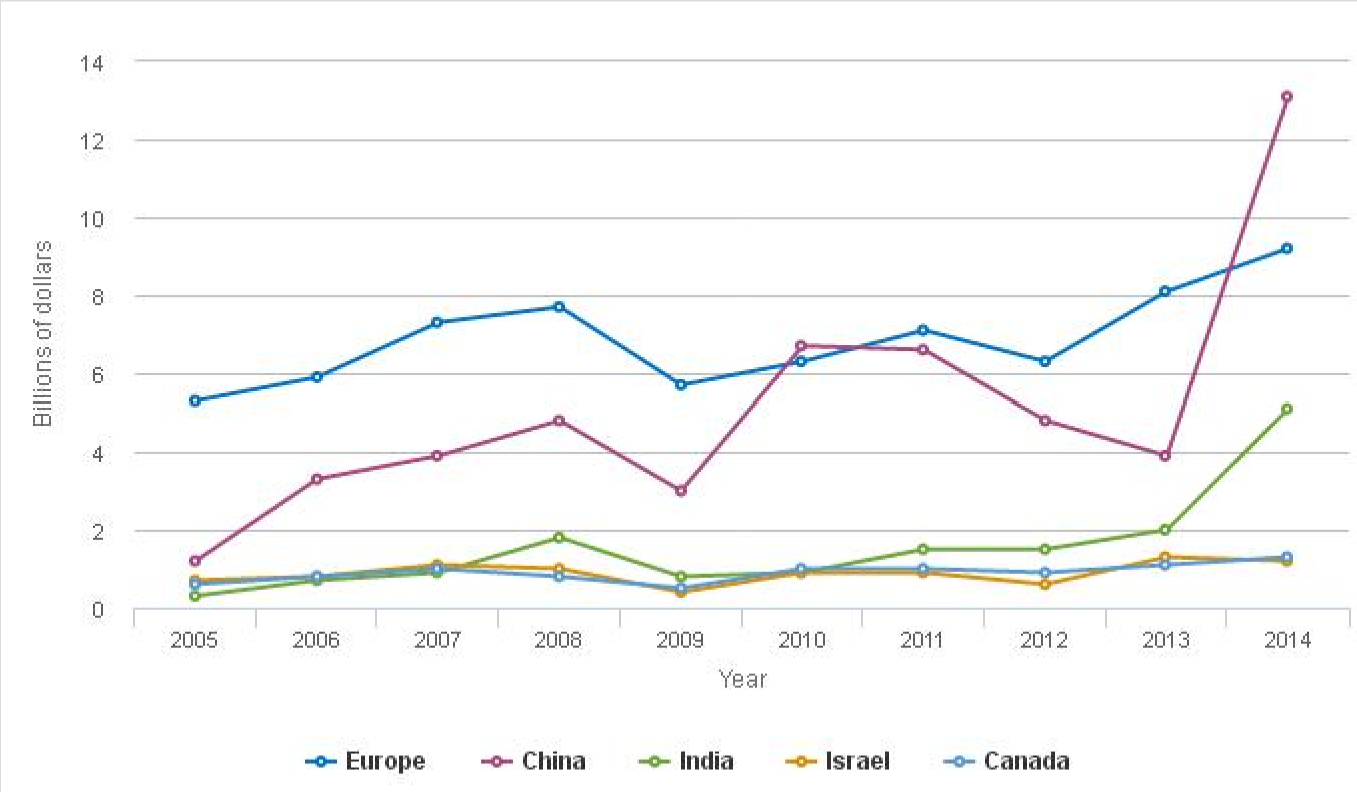
Figure 6-33

Venture capital investment, by selected region/country/economy: 2005–14



SOURCE: Dow Jones, special tabulations (2015) from VentureSource database, http://www.dowjones.com/info /venture-capital-data.asp, accessed 15 March 2015.

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Between 2005 and 2013, global venture capital investment remained in the range of $32 billion to $50 billion before surging to $79 billion in 2014, a 57% increase from 2013 (Figure 6-32). The jump in global investment occurred across all regions and countries, led by the United States and China. Investment in the United States reached $49 billion, its highest level since the 2000 dot-com bubble's $87 billion. China's venture capital investment jumped from $4 billion in 2013 to $13 billion in 2014 (Figure 6-33).

Faster venture capital growth overseas over the past decade reduced the U.S. global share from 75% in 2005 to 62% in 2014 (Figure 6-32). The expansion of venture capital outside of the United States coincides with the globalization of finance, greater commercial opportunities in rapidly growing developing countries, and the decline of yields on existing venture capital investments in U.S. companies.[ii] In China, venture capital grew from $1 billion in 2005 to $13 billion in 2014, resulting in its global share reaching 17% (Figure 6-33). India's share of global investment grew from 1% to 6%.

Venture capital investment is generally categorized into four broad stages of financing:

- *Seed* supports proof-of-concept development and initial product development and marketing.
- *First round* supports product development and marketing and the initiation of commercial manufacturing and sales.

- *Expansion* provides working capital for company expansion, funds for major growth (including plant expansion, marketing, or developing an improved product), and financing to prepare for an initial public offering (IPO).
- *Later stage* includes acquisition financing and management and leveraged buyouts. Acquisition financing provides resources for the purchase of another company, and management and leveraged buyouts provide funds to enable operating management to acquire a product line or business from either a public or a private company.

Venture capital investment has become more concentrated in later stages over the past decade. Observers have attributed this shift to a desire to lower investment risk, a decline in yields on existing earlier stage investments, and a sharp decline in IPOs and acquisitions of firms backed by venture capital, requiring venture capital investors to commit additional resources in the face of lower returns. In 2014, later stage venture capital invested in the United States comprised 65% of total investment, up from 50% in 2005 (Figure 6-34; Appendix Table 6-53). The first round share especially, and the expansion share, declined during this period.

[ii] Another possibility is that the behavior of venture capital investors changed because fewer opportunities for attractive risky investments were available in the 2000s than in the 1990s.

Figure 6-34

U.S. venture capital investment, by financing stage: Selected years, 2005–14

NOTES: Seed stage consists of proof-of-concept development and initial product development and marketing. First round consists of product development and marketing and the initiation of commercial manufacturing and sales. Expansion consists of second-round financing that provides working capital for company expansion and financing to prepare for an initial public offering. Later stage includes acquisition financing and management and leverage buyouts.

SOURCE: Dow Jones, special tabulations (2015) from VentureSource database, http://www.dowjones.com/info/venture-capital-data.asp, accessed 15 March 2015. See appendix table 6-53.

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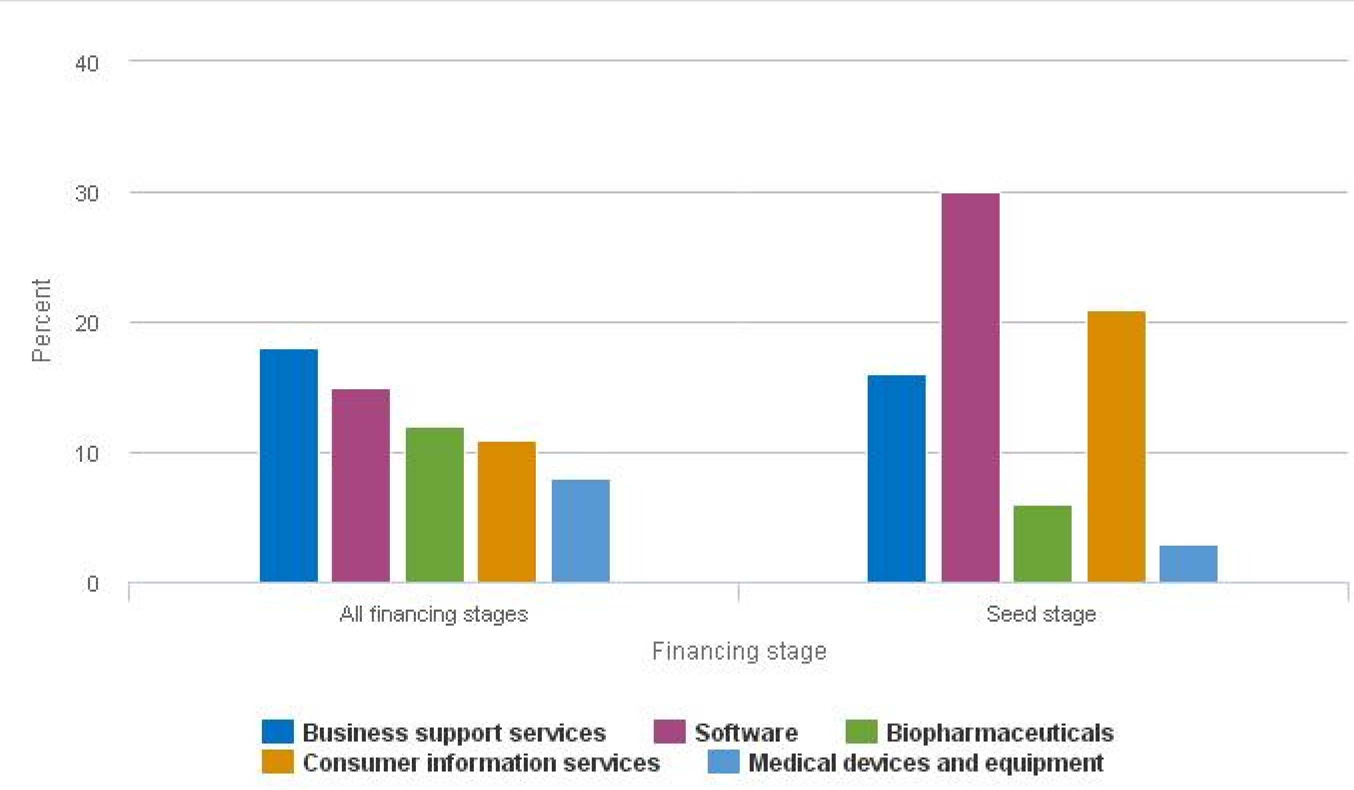
Investment in the seed stage, the earliest stage, has remained at 1% or less of total U.S. venture capital investment over the last decade (Figure 6-34; Appendix Table 6-53). Despite the jump in total U.S. venture capital investment between 2013 and 2014, investment in the seed stage fell from $354 million to $279 million. Researchers and observers have expressed concern that the lack of early stage venture capital financing contributes to the "valley of the death," the inability of new and nascent firms to obtain financing to commercialize their inventions and technology.

Five technologies—biopharmaceuticals, business support services, consumer information services, medical devices and equipment, and software—have dominated U.S. venture capital investment during 2011–14 (Figure 6-35; Appendix Table 6-53):

Figure 6-35

U.S. venture capital investment, by selected financing stage and technology/industry: 2011–14



NOTES: Technologies are classified by Dow Jones. Seed stage consists of proof-of-concept development and initial product development and marketing.

SOURCE: Dow Jones, special tabulations (2015) from VentureSource database, http://www.dowjones.com/info/venture-capital-data.asp, accessed 15 March 2015. See appendix table 6-53.

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- Business support services led these technologies in venture capital investment, receiving 18% of total investment in 2011–14. This technology area also received a significant share of seed investment (16%).
- Software had the second highest share of total investment (15%) and attracted the most seed investment of any technology (30%).
- Biopharmaceuticals was third, accounting for 12% of total investment and 6% of seed investment.
- Consumer information services closely followed biopharmaceuticals, receiving 11% of total investment. This technology had the second highest share in seed investment (21%).
- Medical devices and equipment was the fifth-largest technology, accounting for 8% of total investment and 3% of seed investment.

SBIR investment. The U.S. government's SBIR program provides early stage public financing to help U.S. small or start-up companies to commercialize technology derived from federal R&D.[iii] The SBIR program provides financing in two phases:

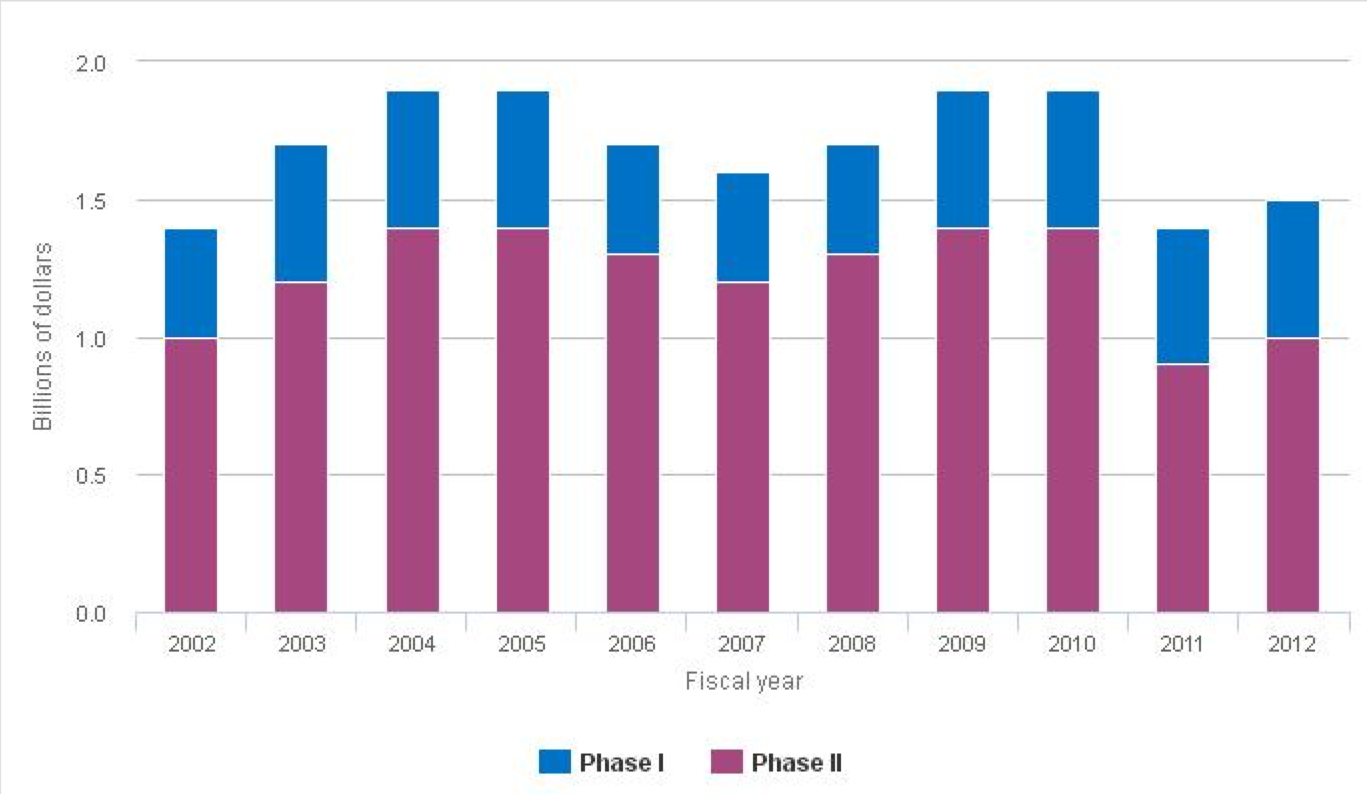
- Phase I funds the evaluation of the scientific and technical merit and feasibility of a company's new ideas.
- Phase II funds further scientific and technical review and requires a commercialization plan.

SBIR provided $1.5 billion in early stage financing in FY 2012, more than fivefold the amount of seed stage venture capital (Figure 6-36). The U.S. Departments of Defense and Health and Human Services provide the bulk of SBIR financing (almost 80% of total SBIR funding) with smaller amounts from the Department of Energy, the National Aeronautics and Space Administration, and NSF (Figure 6-37). Most SBIR financing occurs in Phase II, which provided $1.0 billion to fund 2,000 awards in FY 2012. Phase I provided $0.5 billion for 3,500 awards.

[iii] For more information on SBIR, see chapter 4 .

Figure 6-36

SBIR investment, by financing phase: FYs 2002–12



SBIR = Small Business Innovation Research program.

NOTES: SBIR investment is by fiscal year. Investment is the amount obligated by U.S. federal agencies for SBIR financing. Phase I evaluates the scientific and technical merit and feasibility of ideas. Phase II is subject to further scientific and technical review and requires a commercialization plan.

SOURCE: SBIR Annual Report data, http://www.sbir.gov/awards/annual-reports, accessed 15 May 2015.

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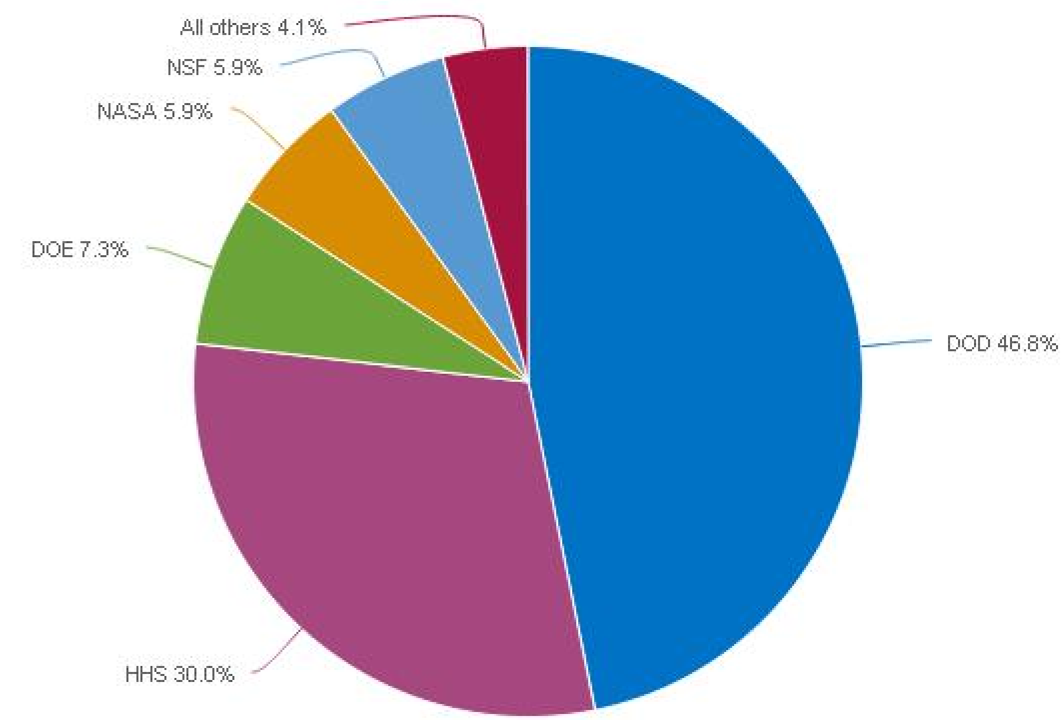
Figure 6-37

SBIR funding, by share of selected federal agency: FYs 2010–12



DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; SBIR = Small Business Innovation Research program.

NOTES: Funding is budget obligations for each federal agency. All others includes Department of Commerce, Department of Education, Department of Homeland Security, Department of Transportation, Environmental Protection Agency, and U.S. Department of Agriculture.

SOURCE: SBIR Annual Report data, http://www.sbir.gov/awards/annual-reports, accessed 15 May 2015.

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SBIR financing was relatively stable in FYs 2003–10 before falling sharply (more than 25%) in FYs 2011–12 because of declines in Phase II funding (Figure 6-36). The decline was due to cutbacks in research funding as part of reduced government spending after the 2008–09 recession.[iv] In FY 2012, SBIR provided $1.0 billion for nearly 2,000 Phase II awards compared with $1.4 billion awarded to 1,800 companies in FY 2010. The recent sharp decline in SBIR financing may be of concern given that some researchers and policymakers believe that the United States lacks sufficient capital to finance small or start-up companies seeking to commercialize their technologies.

[iv] SBIR is funded through a fixed percentage (typically 2.5%) of the sponsoring agencies' overall research budget.

Investment and Innovation in Clean Energy Technologies

This section is devoted to examining clean energy and related technologies. Clean energy, like KTI industries, has a strong link to S&T. Clean energy and related technologies—including biofuels, solar, wind, energy efficiency, pollution prevention, smart grid, and CO_2 sequestration—have become a policy focus in developed and developing countries. These technologies are knowledge and technology intensive and thus closely linked to scientific R&D.

Production, investment, and innovation in these energies and technologies are rapidly growing in many countries in response to rising energy demand, the volatile cost of fossil fuels, and efforts by many countries to reduce their emissions of greenhouse gases. Governments have enacted various policy measures, including subsidies and tax incentives, and have increased funding for energy R&D to spur the development of effective, affordable alternative energy sources.

This section will examine public research, development and demonstration (RD&D) and private investment in clean energy and related technologies. Private investment consists of early stage financing—venture capital and private equity—and later stage financing. The public RD&D data discussed here are not comparable with the energy R&D data described in chapter 4.[i] The public RD&D includes coverage of nuclear energy, which is not covered by the private investment data.

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[i] The International Energy Agency (IEA) manual states: "The IEA concept of Energy RD&D differs from the Frascati concept of R&D, in that (i) it focuses on energy related programmes only; (ii) it includes 'demonstration projects'; and (iii) it includes state owned companies…. The energy RD&D data collected by the IEA should not be confused with the data on government budget appropriations or outlays on R&D (GBAORD) collected by the OECD Directorate for Science, Technology, and Industry for the socio-economic objective 'Production, distribution and rational utilisation of energy'" (IEA 2011:16–17).

Public RD&D Expenditures in Clean Energy and Other Non-Fossil Fuel Technologies

Global government investment in RD&D in clean energy and other non-fossil fuel technologies—renewables, energy efficiency, capture and storage of CO_2, nuclear, fuel cells, and other power and storage technologies—was an estimated $12.7 billion in 2013 (Figure 6-38; Appendix Table 6-54, Appendix Table 6-55, Appendix Table 6-56, Appendix Table 6-57, Appendix Table 6-58, Appendix Table 6-59, Appendix Table 6-60, Appendix Table 6-61, Appendix Table 6-62, and Appendix Table 6-63).[i] Renewables was the largest area, receiving $3.7 billion (Figure 6-39). The next two largest areas were nuclear ($3.4 billion) and energy efficiency ($3.2 billion).

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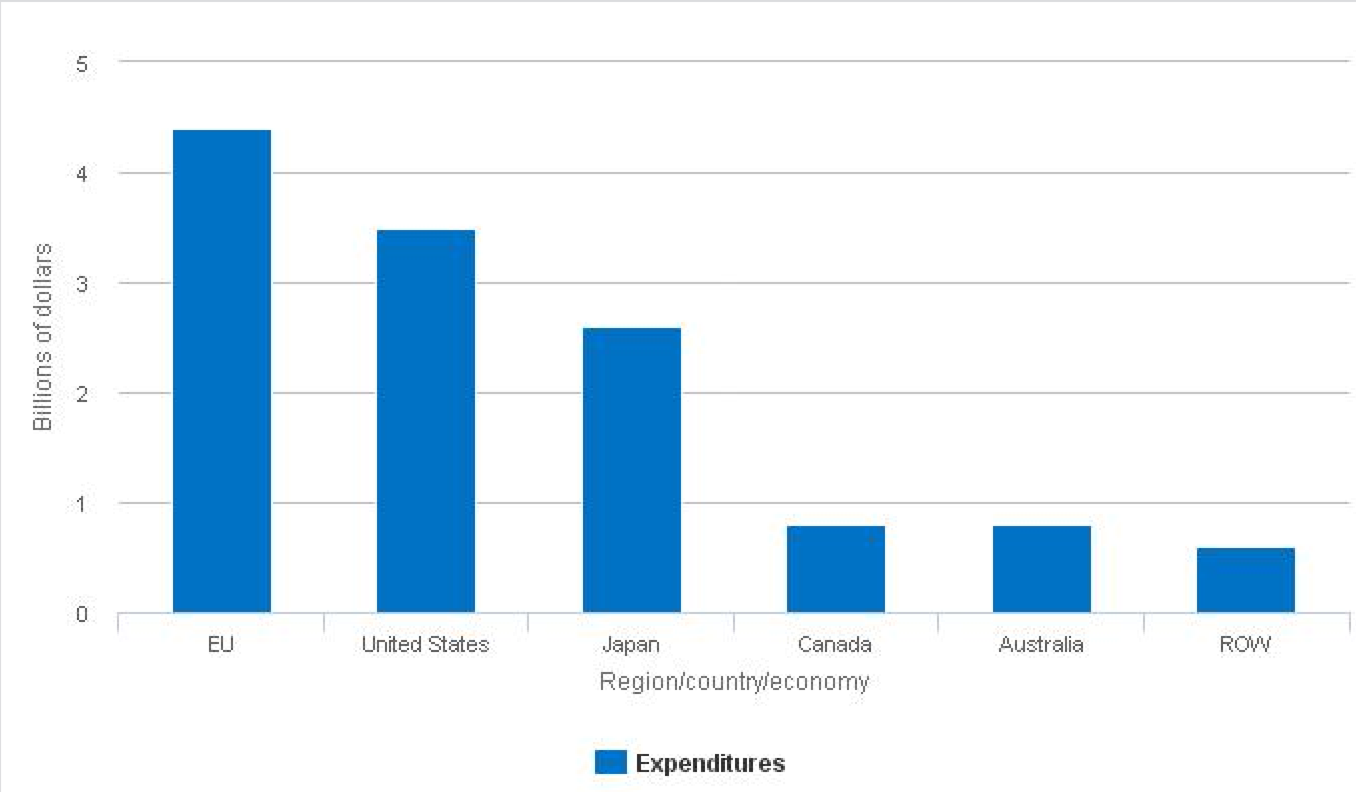
[i] The International Energy Agency has no official definition of clean energy. This discussion includes public research, development, and demonstration in energy efficiency, renewable energy, nuclear, hydrogen and fuel cells, CO_2 capture and storage, and other power and storage technologies.

Figure 6-38

Government RD&D expenditures in clean energy and other non-fossil fuel technologies, by selected region/country/economy: 2013



EU = European Union; RD&D = research, development, and demonstration.

NOTES: Clean energy and other non-fossil fuel technologies include renewables (solar, wind, biofuels, ocean energy, and hydropower), nuclear, hydrogen and fuel cells, CO_2 capture and storage, other power and storage, and energy efficiency. The EU includes Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Spain, Sweden, and the United Kingdom. ROW includes New Zealand, South Korea, and Switzerland.

SOURCES: International Energy Agency, Statistics and Balances, http://www.iea.org/stats/index.asp, accessed 15 February 2015;. See appendix table 6-54.

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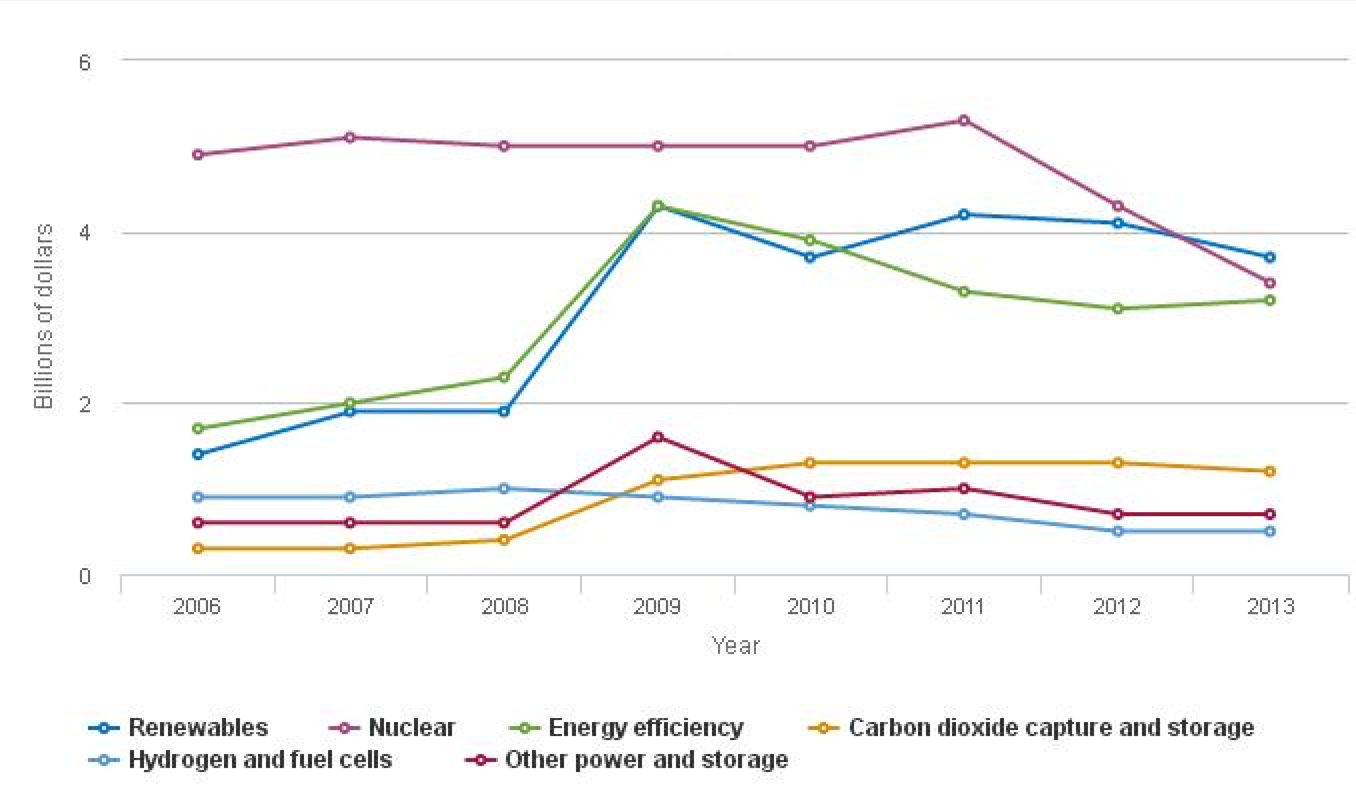
Figure 6-39

Global public RD&D expenditures on clean energy and other non-fossil fuel technologies, by selected technology: 2006–13



RD&D = research, development, and demonstration.

NOTE: Clean energy and other non-fossil fuel technologies include renewables (solar, wind, biofuels, ocean energy, and hydropower), nuclear, hydrogen and fuel cells, CO_2 capture and storage, other power and storage, and energy efficiency.

SOURCES: International Energy Agency, Statistics and Balances, http://www.iea.org/stats/index.asp, accessed 15 February 2015. See appendix tables 6-55–6-63.

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The EU is the largest investor of public RD&D in clean energy and other non-fossil fuel technologies ($4.4 billion), followed by the United States ($3.5 billion) and Japan ($2.6 billion) (Figure 6-38; Appendix Table 6-54). Canada and Australia each spent more than $800 billion.

Public RD&D for clean energy and other non-fossil fuels rose steadily during the 2000s to spike at $17.3 billion in 2009 because of stimulus spending in the United States; it then dropped to $12.7 billion in 2013. Trends among the individual technology areas varied between 2006 and 2013 (Figure 6-39):

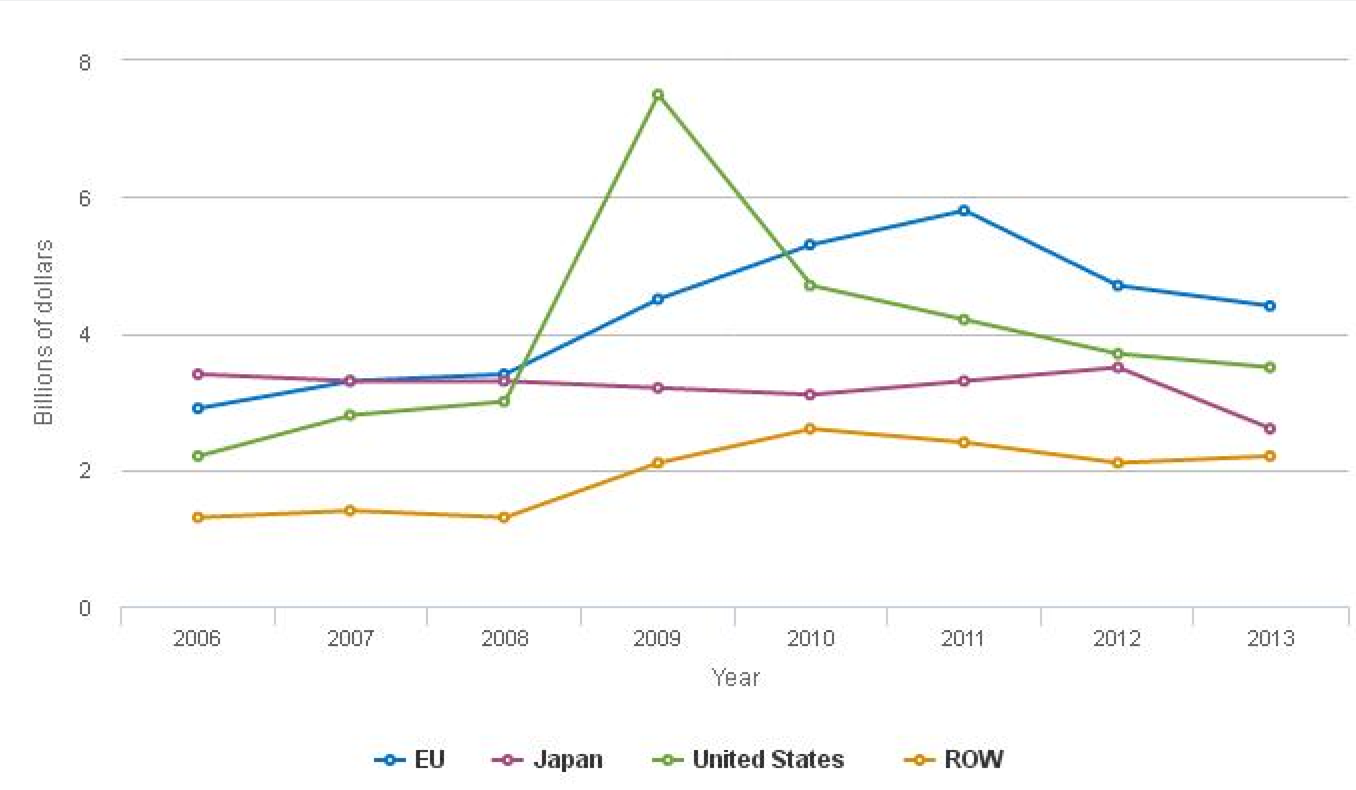
- CO_2 capture and storage had the fastest growth, rising from $300 million to $1.2 billion (Appendix Table 6-62).
- Renewable energy nearly tripled to $3.7 billion (Appendix Table 6-58).
- Energy efficiency nearly doubled to $3.2 billion (Appendix Table 6-56).
- Nuclear energy contracted by 30% to reach $3.4 billion (Appendix Table 6-55).

The United States and the EU led the worldwide growth in public RD&D (Figure 6-40). U.S. RD&D followed a modest upward trend, interrupted by a spike and subsequent decline related to the American Recovery and Reinvestment Act of 2009. U.S. expenditures on energy efficiency and renewables each reached $1.3 and $1.0 billion, respectively (Appendix Table 6-56, and Appendix Table 6-58).

After rising steadily between 2006 and 2011 to reach $5.8 billion, EU investment declined to $4.4 billion in 2013 (Figure 6-40). Japan's investment fell because of a decline in nuclear energy investment (Appendix Table 6-55).

Figure 6-40

Public RD&D on clean energy and other non-fossil fuel technologies, by selected region/country/economy: 2006–13



EU = European Union; RD&D = research, development, and demonstration; ROW = rest of world.

NOTES: Clean energy and other non-fossil fuel technologies include renewables (solar, wind, biofuels, ocean energy, and hydropower), nuclear, hydrogen and fuel cells, CO_2 capture and storage, other power and storage, and energy efficiency. The EU includes Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Spain, Sweden, and the United Kingdom. ROW includes Australia, Canada, Norway, and Switzerland.

SOURCES: International Energy Agency, Statistics and Balances, http://www.iea.org/stats/index.asp, accessed 15 February 2015. See appendix table 6-54.

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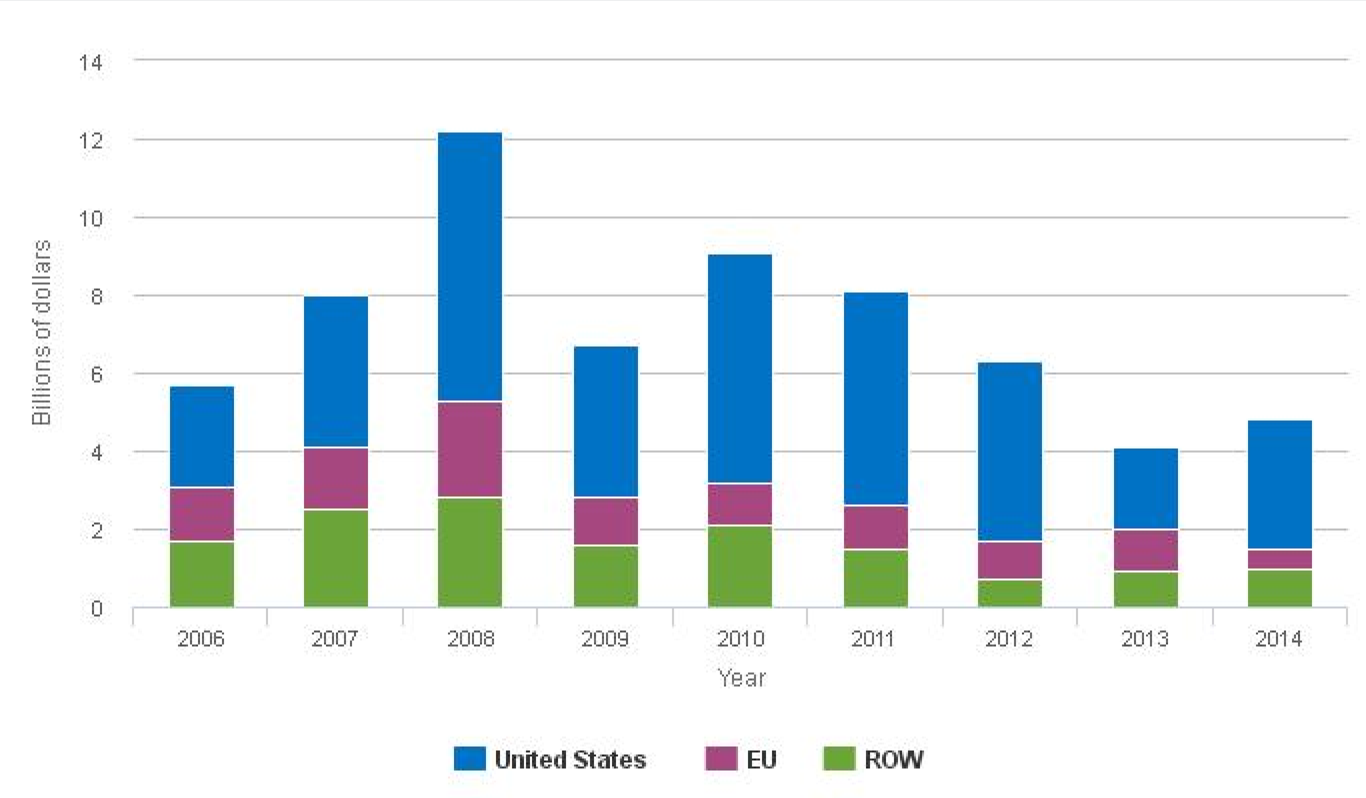
Early Stage Private Financing of Clean Energy

Two types of early stage financing, venture capital and private equity investment, are useful indicators of market assessment of nascent and future trends in clean energy technologies. Global venture capital and private equity investment in clean energy was $4.8 billion in 2014, comprising 2% of commercial financial investment (Figure 6-41). The United States attracted the most venture capital and private equity of any country ($3.3 billion).

Figure 6-41

Global venture capital and private equity investment in clean energy technologies, by selected region/country: 2006–14



EU = European Union; ROW = rest of world.

NOTE: Clean energy technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency technologies.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2014).

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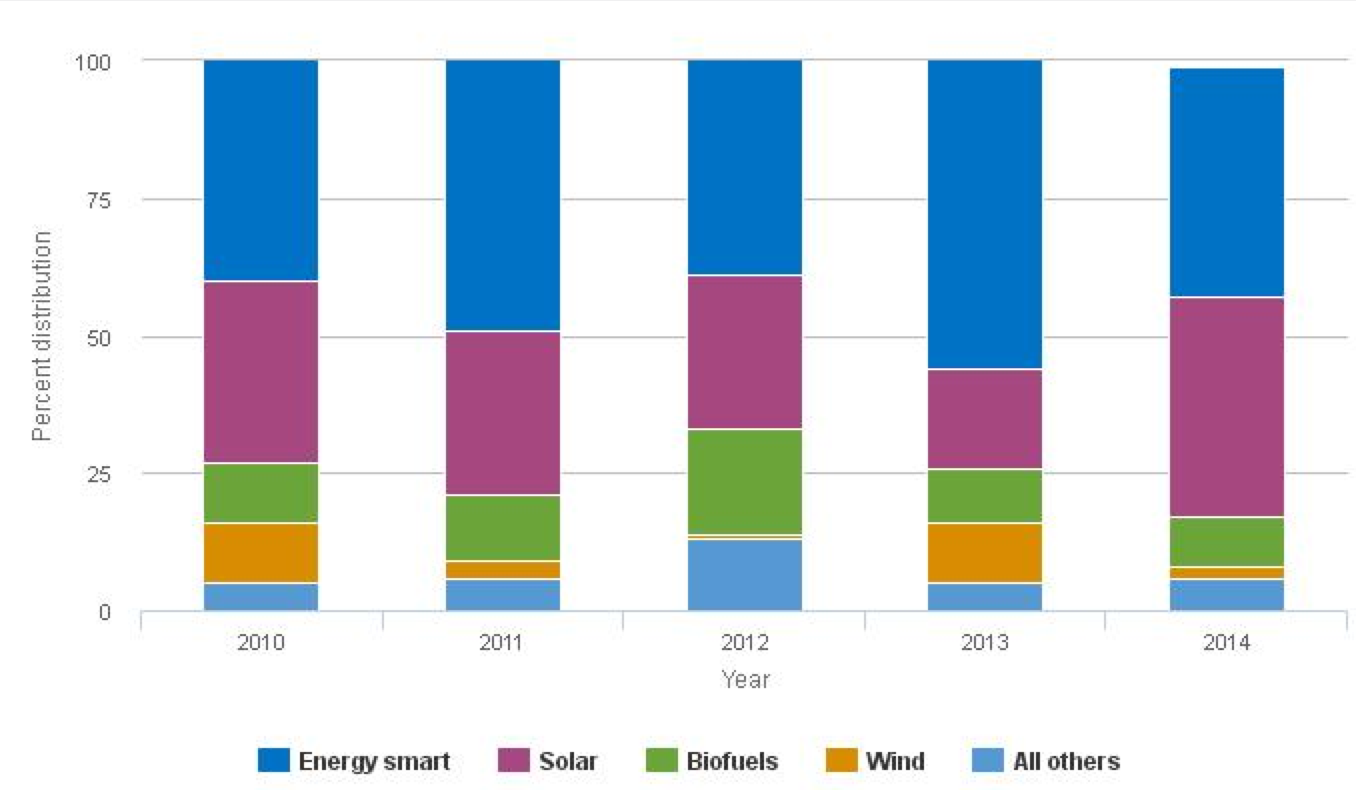
After peaking at an all-time high of $12.3 billion in 2008, global investment plunged to $4.2 billion in 2013 before increasing to $4.8 billion in 2014. The fall-off in investment during 2009–14 has been attributed to the difficulty of venture capitalists raising new funds and the lack of successful exits for existing venture-backed clean energy companies.

U.S. venture capital and private equity investment has paralleled the trend of global investment over the last decade. The jump in investment between 2013 and 2014 was driven largely by a $1 billion increase in solar investment (Figure 6-41). Over the last 5 years, energy smart has been the largest technology area, accounting for an average 46% share between 2010 and 2014 (Figure 6-42).

Figure 6-42

U.S. venture capital and private equity investment in clean energy technologies, by selected technology: 2010–14



NOTE: Clean energy technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency technologies.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2014).

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The energy smart category covers a wide range of technologies, from digital energy applications to efficient lighting, electric vehicles, and the smart grid that maximizes the energy efficiency of existing energy sources and networks. Several factors account for the popularity of energy smart technologies. They (1) are less capital intensive than other clean energy technologies, (2) give a shorter time horizon than most other energy technologies, (3) can be applied to a wider range of energy products and services, and (4) are less reliant on government incentives or subsidies.

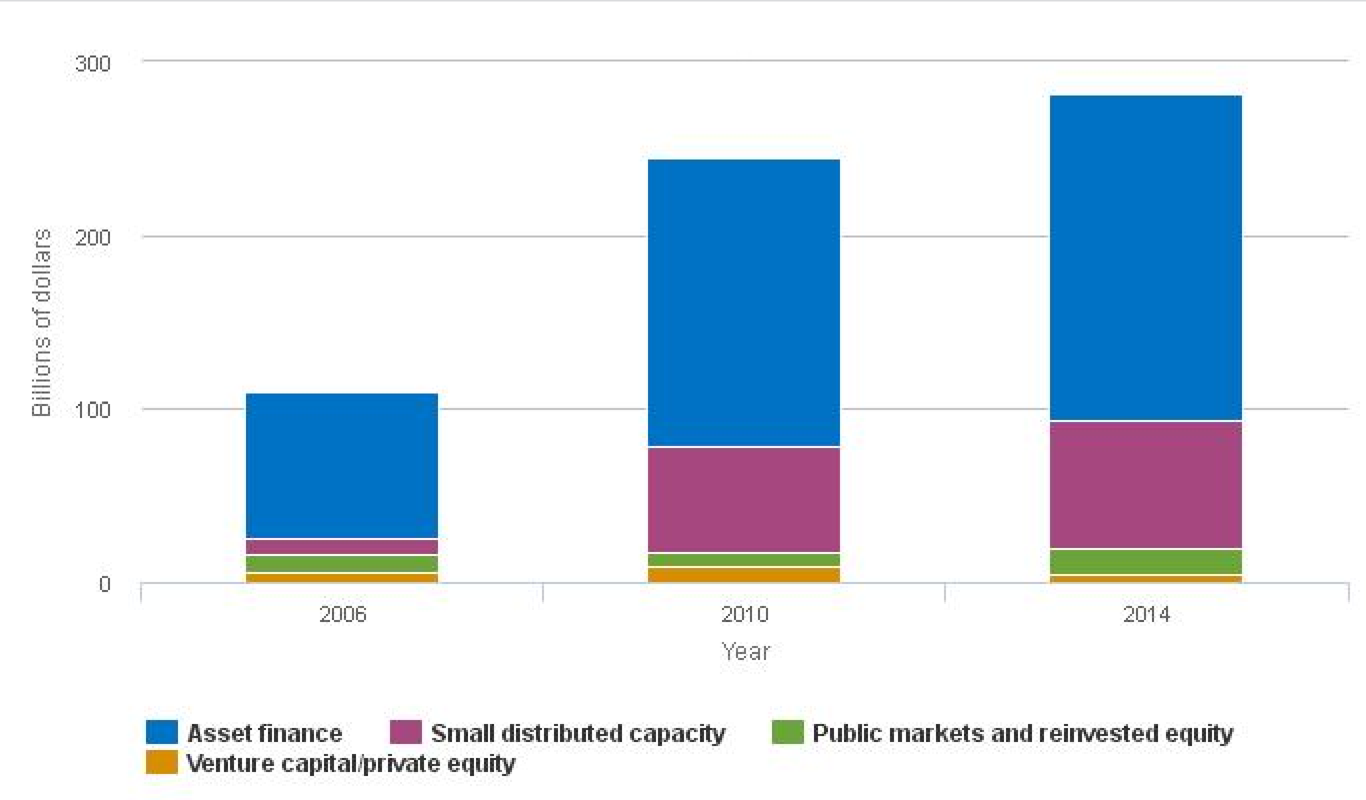
Solar is the second-largest technology area, accounting for 30% of investment over the last 5 years. Biofuels is the third-largest area (12% share).

Private Investment in Clean Energy Technologies

Private investment in clean energy technologies consists of early stage financing, venture capital and private equity, later stage financing, and asset finance—capital based on future expected income streams, public markets, reinvested equity, and small distributed capacity—installation of photovoltaics on commercial and residential structures (Figure 6-43). Asset finance and small-distributed capacity are by far the largest financing mechanisms of clean energy.

Figure 6-43

Private investment in clean energy technologies, by type of financing: 2006, 2010, and 2014



NOTES: Clean energy technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency technologies. Private investment includes asset finance, small distributed capacity, venture capital, private equity, reinvested equity, and public markets. Mergers and acquisitions are excluded.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2014).

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Global private investment in clean energy technologies was $281 billion in 2014 (Figure 6-44).[i] Two technologies—wind and solar—dominate clean energy investment, with a combined share of 86% (Figure 6-45). Energy smart technologies are the third-largest area.

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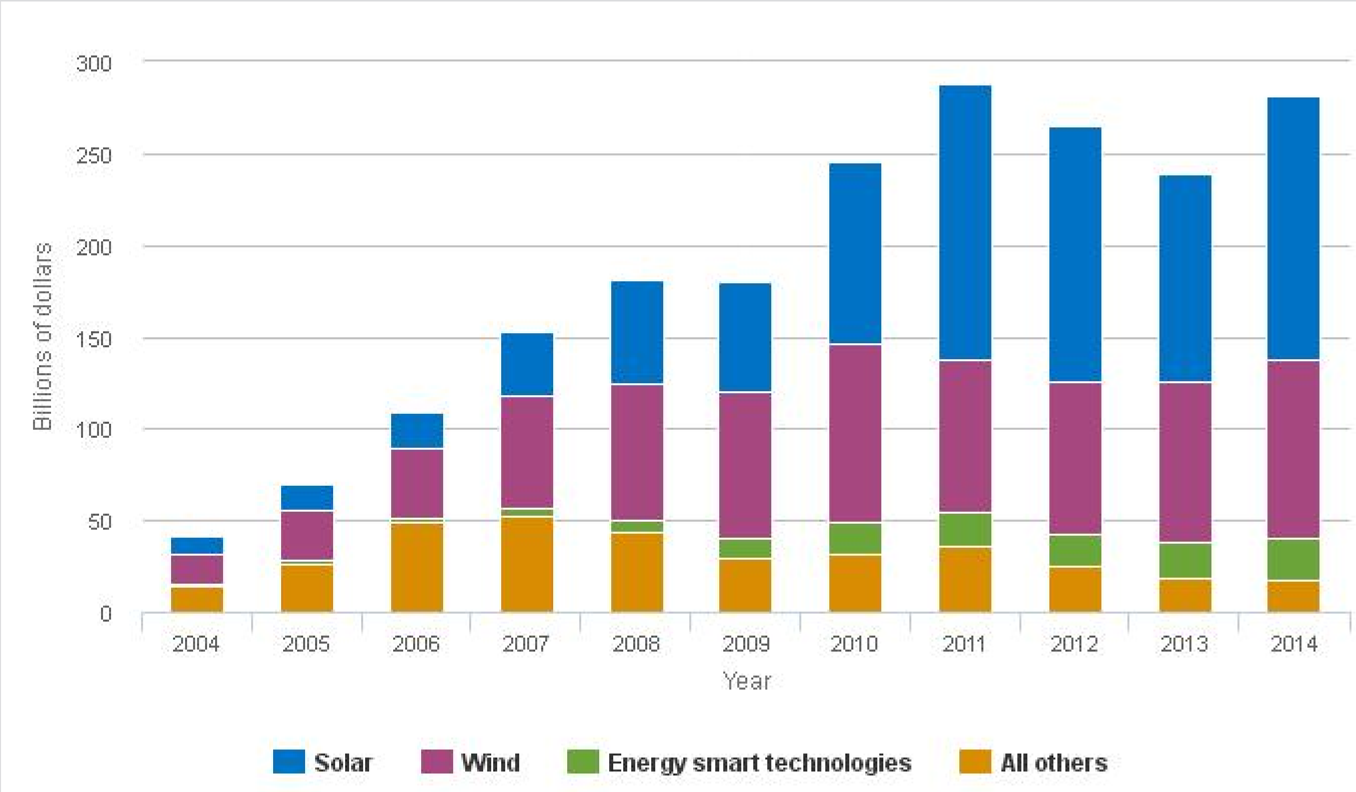
[i] Bloomberg's data include investment in renewable energy, biofuels, energy efficiency, smart grid and other energy technologies, CO_2 capture and storage, and infrastructure investments targeted purely at integrating clean energy. Investment in solar hot water, combined heat and power, renewable heat, and nuclear are excluded, as are the proceeds of mergers and acquisitions (which do not contribute to new investment).

Figure 6-44

Private investment in clean energy technologies, by selected technology: 2004–14



NOTES: Clean energy technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency technologies. Private investment includes asset finance, small distributed capacity, venture capital, private equity, reinvested equity, and public markets. Mergers and acquisitions are excluded.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2014).

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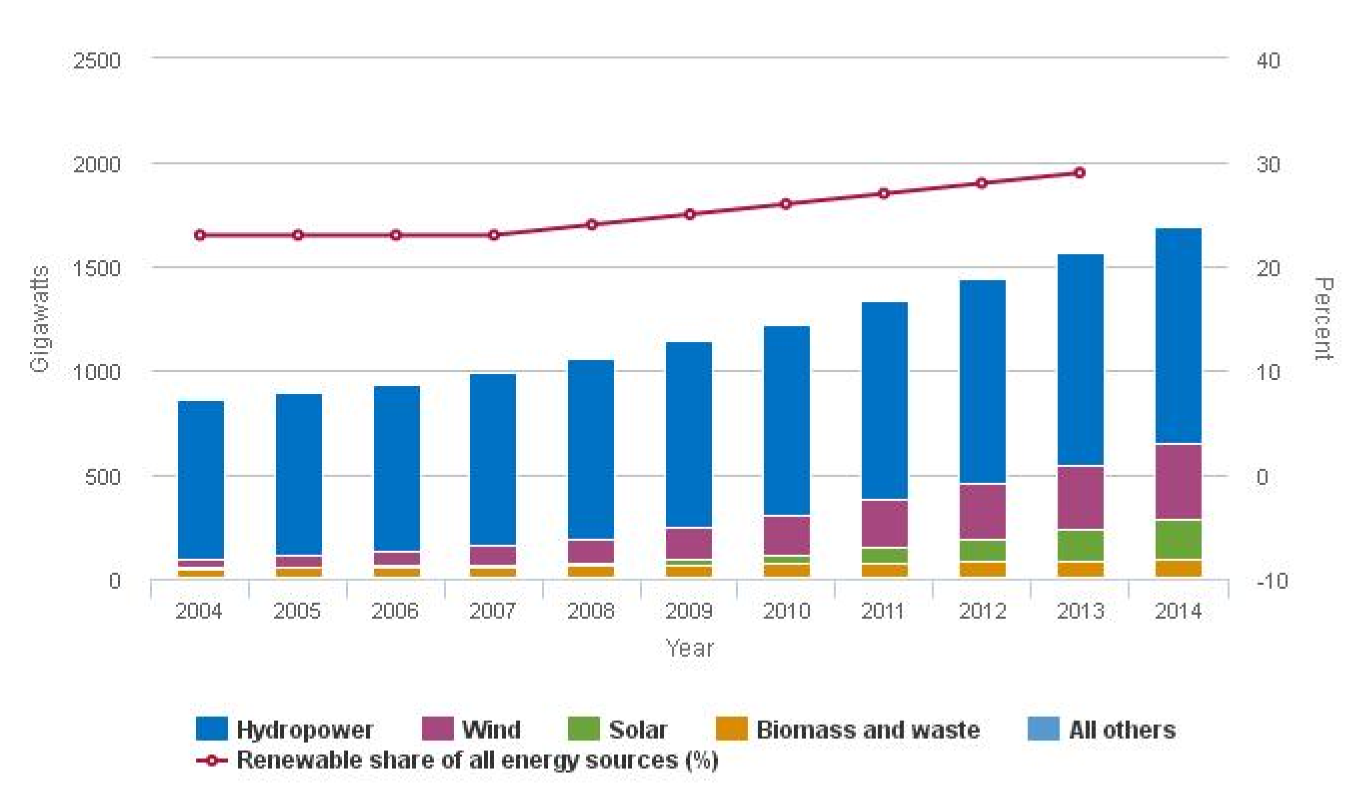
Figure 6-45

Global generation capacity of renewable energy, by source: 2004–14



NA = not available.

NOTES: Renewable energy includes biomass and waste, geothermal, hydropower, marine, solar, and wind. Renewable share of total is not available for 2014.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2014).

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Trends in global private investment. Between 2005 and 2014, global clean energy investment quadrupled from $70 billion to $281 billion (Figure 6-44; Appendix Table 6-64). After rising rapidly after the recession, investment fell from $288 billion in 2011 to $240 billion in 2013 before rebounding to $281 billion in 2014. Postrecession global investment growth has slowed because of the sluggish global economy, cutbacks by many governments on incentives to support clean energy, and declining costs of solar photovoltaics and wind technologies, which in turn have reduced the per-unit cost of investment in these technologies.

Solar led the growth of clean energy investment over the last decade, rising 10-fold from $14 billion to $144 billion. Investment in wind energy grew from $28 billion to $97 billion during this period. Investment in energy smart technologies also increased rapidly, although from a much lower level.

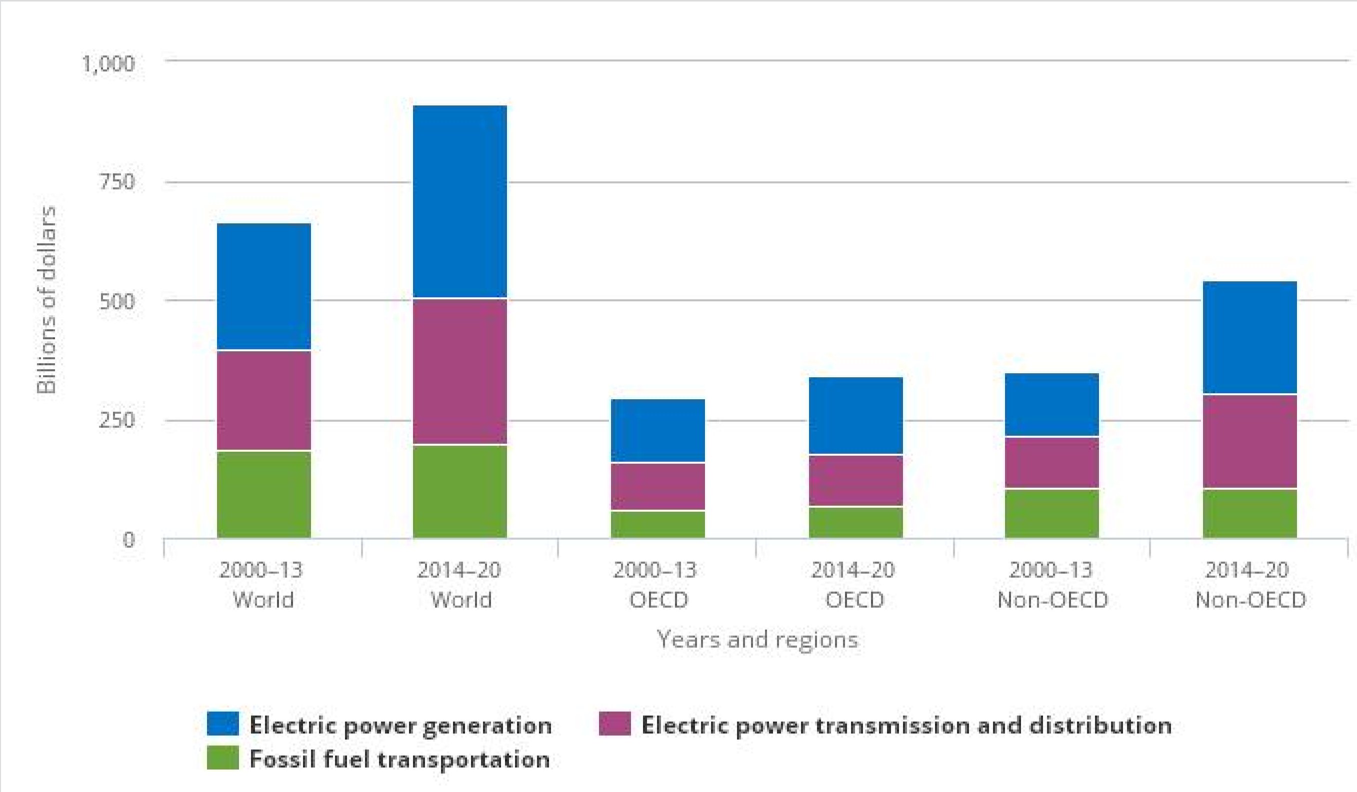
The large expansion of investment in wind and solar over the last decade has been accompanied by ever-increasing solar and wind generation capacity (Figure 6-45). Global solar and wind generation capacity jumped from 60 gigawatts in 2005 to 552 gigawatts in 2014. In 2014, the world added nearly 100 gigawatts of solar and wind generation capacity, an all-time record. The rapid expansion of solar and wind generation has driven the increase in the renewable share of all energy generation sources during this period.

The rise of clean energy investment has occurred in a broader environment of rising investment in *energy infrastructure*. Energy infrastructure consists of power plants, electricity transmission and distribution grids, and the transportation of fossil fuels. The International Energy Agency (IEA) estimates that public and private investment in energy infrastructure more than doubled from $290 billion in 2000 to $650 billion in 2012. Most of this growth occurred in financing of new power plants. The rapid rise in energy infrastructure investment has been driven by growing energy demand, particularly in developing countries. Growth in investment in renewable energy has been driven by the desire to reduce dependence on fossil fuels and reduce CO_2 emissions. In addition, clean energy has been attractive for developing countries because sourcing distributed generation from clean energy sources reduces costly investment in utility plants and distribution networks.

Investment in energy infrastructure, including the clean energy sector, is likely to continue growing. The IEA projects that global investment in energy infrastructure will average an annual $900 billion during 2014–20 compared with $660 billion in 2000–13 (Figure 6-46). Investment in renewable energy sources is projected to increase substantially in both OECD and non-OECD countries (Table 6-7 and Table 6-8).

Figure 6-46

Average annual investment in energy infrastructure for selected regions: 2000–13 and 2014–20



OECD = Organisation for Economic Co-operation and Development.

SOURCE: International Energy Agency, World Energy Investment Outlook, http://www.iea.org/publications/freepublications/publication/weo-2014-special-report---investment.html, accessed 15 March 2015.

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Table 6-7 Average annual investment in the power sector of the OECD, United States, and the EU, by energy source: 2000–13 and 2014–20

(Billions of dollars)

	OECD		United States		EU	
Energy source	2000–13	2014–20	2000–13	2014–20	2000–13	2014–20
All energy sources	135	166	35	52	66	61
Renewables	87	110	16	31	53	47
Wind	29	49	9	8	17	24
Solar	33	25	4	9	23	14
Bioenergy	11	13	2	8	8	3
Hydro	11	14	1	2	3	4
All others	3	9	0	4	2	2

	OECD		United States		EU	
Energy source	2000–13	2014–20	2000–13	2014–20	2000–13	2014–20
Nuclear	4	17	0	5	1	6
Fossil fuels	44	39	19	16	12	8

EU = European Union; OECD = Organisation for Economic Co-operation and Development.

SOURCE: International Energy Agency, World Energy Investment Outlook, http://www.iea.org/publications/freepublications/publication/WEIO2014.pdf, accessed 15 March 2015.

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Table 6-8 Average annual investment in the power sector of non-OECD countries, China, and India, by energy source: 2000–13 and 2014–20

(Billions of dollars)

	Non-OECD		China		India	
Energy source	2000–13	2014–20	2000–13	2014–20	2000–13	2014–20
All energy sources	134	241	71	110	46	32
Renewables	67	131	36	72	7	15
Wind	14	35	9	25	3	6
Solar	5	23	3	13	0	3
Bioenergy	6	9	2	3	1	1
Hydro	41	59	22	28	3	4
All others	1	5	0	3	0	1
Nuclear	5	29	2	15	7	3
Fossil fuels	62	81	33	23	32	14

OECD = Organisation for Economic Co-operation and Development.

SOURCE: International Energy Agency, World Energy Investment Outlook, http://www.iea.org/publications/freepublications/publication/WEIO2014.pdf, accessed 15 March 2015.

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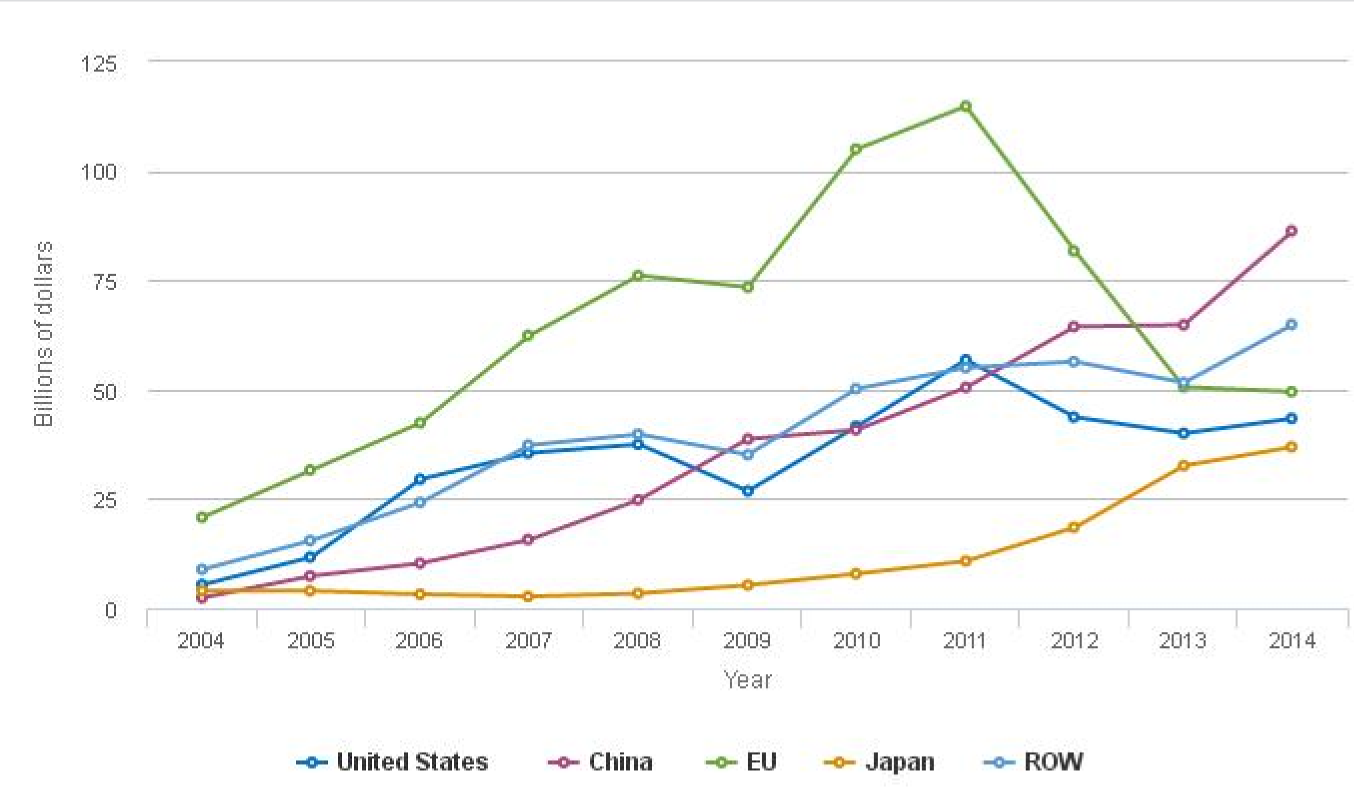
Patterns and trends in commercial investment of major economies. China leads the world in attracting clean energy investment (31% global share) (Appendix Table 6-64). The EU is second (18%), closely followed by the United States (15%). Japan is the fourth largest (13%).

China's private investment rose exponentially from $10 billion in 2006 to $86 billion in 2014 (Figure 6-47; Appendix Table 6-64). The uninterrupted growth of clean energy investments in China reflects the government's policies targeted at wind and solar energy to make China a major world producer in these technologies, reduce China's reliance on fossil fuels, and cut its CO_2 emissions. Investment in solar has driven China's growth over the last 5 years, climbing from $6 billion to $39 billion, making China the leading country in solar investment. China's rapid rise reflects its emergence as a major manufacturer of low-cost photovoltaic modules, as well as growing installation of utility scale and residential solar installations in China. China has also had impressive growth in investment in wind energy (from $27 billion in 2010 to $38 billion in 2014), making China the leading country in investment in wind.

Figure 6-47

Private investment in clean energy technologies, by selected region/country/economy: 2004–14



EU = European Union; ROW = rest of world.

NOTES: Clean energy technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency technologies. Private investment includes asset finance, small distributed capacity, venture capital, private equity, reinvested equity, and public markets. Mergers and acquisitions are excluded.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2014).

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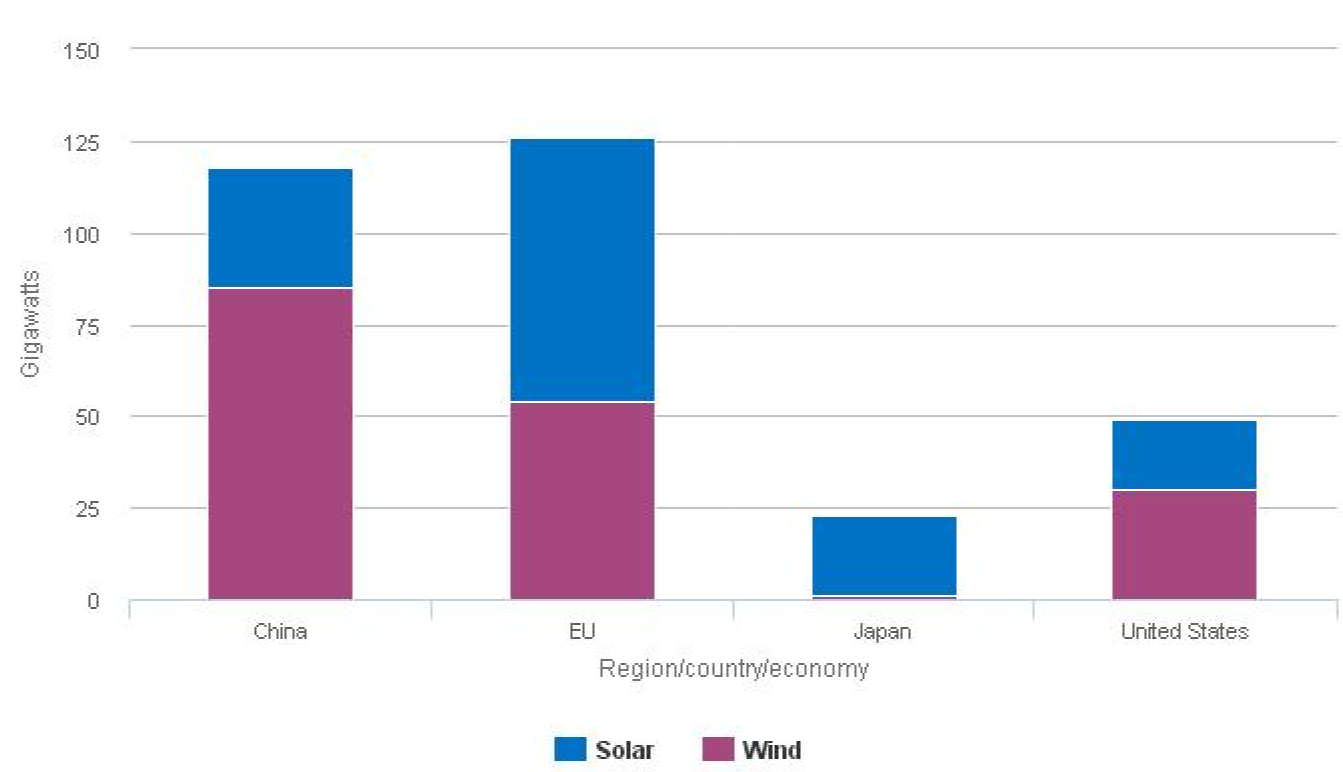
China's solar and wind generation capacity has grown rapidly, showing that its clean energy sector is shifting from a primary focus on exports to domestic consumption. Between 2010 and 2014, China's wind and solar generation capacity increased by nearly 120 gigawatts, the largest increase of any single country (Figure 6-48).

Figure 6-48

Cumulative installation of generation capacity of solar and wind, by energy source and selected region/country/economy: 2010–14



EU = European Union.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2014).

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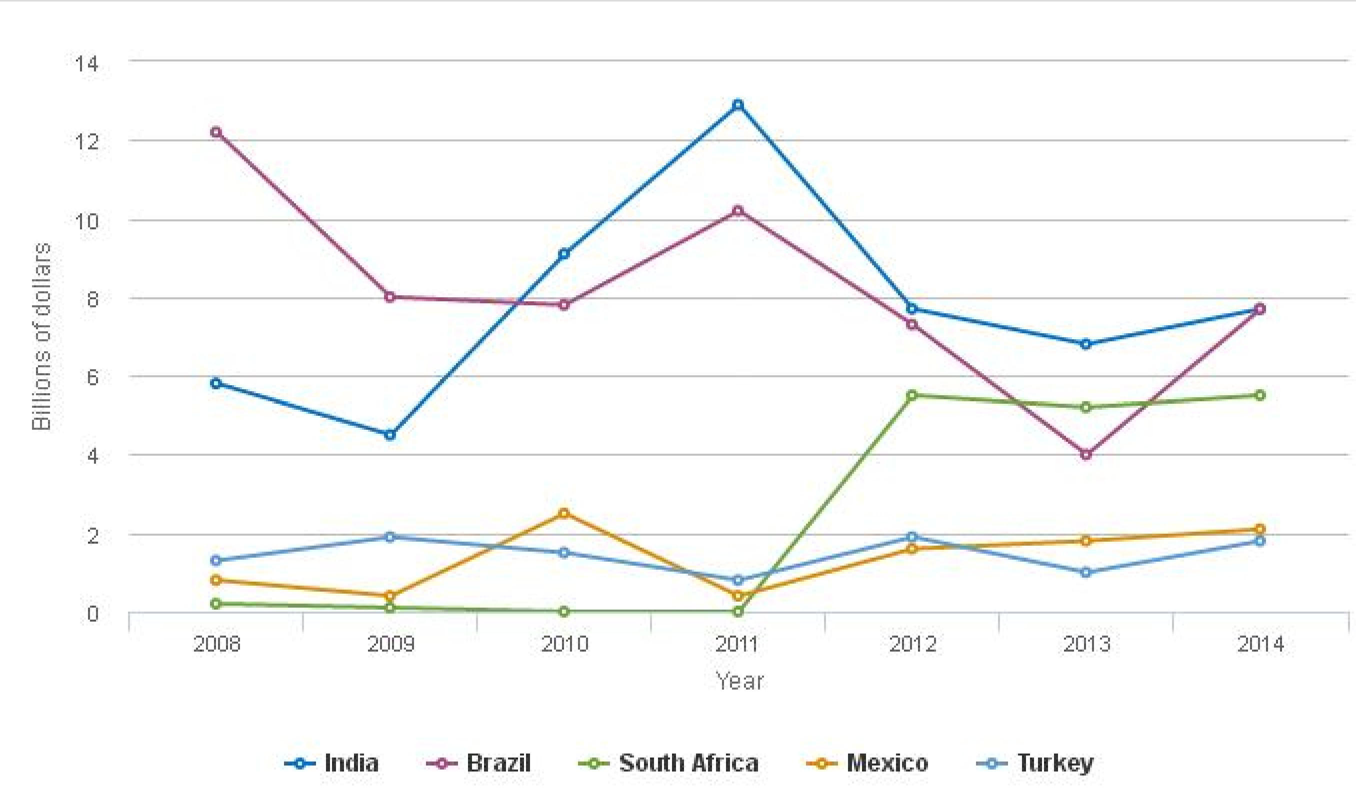
In other developing countries, Brazil and India each attracted $8 billion with the bulk of funds supporting wind power in Brazil and wind and solar in India (Figure 6-49; Appendix Table 6-64). In both, investment scaled back substantially, reflecting economic, regulatory, and political factors. South Africa has had one of the fastest growth rates in commercial investment among developing countries over the last several years.

Figure 6-49

Private investment in clean energy technologies, by selected country: 2008–14



NOTES: Clean energy technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency technologies. Private investment includes asset finance, small distributed capacity, venture capital, private equity, reinvested equity, and public markets. Mergers and acquisitions are excluded.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2014).

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Investment in the EU has fallen sharply because of cutbacks in clean energy incentives in response to fiscal austerity measures and the declining per-unit cost of investment in solar and wind technologies (Figure 6-47; Appendix Table 6-64). EU member countries with major declines in investment have included Germany, Spain, and Italy. Despite the recent curtailment of clean energy investment, the EU added a combined 125 gigawatts in solar and wind generation capacity between 2010 and 2014 (Figure 6-48).

Investment in the United States has been uneven. After the expiration of temporary financing provisions and subsidies led to a postrecession spike of $57 billion in 2011, investment fell to about $40 billion in 2012–14 (Figure 6-47; Appendix Table 6-64). The U.S. global share slipped from 20% to 15% during this period. The holding pattern of U.S. clean energy investment has been attributed to investor uncertainty over the future of the production tax credit and other clean energy incentives, as well as lack of clarity over U.S. energy policy. Investment in wind energy declined from $14 billion to $7 billion between 2012 and 2014 because of uncertainty over the timing and provisions of the production tax credit, which was extended by Congress in late 2013. Solar investment grew strongly, driven by utility-scale installations and soaring growth in residential installations because of the plunge in cost of photovoltaics and the adoption of leasing and other innovative financing methods.

Between 2010 and 2014, the United States added a combined 49 gigawatts in solar and wind generation capacity, less than half the amount of capacity added in China or the EU (Figure 6-48).

Clean energy investment in Japan has soared largely because of generous government incentives for solar investment enacted several years ago in response to the government's push to diversify energy sources in the wake of the Fukushima nuclear reactor accident (Figure 6-47; Appendix Table 6-64). Investment in solar climbed from $7 billion to $34 billion between 2010 and 2014, propelling total investment to $37 billion in 2014. Between 2010 and 2014, Japan added 22 gigawatts in solar energy capacity (Figure 6-48).

In other developed economies, Canada's investment has grown rapidly, climbing from $1 billion to $8 billion over the last decade, led by wind and solar (Appendix Table 6-64).

Patenting of Clean Energy and Pollution Control Technologies

Clean energy and pollution control technology patents comprise four broad areas: alternative energy, with 5,300 patents granted; energy storage, with 1,700 patents; smart grid, with 1,300 patents; and pollution mitigation, with 2,400 patents (Appendix Table 6-65, Appendix Table 6-66, Appendix Table 6-67, Appendix Table 6-68, and Appendix Table 6-69). These broad categories are further divided into 28 finer technology areas. (For more information on this classification of clean energy patent technologies, which was developed by NSF, please see the NCSES working paper, *Identifying Clean Energy Supply and Pollution Control Patents*.[i])

The number of patents in these technologies has soared since 2009, in line with the rapid growth of all USPTO patents (Figure 6-50; Appendix Table 6-65).[ii] Five technologies—solar, hybrid and electric vehicles, smart grid, fuel cell, and battery—led the growth of clean energy patents between 2003 and 2014 (Appendix Table 6-68, Appendix Table 6-70, Appendix Table 6-71, Appendix Table 6-72, and Appendix Table 6-73):

- Solar energy increased by more than fivefold to reach 1,600 patents.
- Hybrid and electric vehicles tripled to reach 1,300 patents.
- Smart grid more than doubled to reach 1,300 patents.
- Battery more than doubled to reach 800 patents.
- Fuel cell almost doubled to reach 800 patents.

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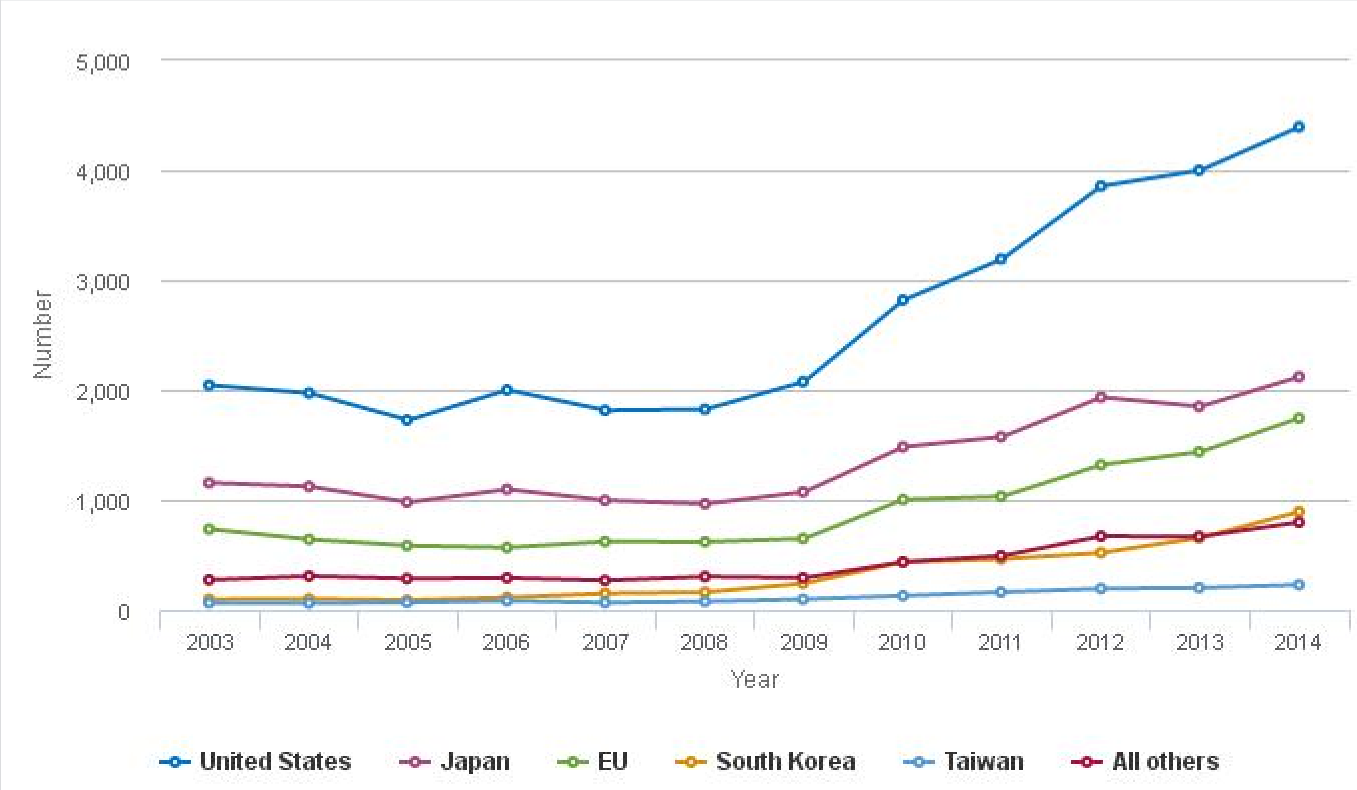
[i] See D'Amato (2015) for more information on NSF's classification of clean energy patents.

[ii] The USPTO initiated a green technology pilot program on 7 December 2009 that expedites processing of some applications related to green technologies. For more information, see http://www.uspto.gov/patents/init_events/green_tech.jsp.

Figure 6-50

USPTO patents in alternative energy and pollution control technologies, by selected region/country /economy of inventor: 2003–14



EU = European Union; USPTO = U.S. Patent and Trademark Office.

NOTES: Clean energy and pollution control technologies include alternative energy, energy storage, smart grid, and pollution mitigation. Alternative energy includes solar, wind, nuclear, hydropower, wave/tidal/ocean, geothermal, and electric/hybrid. Energy storage includes batteries, compressed air, flywheels, superconductivity, magnet energy systems, ultracapacitors, hydrogen production and storage, and thermal energy. Pollution mitigation includes recycling; control of air, water, and solid waste pollution; environmental remediation; cleaner coal; and capture and storage of carbon and other greenhouse gases. Technologies are classified by The Patent Board™. Patent grants are fractionally allocated among regions/countries on the basis of the proportion of the residences of all named inventors.

SOURCE: The Patent Board™, Proprietary Patent database, special tabulations (2014). See appendix table 6-65.

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U.S. resident inventors were granted 43% of all clean energy and pollution control patents in 2014. The next three largest recipient countries are Japan (21%), the EU (17%), and South Korea (9%) (Figure 6-50). Between 2003 and 2014, Japan's share fell from 26% to 21%. South Korea's share rose from 2% to 9% because of strong growth in electric and hybrid vehicles, fuel cell, and battery technology (Appendix Table 6-71, Appendix Table 6-72, and Appendix Table 6-73). Patents granted to China and Taiwan have been increasing rapidly, though from a very low base (Appendix Table 6-65). In 2014, China and Taiwan's shares of total patents were 2% each, up from 1% or less in 2003.

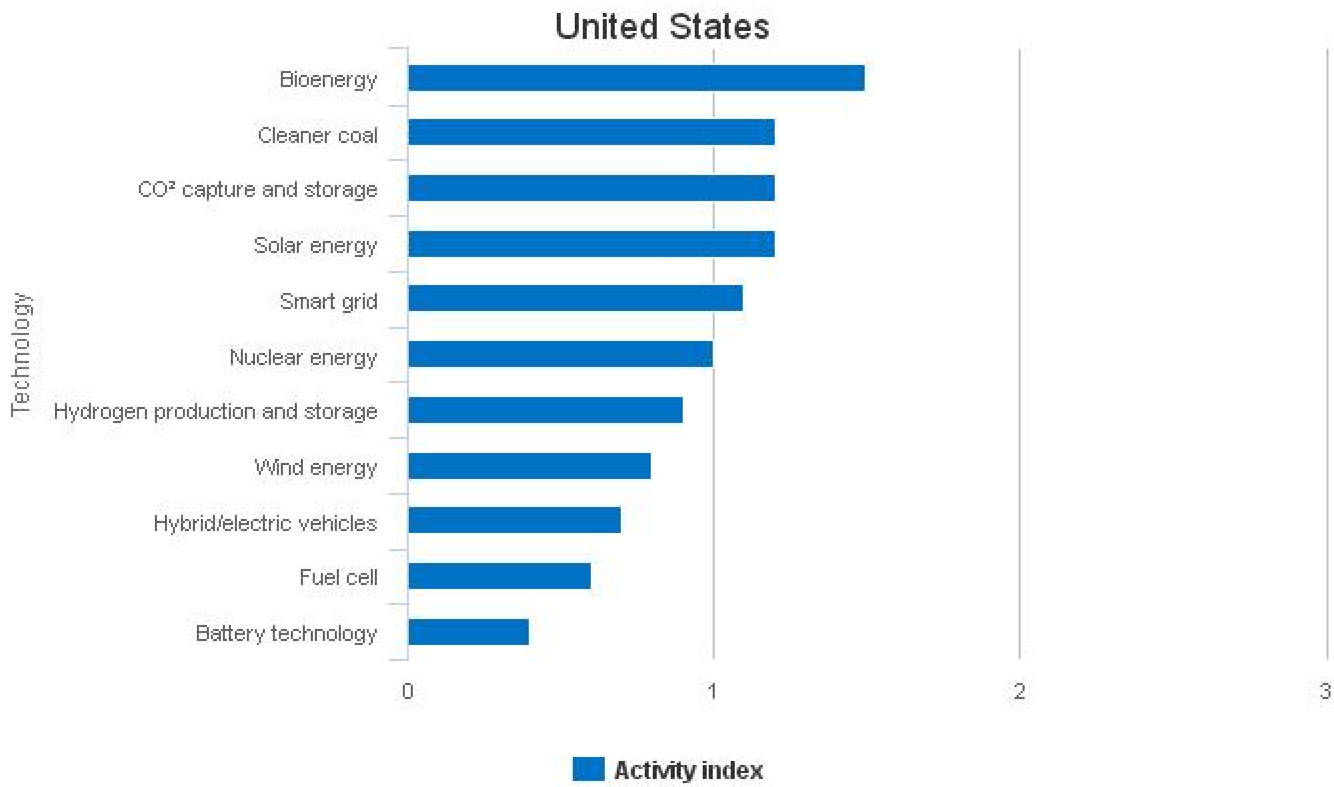
Patent technology activity indexes measure the world share of a region, country, or economy in clean energy and clean technologies relative to its world share in patents in all technologies. A ratio greater than 1 signifies that patents by a region/country/economy are concentrated in a particular technology.

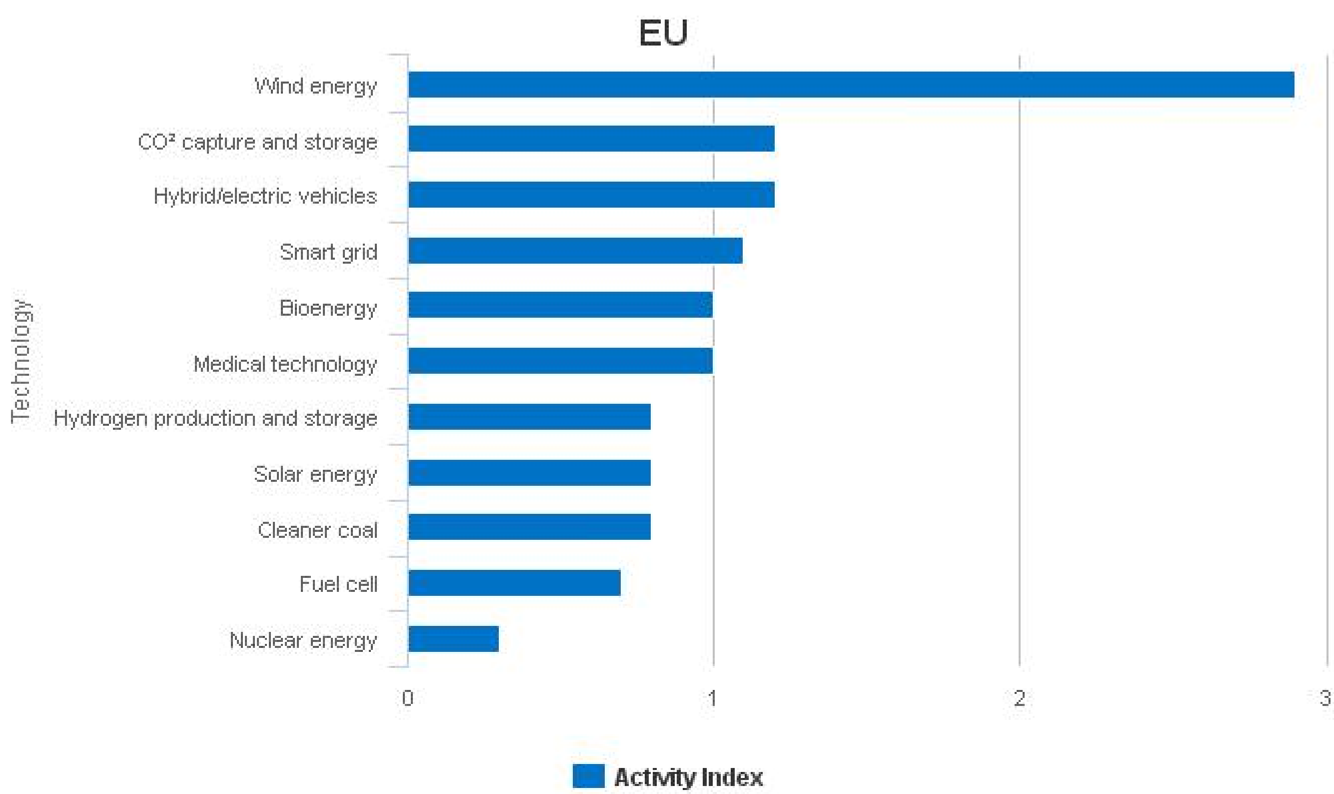
Chapter 6. **Industry, Technology, and the Global Marketplace**

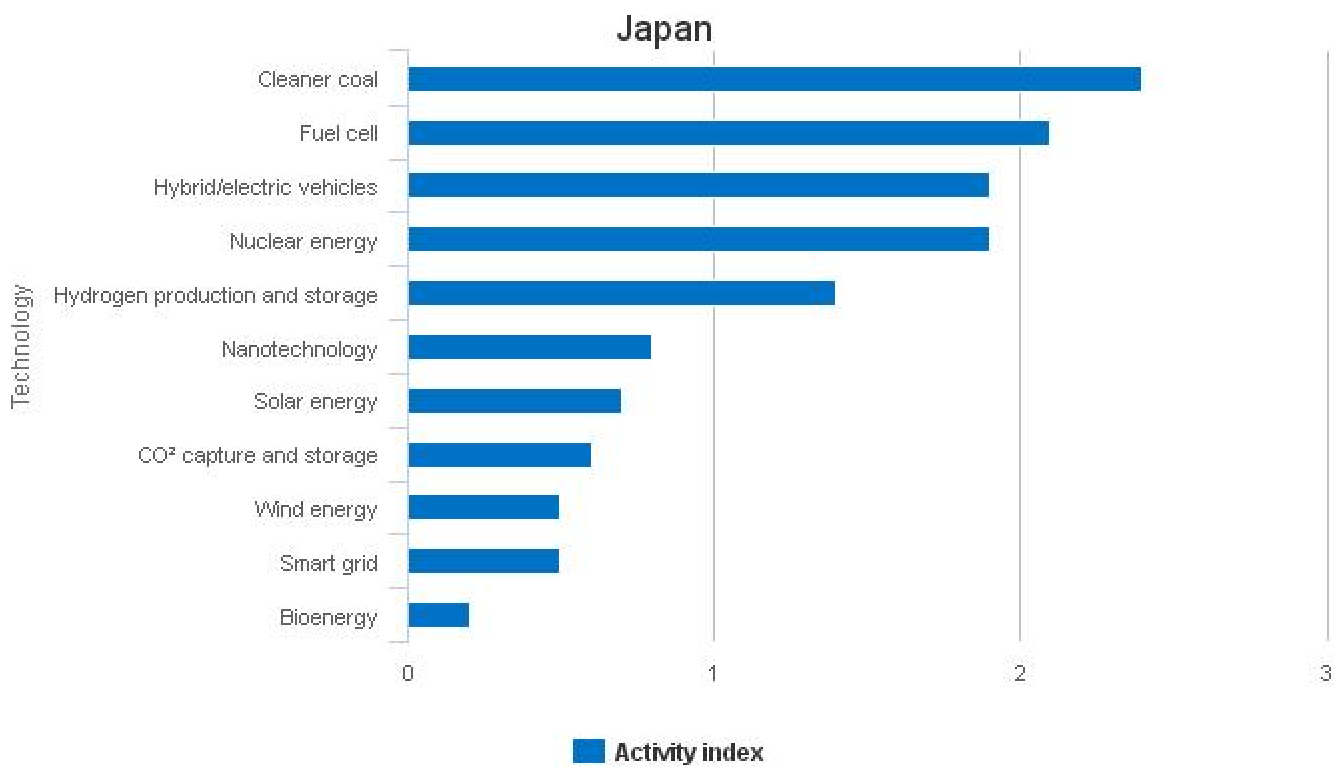
The U.S. has a high concentration in bioenergy, cleaner coal, CO_2 capture and storage, solar, and smart grid technologies, and relatively low patent activity in wind, electric and hybrid vehicles, fuel cells, and batteries (Figure 6-51; Appendix Table 6-68 and Appendix Table 6-70, Appendix Table 6-71, Appendix Table 6-72, Appendix Table 6-73, Appendix Table 6-74, Appendix Table 6-75, Appendix Table 6-76, and Appendix Table 6-77). The higher-than-average patenting activity in solar may reflect the substantial level of venture capital investment to commercialize advanced and leading-edge solar technologies. Similarly, U.S. patenting activity in CO_2 capture and storage may reflect substantial U.S. public investment in RD&D in this technology area, which requires multimillion dollar investment to build demonstration coal generation plants to test and develop this technology.

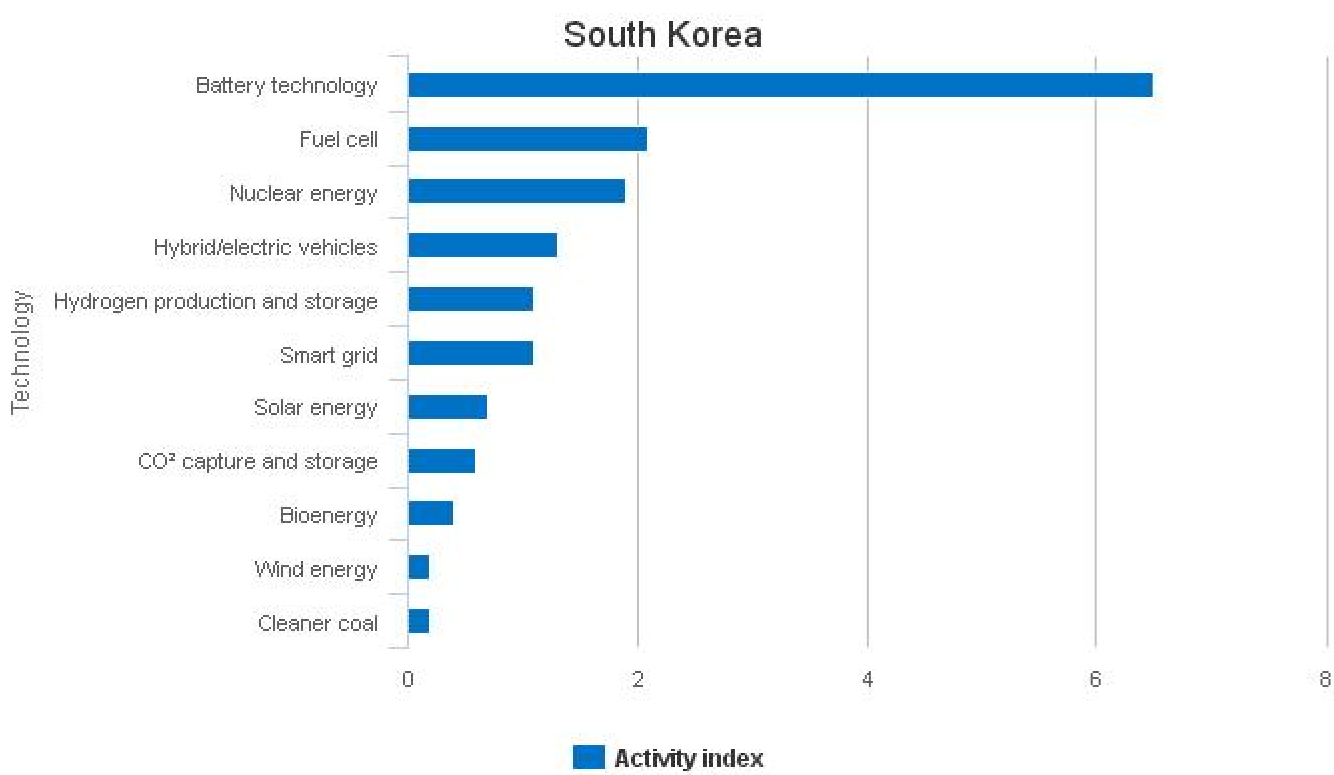
Figure 6-51

Patent activity index of selected clean energy technologies for the United States, the EU, Japan, and South Korea: 2012–14









EU = European Union.

NOTES: A patent activity index is the ratio of a country’s share of a technology area to its share of all patents. A patent activity index greater (less) than 1.0 indicates that the country is relatively more (less) active in the technology area. Patents are classified by the World Intellectual Property Organization's (WIPO's) classification of patents, which classifies International Patent Classification (IPC) codes under 35 technical fields. IPC reformed codes, which take into account changes that were made to the WIPO classification in 2006 under the eighth version of the classification, were used to prepare these data. Fractional counts of patents were assigned to each IPC code on patents to assign the proper weight of a patent to the corresponding IPC codes and their associated technical fields under the classification. Patents are fractionally allocated among regions/countries/economies based on the proportion of residences of all named inventors.

SOURCES: Science-Metrix, LexisNexis, and SRI International.

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The EU has a very high concentration in wind; relatively high concentrations in CO_2 capture and storage, electric and hybrid vehicles, and smart grid; and relatively low concentrations in hydrogen production and storage, solar, cleaner coal, and nuclear energy (Figure 6-51; Appendix Table 6-68, Appendix Table 6-70, Appendix Table 6-71, Appendix Table 6-73, Appendix Table 6-75, Appendix Table 6-76, Appendix Table 6-77, Appendix Table 6-78, and Appendix Table 6-79). The EU's higher-than-average activity in CO_2 capture and storage may reflect the EU's substantial public investment in RD&D in this technology area.

Japan has a high concentration of patents in fuel cells, cleaner coal, nuclear energy, electric and hybrid technologies, and hydrogen production and storage but relatively low activity in solar, CO_2 capture and storage, wind, smart grid, and bioenergy (Figure 6-51; Appendix Table 6-68, Appendix Table 6-70, Appendix Table 6-71, Appendix Table 6-72, Appendix Table 6-73, and Appendix Table 6-74, Appendix Table 6-76 – Appendix Table 6-77, and Appendix Table 6-79).

South Korea has a very high concentration in batteries and a high concentration in fuel cells, nuclear energy, hybrid and electric vehicles, hydrogen production and storage, and smart grid (Figure 6-51; Appendix Table 6-68, Appendix Table 6-71, Appendix Table 6-72, Appendix Table 6-73, Appendix Table 6-78, and Appendix Table 6-79). It has lower-than-average activity in all other technologies.

Conclusion

The United States continues to be the leading global economy in technology-based industries, as measured by its overall performance, market position in these industries, and position in patenting and other measures of innovation-related activities. The strong competitive position of the U.S. economy overall is tied to continued U.S. global leadership in many KTI industries. The United States continues to hold the dominant market position in commercial KI services, which account for nearly one-fifth of global economic activity, and in HT manufacturing industries. The U.S. trading position in commercial KI services and licensing of patents and trade secrets remains strong, as evidenced by the continued U.S. surpluses in these areas. The United States is the second-largest source of public RD&D in clean energy and related technologies and attracts the most venture capital financing of any country in these technologies. Output of U.S. KTI industries has recovered from the global recession in line with the strengthening economy.

The overall U.S. ranking notwithstanding, its market position in almost all of the KTI industries has been static or has slipped. U.S. production and employment have fallen sharply in the HT manufacturing industries of communications and computers, coinciding with U.S. companies moving assembly and other activities to China and other countries. The U.S. trade position in these products has shifted to deficit because exports have declined and imports have increased. Although output of U.S. KTI industries has had a strong recovery from the global recession, gains in employment have been limited and confined to commercial KI services.

For much of the 2000s, the EU's position was similar to that of the United States—relatively strong overall economic performance and flat or slight declines in its market position in KTI industries. But the EU's KTI industries have not recovered from the global recession because of the EU's weak economy, resulting in an erosion of the market position of its KTI industries.

Over the last decade, Japan's economy showed less dynamism compared with the economies of the United States and the EU, and its market position declined steeply in many KTI industries. Japan's loss of market position in HT manufacturing industries was due, in part, to Japanese companies shifting production to China and other Asian economies. Japan's KTI industries have not recovered from the global recession, coinciding with the uncertain and halting progress of the economy.

China has become a leading provider of commercial KI services and the second-largest global producer in HT manufacturing industries and has narrowed its gap with the United States. China has become the largest global exporter in HT manufactured products and has developed surpluses in trade of HT manufacturing products and commercial KI services. It has become the world's largest recipient of commercial financing for clean energy and a leading producer in the solar industry. However, China's indicators of indigenous capability in KTI industries and other areas are uneven. Much of China's HT manufacturing output is controlled by MNCs that import higher-value components from other countries for final assembly in, and export from, China. Chinese companies have made limited progress in more technologically advanced and higher-end manufacturing activities. In an indicator of innovative capacity, China's share of USPTO and economically valuable patents has grown but remains low.

Other developing economies—including Brazil and India—showed progress in their overall economic growth and technological capabilities and improved their market positions in many KTI industries. In recent years, their previously strong KTI growth rates have moderated but remain ahead of those of many developed countries.

Glossary

Affiliate: A company or business enterprise located in one country but owned or controlled (10% or more of voting securities or equivalent) by a parent company in another country; may be either incorporated or unincorporated.

Commercial knowledge-intensive (KI) services: KI services that are generally privately owned and compete in the marketplace without public support. These services are business, information, and financial services.

Company or firm: A business entity that is either in a single location with no subsidiaries or branches or the topmost parent of a group of subsidiaries or branches.

European Union (EU): As of September 2015, the EU comprised 28 member nations: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom. Unless otherwise noted, data on the EU include all 28 member countries.

Foreign direct investment: Financial investment by which a person or an entity acquires a lasting interest in and a degree of influence over the management of a business enterprise in a foreign country.

Gross domestic product (GDP): The market value of all final goods and services produced within a country within a given period of time.

High-technology (HT) manufacturing industries: Those that spend a relatively high proportion of their revenue on R&D, consisting of aerospace, pharmaceuticals, computers and office machinery, semiconductors and communications equipment, and scientific (medical, precision, and optical) instruments.

Information and communications technologies (ICT) industries: A subset of knowledge- and technology-intensive industries, consisting of two high-technology manufacturing industries, computers and office machinery and communications equipment and semiconductors, and two knowledge-intensive services industries, information and computer services, which is a subset of business services.

Intellectual property: Intangible property resulting from creativity that is protected in the form of patents, copyrights, trademarks, and trade secrets.

Intra-EU exports: Exports from European Union (EU) countries to other EU countries.

Knowledge- and technology-intensive (KTI) industries: Those that have a particularly strong link to science and technology. These industries are five service industries, financial, business, communications, education, and health, and five manufacturing industries, aerospace, pharmaceuticals, computers and office machinery, semiconductors and communications equipment, and scientific (medical, precision, and optical) instruments.

Knowledge-intensive (KI) industries: Those that incorporate science, engineering, and technology into their services or the delivery of their services, consisting of business, information, education, financial, and health services.

Normalizing: To adjust to a norm or standard.

Productivity: The efficiency with which resources are employed within an economy or industry, measured as labor or multifactor productivity. Labor productivity is measured by gross domestic product (GDP) or output per unit of labor. Multifactor productivity is measured by GDP or output per combined unit of labor and capital.

Triadic patent: A patent for which patent protection has been applied within the three major world markets: the United States, Europe, and Japan.

Value added: A measure of industry production that is the amount contributed by a country, firm, or other entity to the value of the good or service. It excludes the country, industry, firm, or other entity's purchases of domestic and imported supplies and inputs from other countries, industries, firms, and other entities.

Value chain: A chain of activities to produce goods and services that may extend across firms or countries. These activities include design, production, marketing and sales, logistics, and maintenance.

Venture capitalist: Venture capitalists manage the pooled investments of others (typically wealthy investors, investment banks, and other financial institutions) in a professionally managed fund. In return, venture capitalists receive ownership equity and almost always participate in managerial decisions.

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Chapter 7.

Science and Technology: Public Attitudes and Understanding

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Highlights

Interest, Information Sources, and Involvement

Four out of 10 Americans say they are "very interested" in new scientific discoveries, and 6 out of 10 say they are "very interested" in new medical discoveries.

- Other science-related issues also interest many Americans; these include environmental pollution and use of new inventions and technologies.
- Interest in environmental pollution has declined slowly since 1990, when more than 6 in 10 Americans said they were very interested in the topic. Only about 4 in 10 Americans gave this response in 2014.

The Internet remains Americans' primary source for science news and information seeking.

- Nearly half of Americans cited the Internet as their primary source of science and technology (S&T) information in 2014 compared with about one-tenth of Americans in 2001. Television and newspapers continue to be used less often as sources of science news and information.
- For those who say they use the Internet as their primary source of information, about 4 in 10 say they use a search engine (e.g., Google) to find science information. About 2 in 10 say they use online newspapers.

Public Knowledge about S&T

Americans correctly answered an average of 5.8 out of 9 factual knowledge questions in 2014, a score similar to those in recent years but high in terms of the overall historical trend.

- Americans with more formal education tend to provide a greater number of correct answers on science knowledge questions.
- Men tend to do better on questions focused on the physical sciences, whereas women do slightly better on questions focused on the biological sciences, for the specific questions asked.
- An experiment examined the standard question used to measure knowledge about evolution. This research found that a wording change substantially increased the percentage of correct responses and this change also improved correlation with knowledge of evolution and science more generally. Levels of factual scientific knowledge in the United States are comparable with those in Europe and are generally higher than levels in countries in other parts of the world.

Two-thirds of Americans could correctly answer two multiple-choice questions dealing with probability in the context of medical treatment, and about half could describe the best way to conduct a drug trial.

- The percentage of Americans providing correct responses to these questions is as high as it has ever been; nearly half of Americans correctly answered all of these scientific reasoning questions.

Public Attitudes about S&T in General

Americans perceive far more benefits than harms from science and want governments to fund research.

- About 7 in 10 Americans say that they believe the benefits from science are greater than the harms, and almost 9 in 10 agree that S&T will create more opportunities for future generations.
- However, Americans increasingly worry that science is making life "change too fast." About half of Americans expressed this view in 2014, up from about one-third in 2004.
- About 4 in 10 Americans say we are spending "too little" to "support scientific research." This number has stayed relatively steady for many years, although relatively few Americans (1 in 10) now say we spend "too much."

Americans are more likely to have "a great deal of confidence" in leaders of the scientific community than in leaders of any group except the military.

- About 4 in 10 Americans express high levels of confidence in the scientific community. This ranks second only to the military, for which half of Americans say they have "a great deal of confidence."
- Although the medical community remains one of the most respected groups in America, the percentage of Americans who express "a great deal of confidence" in the medical community has decreased since the 1970s and has tied with its previous low in 2002, with slightly fewer than 4 in 10 expressing high confidence.

Public Attitudes about Specific S&T-Related Issues

The wide range of survey data on Americans' opinions on overall environmental protection yields conflicting findings.

- In 2015, about half of Americans said the environment should be made a priority over economic growth, up from about 3 in 10 in 2011. This level is still, however, below the nearly 6 in 10 who gave this response in 2001.
- Americans are, on average, less likely to choose the environment over the economy than residents of many other countries.
- About 4 in 10 Americans say they are "very interested" in environmental pollution news, down from about 6 in 10 in 1990.
- About 3 in 10 Americans say they worry "a great deal" about the quality of the environment, similar to the historic low in 2014.

Americans remain divided on the severity and nature of climate change.

- Slightly more than half of Americans say they worry about climate change, a percentage that is relatively low compared with surveys conducted since 1989. Fewer than 4 in 10 think it will pose a serious threat to their own way of life.
- Only about 6 in 10 Americans believe there is scientific consensus on the fact that climate change is occurring.

When given the choice, a majority of Americans say they would prefer to focus on non–fossil fuel alternatives.

- About 6 in 10 consumers say they would choose to prioritize conservation over fossil fuel development; the same proportion would focus on alternative energy over fossil fuel development.
- The vast majority of Americans (about 8 in 10) say they would like to see more emphasis on both fuel efficiency standards for vehicles and renewable energy development.

- Different surveys about how Americans feel about nuclear energy suggest that support may be as low as about 4 in 10 Americans or as high as about 6 in 10 Americans.

A minority of Americans think genetically engineered (GE) foods are safe.

- Three in 10 Americans see GE foods as "safe to eat," and a similar proportion believes that scientists understand the risks of these foods.

Most Americans view using stem cells from human embryos in medical research as "morally acceptable."

- Gallup research shows that more than 6 in 10 Americans see using stem cells from human embryos as acceptable. This percentage reached a historic high in 2014.

Most Americans think other countries are doing a better job on science, technology, engineering, and mathematics (STEM) education.

- In 2014, fewer than 1 in 10 Americans think that American kindergarten through grade 12 STEM education is among the best in the world.

Introduction

Chapter Overview

Science and technology (S&T) is central to American life. It shapes many of our daily activities, including how we interact at home, at work, and in our communities. Millions of Americans use S&T at work (see chapter 3), whereas others use these innovations to produce the goods and services that improve and reshape our lives. S&T gives us new opportunities to get healthy and stay healthy. It influences what and how we eat while providing technologies that keep us connected and entertained. S&T often enters our conversations about daily life decisions and may stimulate us intellectually and emotionally. The centrality of S&T to American life means that Americans' attitudes about and understanding of S&T may matter a great deal.

All technologies also involve risks and benefits, and technologies can embody risks that may take time to become apparent. S&T discussions may often center on potential risks and benefits, as well as moral issues raised by adopting scientific processes and technologies. Societies can do a better job of addressing potential concerns when the nature of these concerns is well understood and discussed (e.g., NRC 1996, 2008). Americans' desire to seek potential benefits from S&T and deal with potential risks may affect what kinds of S&T can be developed or used. For example, Americans must decide how much of society's resources to devote to scientific research, where to devote those resources, and whether to encourage or discourage the development of specific technologies. Individuals may also choose where to focus their careers based on both their personal interests and on where they believe they can make a meaningful contribution.

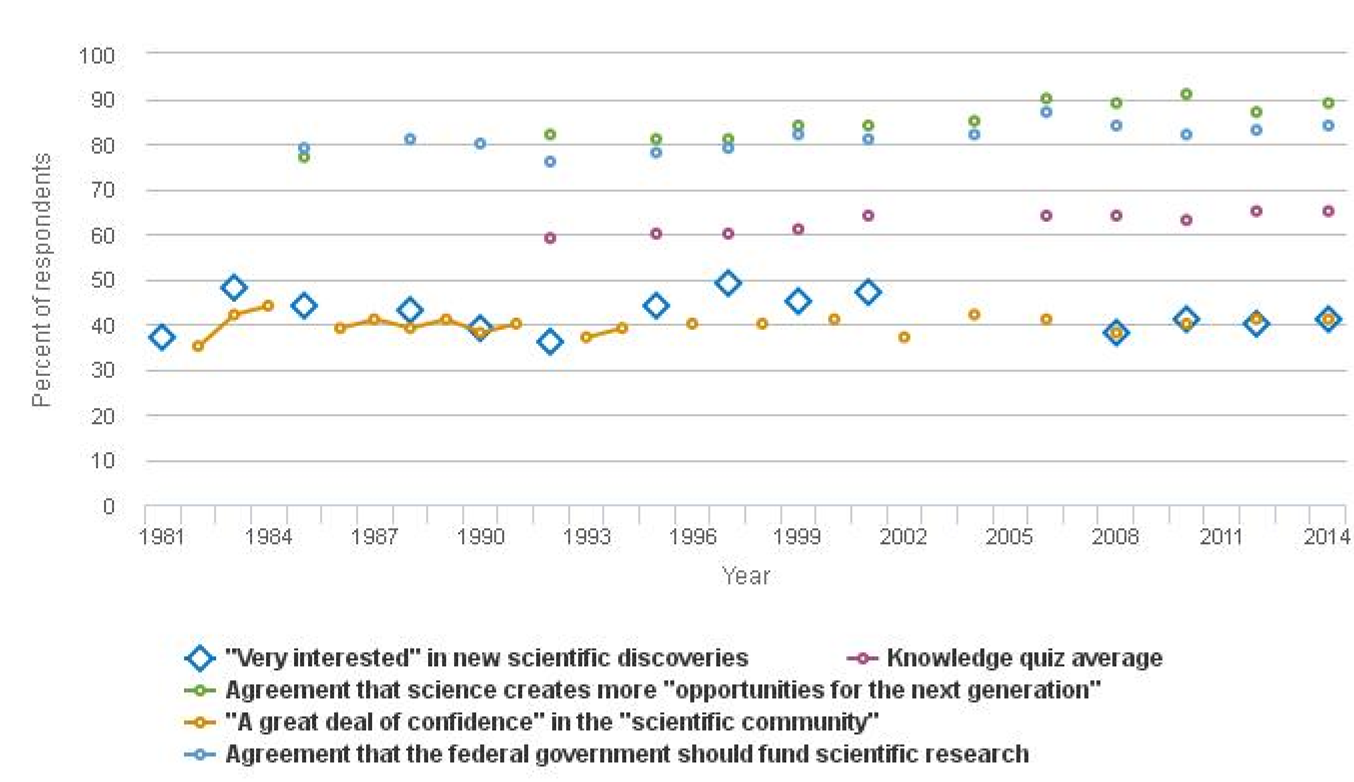
Given the centrality of S&T to life in the United States, this chapter presents indicators about interest in S&T news, where people encounter S&T in the media, trend data regarding knowledge of S&T, and indicators of people's attitudes about S&T-related issues. To put U.S. data in context, the chapter examines trend indicators for past years and comparative indicators for other countries, where such data are available.

A review of five key indicators in this chapter—interest in new scientific discoveries, basic scientific knowledge, belief that science creates opportunity, confidence in the scientific community, and support for science funding—indicates that Americans' overall attitudes about science are either stable or becoming more positive and that knowledge may be slowly increasing. The key indicators were chosen because data are available for a relatively long period for each indicator and because the indicators reflect the main themes raised in the chapter. Looking at these indicators together provides a sense of how Americans' overall attitudes and knowledge about S&T have changed over more than 30 years.

Specifically, the percentage of Americans agreeing that S&T creates new opportunities and that it is important to fund scientific research has been at relatively high levels in recent surveys compared with those from previous decades. Basic knowledge has also grown slightly with time. General confidence in the scientific community and the percentage of Americans saying that they are "very interested" in new scientific discoveries have been relatively stable in recent years (Figure 7-1). Also, as will be discussed in more detail subsequently, a key demographic factor associated with these indicators is overall education level. Science-specific education plays a role similar to overall education. In contrast, respondents' age and sex are either unrelated or weakly related to these types of key indicators (Figure 7-2).

Figure 7-1

Key science and engineering knowledge and attitude indicators: 1981–2014



NA = not available.

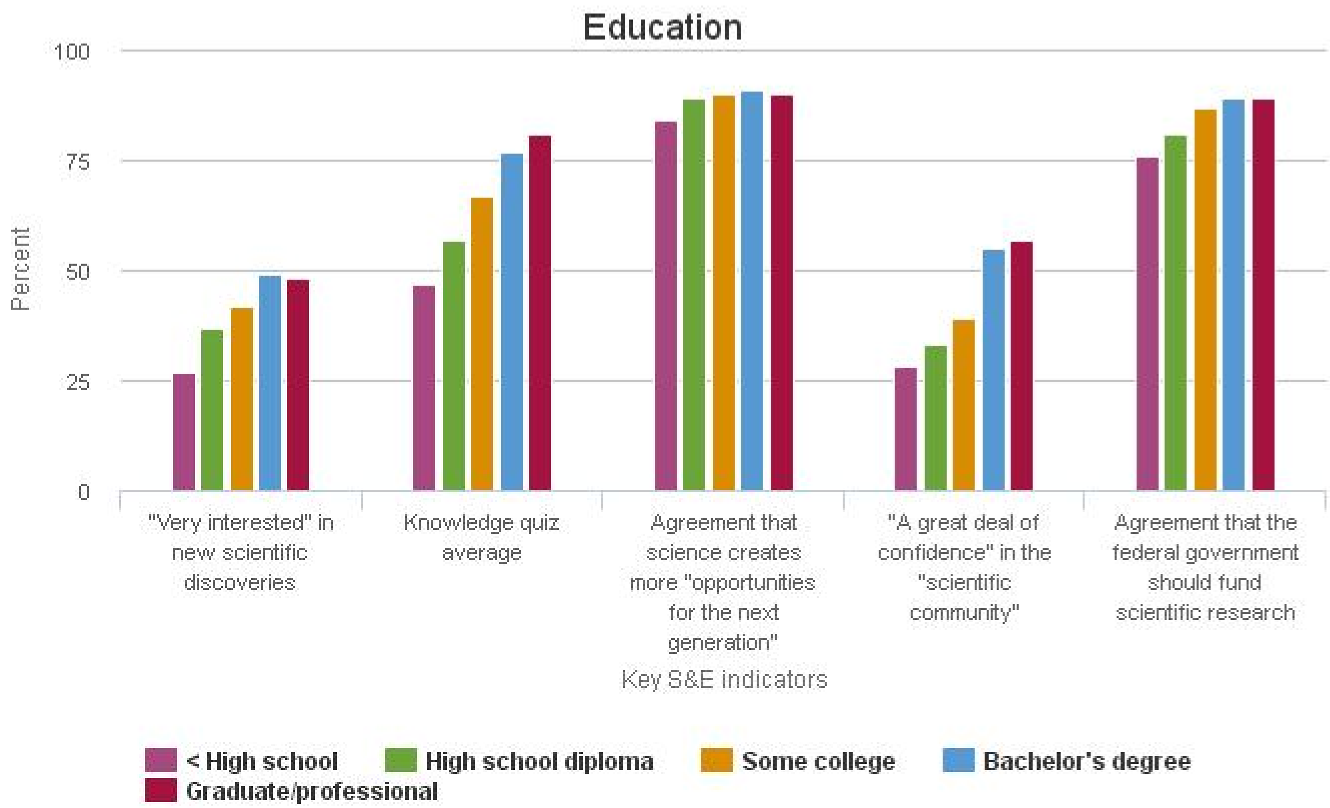
NOTE: Includes the responses "strongly agree" and "agree" to the following statements: *Agreement that science creates more "opportunities for the next generation"* and *Agreement that the federal government should fund scientific research.*

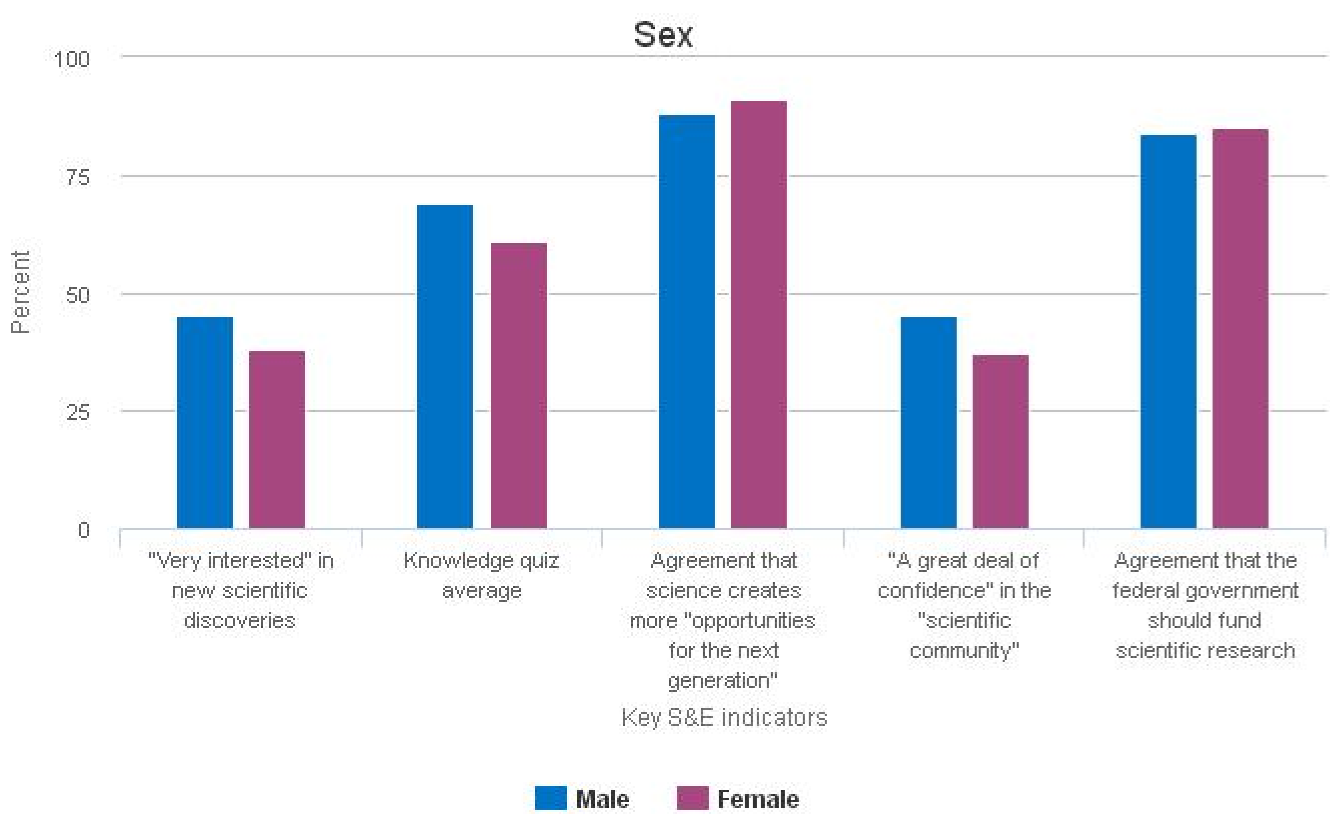
SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (1981–2001); University of Michigan, Survey of Consumer Attitudes (2004); University of Chicago, National Opinion Research Center, General Social Survey (2006–14). See appendix tables 7-1, 7-6, 7-15, 7-19, and 7-23.

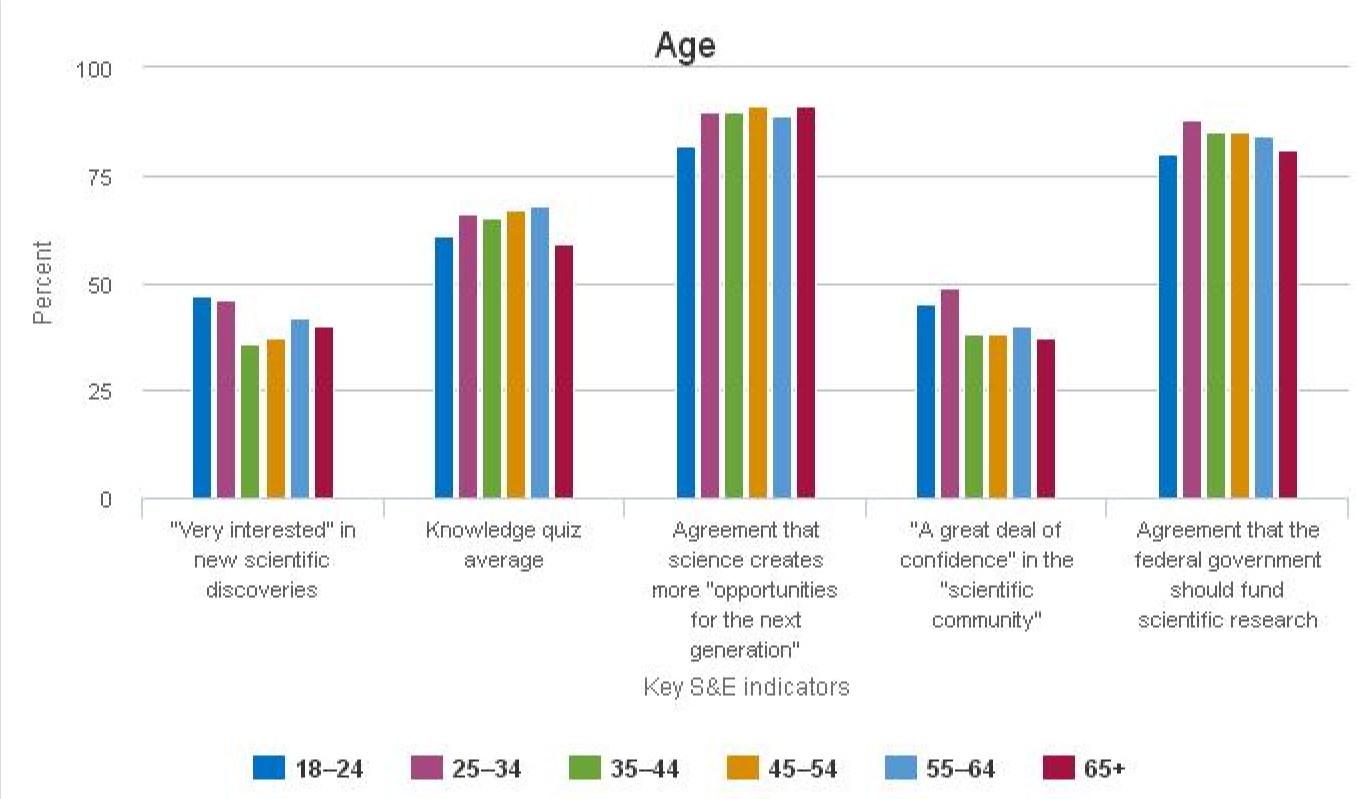
Science and Engineering Indicators 2016

Figure 7-2

Key science and engineering indicators, by selected respondent education, sex, and age: 2014







NOTE: Includes the responses "strongly agree" and "agree" to the following statements: *Agreement that science creates more "opportunities for the next generation"* and *Agreement that the federal government should fund scientific research.*

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2014). See appendix tables 7-1, 7-6, 7-15, 7-19, and 7-23.

Science and Engineering Indicators 2016

Chapter Organization

This chapter is divided into four main sections. The first includes indicators of the public's interest in S&T news, sources of information, and involvement in informal S&T activities. The second section reports on indicators of public knowledge, including trend measures of factual knowledge of S&E and people's understanding of the scientific process. This second section also includes results of survey experiments designed to better understand how question wording affects the accuracy of responses to knowledge questions. The third section presents data on attitudes about S&T in general, including support for government funding of basic research and confidence in the leadership of the scientific community. The fourth section addresses attitudes on public issues in which S&T plays an important role, such as the environment, climate change, energy, nuclear power, and the use of animals in scientific research. It also includes indicators of public opinion about several active lines of research and new technologies, including genetically engineered (GE) food, stem cell research, and cloning.

A Note about Data and Terminology

This chapter emphasizes trends over time, patterns of variation within the U.S. population, and comparisons between public opinion in the United States and in other countries or regions. It reviews survey data from national samples with sound, representative sampling designs. The text focuses on the trends and demographic patterns in the data. Where possible, the focus is on surveys released since the 2014 edition of *Science and Engineering Indicators* was written.

S&T-related questions asked in the biennial General Social Survey (GSS) on behalf of the National Science Foundation (NSF) are a major source of data for this chapter. The GSS is a high-quality, nationally representative survey focused on attitudes and behavior of the U.S. population. Questions about S&T information, knowledge, and attitudes have been included in the GSS since 2006 and have formed the basis of this chapter in *Indicators* since 2008. The GSS collects data primarily through in-person interviews. Comparable survey data collected between 1982 and 2004 by various survey providers contracted by NSF used telephone interviews. Before 1982, these data were collected via in-person interviews. Changes in data collection methods over these years, particularly before 2006 (i.e., the switch to the GSS and the return to face-to-face interviewing), may affect comparisons over time. Situations in which this may be an issue are highlighted in the text.

A range of other data sources are also used in the chapter, although only surveys involving probability-based samples are included. The primary sources of such data include Gallup, the Pew Research Center, and the World Values Survey (WVS). Like all survey data, the results reported in this chapter are subject to many sources of error (e.g., sampling error, response error) and random variation that should be kept in mind when interpreting the findings. Caution is especially warranted when interpreting results from surveys that omit significant portions of the target population, have low response rates, or have topics that are particularly sensitive to subtle differences in question wording. The GSS typically uses face-to-face interviews, but most of the data from groups such as Gallup and the Pew Research Center use telephone samples (including both landlines and mobile phones) that inherently exclude those without telephones. The only Internet-based surveys used in the chapter are those collected by GfK, which chooses its panel based on techniques similar to the telephone samples used by other organizations. Nevertheless, face-to-face surveys are believed to be the best way to obtain high response rates and to maximize participation by respondents with low income or education who may be less likely to respond to other types of surveys (see sidebars, U.S. Survey Data Sources and International Survey Data Sources). The Eurobarometer, a major source of comparable European data, uses face-to-face surveys.

Another important limitation is that up-to-date, high-quality data are not always available. In some cases, there are only single surveys, large gaps between data collection years, or only a small number of questions on any given topic. This challenge is particularly acute when it comes to international data. There have been many surveys on S&T in Europe, but these are not conducted as regularly as the GSS. Data from Asia, even when they are collected, may not be made freely available to researchers. Data from Africa and South America are especially rare. As noted, the current chapter focuses on surveys that have become public after the preparation of the 2014 *Indicators* report. Earlier data can be found in past editions of *Indicators* (e.g., NSB 2014). Bauer, Shukla, and Allum (2012) also summarized relevant survey data up to 2006 from a range of countries and regions. Even in cases in which international comparisons attempt to compare identical questions, the responses may not be wholly comparable because of cultural differences in the meaning of the questions.

Throughout this chapter, the terminology used in the text reflects the wording in corresponding survey questions. In general, survey questions asking respondents about their primary sources of information, interest in issues in the news, and general attitudes use the phrase *science and technology*. Thus, *S&T* is used when discussing these data. Survey questions asking respondents about their confidence in institutional leaders, the prestige of occupations, and their views on different disciplines use terms such as *scientific community*, *scientists*, *researchers*, and *engineers*, so *S&E* is used when appropriate for examining issues related to occupations, careers, and fields of research. Although science and engineering are distinct fields, national survey data that make this distinction are scarce. The term *Americans* is used throughout to refer to U.S. residents included in a national survey; equivalent terms (e.g., *Canadians*) are used for residents of other countries. However, not all respondents were citizens of the countries in which they were surveyed. When discussing data collected on behalf of NSF, the term *recent* is used to refer to surveys conducted since 2006, when data collection shifted to the GSS.

U.S. Survey Data Sources

Table 7-A below describes U.S. surveys utilized in this chapter.

Table 7-A **U.S. Survey Data Sources**

Sponsoring organization	Title	Years used	Questions used	Data collection method	Respondents (*n*); margin of error of general population estimates
National Science Foundation	Public Attitudes Toward and Understanding of Science and Technology (1979–2001); University of Michigan Survey of Consumer Attitudes (2004)	1979–2001, 2004	Information sources, interest, visits to informal science institutions, general attitudes, government spending attitudes, science/mathematics education attitudes, animal research attitudes	Telephone interviews	*n* = 1,574–2,041; ± 2.47%–3.03%
National Opinion Research Center (NORC) at the University of Chicago	General Social Survey (GSS)	1973–2014	Government spending attitudes, confidence in institutional leaders	Face-to-face interviews, supplemented by telephone interviews	Government spending (2000–14): *n* = 1,434–2,256; ± 2.5%–3.9% Confidence in institutional leaders, (1973–2014): *n* = 876–3,278; ± 2.5%–4.4%

Sponsoring organization	Title	Years used	Questions used	Data collection method	Respondents *(n)*; margin of error of general population estimates
NORC at the University of Chicago	GSS science and technology module	2006, 2008, 2010, 2012, 2014	Information sources, interest, visits to informal science institutions, general attitudes, government spending attitudes, science/mathematics education attitudes, animal research attitudes, nanotechnology awareness and attitudes, science knowledge	Face-to-face interviews, supplemented by telephone interviews	*n* = 1,864–2,130; ± 2.5%–3.3%
National Survey of American Public Opinion on Climate Change	American Belief in Climate Change	2012	Climate change	Telephone interviews	*n* = 726; ± 4.0%
Gallup Organization	Various ongoing surveys	1982–2015	Federal priorities, environmental protection, climate change, global warming, nuclear power, alternative energy, animal research, stem cell research, quality of science /mathematics education in U.S. public schools attitudes	Telephone interviews	*n* = ~1,000; ± 3.0%–4.0%
Pew Internet & American Life Project, Pew Research Center	Pew Internet & American Life Survey	2006, 2012	Media use	Telephone interviews	2006: *n* = 2,000; ± 3.0% 2012: *n* = 2,252; ± 2.3%
Pew Research Center for the People and the Press	General Public Science Survey, separate survey of American Association for the Advancement of Science members	2014	Public's and scientists' beliefs about S&T-related issues, benefits of science to well-being of society, animal research attitudes	Telephone interviews (survey of general public)	Public: *n* = 2,002; ± 3.1% Scientists: *n*- = 3,478; ± 1.7%

Sponsoring organization	Title	Years used	Questions used	Data collection method	Respondents (*n*); margin of error of general population estimates
Pew Research Center for the People and the Press	Media surveys (various)	1985–2015	Views of the news media, media believability	Telephone interviews	*n* = ~1,000–1,505; ± 3.4%–4.0%
Pew Research Center for the People and the Press	Political surveys (various)	2008–2015	Information sources, Internet use, national policy attitudes (environment, global warming, energy, stem cell research), government spending for scientific research attitudes	Telephone interviews	*n* = ~1,000–5,122; ± 1.6%–3.5%
Yale Project on Climate Change Communication and the George Mason University Center for Climate Change Communication	Climate Change in the American Mind	2008–2015	Climate change	Online (probability-based sample)	*n* = 1,263; ± 3.0%
NOTES:	All surveys are national in scope and based on probability sampling methods. Statistics on the number of respondents and margin of error are as reported by the sponsoring organization. When a margin of error is not cited, none was given by the sponsor.				

International Survey Data Sources

Table 7-B below describes international surveys utilized in this chapter.

Table 7-B International Survey Data Sources

Sponsoring organization	Title	Years used	Questions used	Data collection method	Respondents ***(n)*; margin of error of general population estimates**
	BBVA Foundation International	2011	Media use, knowledge and attitudes	Face-to-face interviews	*n* = 1,500 for each of 15 countries; ± 2.6%

Sponsoring organization	Title	Years used	Questions used	Data collection method	Respondents *(n)*; **margin of error of general population estimates**
BBVA Foundation (Fundacion BBVA)	Study on Scientific Culture				
British Council, Russia	Survey of Public Attitudes Toward Science and Technology in Russia	2003	Various knowledge items	Paper questionnaires	*n* = 2,107
Council of Canadian Academies	Public Survey of Science Culture in Canada	2013	Various knowledge and attitude items, engagement, science skills	Landline and mobile phone (60%); Internet (40%)	*n* = 2,004; ± 2.2%
Chinese Association for Science and Technology, China Research Institute for Science Popularization	Chinese National Survey of Public Scientific Literacy	2001, 2007, 2010	Various knowledge and attitude items, interest, occupational prestige, visits to informal science institutions	Face-to-face interviews	2001: *n* = 8,350 2007: *n* = 10,059 2010: *n* = 68,416
European Commission	Special Eurobarometer 224/Wave 63.1: *Europeans, Science and Technology* (2005)	2005	Knowledge, trust in scientists, public support for basic research, other attitudes, visits to informal science institutions	Face-to-face interviews	(EU total) n = 26,403; Austria: 1,034 Belgium: 1,024 Cyprus: 504 Czech Republic: 1,037 Denmark: 1,013 Estonia: 1,000 Finland: 1,007 France: 1,021 Germany: 1,507 Greece: 1,000 Hungary: 1,000 Ireland: 1,008 Italy: 1,006 Latvia: 1,034 Lithuania: 1,003 Luxembourg: 518 Malta: 500 The Netherlands: 1005 Poland: 999 Portugal: 1009 Slovakia: 1241 Slovenia: 1,060 Spain: 1,036 Sweden: 1,023 United Kingdom: 1,307
		2005			

Sponsoring organization	Title	Years used	Questions used	Data collection method	Respondents ***(n)*; margin of error of general population estimates**
	Special Eurobarometer 224b/Wave 64.3: *Europeans and Biotechnology in 2005: Patterns and Trends* (2006)		Biotechnology attitudes		(EU total) *n* = ~25,000; Member States Austria: ~1,000 Belgium: ~1,000 Cyprus: ~1,000 Czech Republic: ~1,000 Denmark: ~1,000 Estonia: ~1,000 Finland: ~1,000 France: ~1,000 Germany: ~1,000 Greece: ~1,000 Hungary: ~1,000 Ireland: ~1,000 Italy: ~1,000 Latvia: ~1,000 Lithuania: ~1,000 Luxembourg: ~1,000 Malta: ~1,000 The Netherlands: ~1,000 Poland: ~1,000 Portugal: ~1,000 Slovakia: ~1,000 Slovenia: ~1,000 Spain: ~1,000 Sweden: ~1,000 United Kingdom: ~1,000
	Special Eurobarometer 300/Wave 69.2: *Europeans' Attitudes Towards Climate Change* (2008)	2008	Climate change attitudes		(EU total) *n* = ~26,661; Member States: Austria: 1,000 Belgium: 1,003 Bulgaria: 1,000 Cyprus: 504 Czech Republic: 1,014 Denmark: 1,005 Estonia: 1,006 Finland: 1,004 France: 1,040 Germany: 1,534 Greece: 1,000 Hungary: 1,000 Ireland: 1,004 Italy: 1,022 Latvia: 1,008 Lithuania: 1,021 Luxembourg: 501 Malta: 500 The Netherlands: 1,041 Poland: 1,000 Portugal: 1,001 Romania: 1,019 Slovakia: 1,085 Slovenia: 1,003 Spain: 1,033 Sweden: 1,007 United Kingdom: 1,306
	Special Eurobarometer 340/Wave 73.1: *Science and Technology Report* (2010)	2010	Science and technology attitudes and interest, support for basic research, animal research attitudes		(EU total) *n* = ~26,671; Member States: Austria: 1,000 Belgium: 1,012 Bulgaria: 1,009 Cyprus: 502 Czech Republic: 1,043 Denmark: 1,006 Estonia: 1,004 Finland: 1,001 France: 1,018 Germany: 1,531 Greece: 1,000 Hungary: 1,017 Ireland: 1,007 Italy: 1,018 Latvia: 1,013 Lithuania: 1,026 Luxembourg: 503 Malta: 500 The

Sponsoring organization	Title	Years used	Questions used	Data collection method	Respondents *(n)*; **margin of error of general population estimates**
					Netherlands: 1,018 Poland: 1,000 Portugal: 1,027 Romania: 1,060 Slovakia: 1,030 Slovenia: 1,004 Spain: 1,004 Sweden: 1,007 United Kingdom: 1,311
	Special Eurobarometer 341/Wave 73.1: *Europeans and Biotechnology in 2010: Winds of change?* (2010)	2010	Nuclear energy, nanotechnology, emerging biotechnologies, synthetic biology, and genetically engineered foods attitudes		(EU total) *n* = ~26,671; Member States: Austria: 1,000 Belgium: 1,012 Bulgaria: 1,009 Cyprus: 502 Czech Republic: 1,043 Denmark: 1,006 Estonia: 1,004 Finland: 1,001 France: 1,018 Germany: 1,531 Greece: 1,000 Hungary: 1,017 Ireland: 1,007 Italy: 1,018 Latvia: 1,013 Lithuania: 1,026 Luxembourg: 503 Malta: 500 The Netherlands: 1,018 Poland: 1,000 Portugal: 1,027 Romania: 1,060 Slovakia: 1,030 Slovenia: 1,004 Spain: 1,004 Sweden: 1,007 United Kingdom: 1,311
	Special Eurobarometer 401/wave 6: *Responsible Research and Innovation (RRI) Science and Technology* (2013)	2013	Research, innovation, science, and technology attitudes		(EU total) *n* = ~27,563 Member States: Austria: 1,022 Belgium:1,000 Bulgaria: 1,018 Croatia: 1,000 Cyprus: 505 Czech Republic:1,000 Denmark: 1,004 Estonia: 1,003 Finland: 1,003 France: 1,027 Germany: 1,499 Greece: 1,000 Hungary: 1,033 Ireland: 1,002 Italy: 1,016 Latvia: 1,006 Lithuania: 1,027 Luxembourg: 505 Malta: 500 The Netherlands: 1,019 Poland: 1,000 Portugal: 1,015 Romania: 1,027 Slovakia: 1,000 Slovenia: 1,017 Spain: 1,003 Sweden: 1,006 United Kingdom: 1,306
	Special Eurobarometer 419/wave 6: *Public Perceptions of*	2014	Science, research, and innovation public attitudes		(EU total) *n* = ~27,910 Member States: Austria: 1,005 Belgium:1,025 Bulgaria: 1,033 Cyprus: 503 Croatia: 1,010 Czech Republic: 1,100 Denmark: 1,004

Sponsoring organization	Title	Years used	Questions used	Data collection method	Respondents *(n)*; margin of error of general population estimates
	Science, Research, and Innovation (2014)				Estonia: 1,012 Finland: 1,017 France: 1,018 Germany: 1,511 Greece: 1,012 Hungary: 1,060 Ireland: 1,006 Italy: 1,014 Latvia: 1,016 Lithuania: 1,013 Luxembourg: 501 Malta: 501 The Netherlands: 1,030 Poland: 1,082 Portugal: 1,009 Romania: 1,020 Slovakia: 1,007 Slovenia: 1,034 Spain: 1,009 Sweden: 1,050 United Kingdom: 1,308
India National Council of Applied Economic Research	National Science Survey	2004	Various knowledge and attitude items, visits to informal science institutions	Face-to-face interviews	*n* = 30,255
Japan Science and Technology Agency, Research Institute of Science and Technology for Society	Survey of Scientific Literacy	2011	Various knowledge items	Internet Survey and interviews	*n* = 812–984
Korea Foundation for the Advancement of Science and Creativity (formerly Korea Science Foundation)	Survey of Public Attitudes Toward and Understanding of Science and Technology	2004, 2006, 2008	Interest, various knowledge and attitude items, visits to informal science institutions	Face-to-face interviews	*n* = 1,000; ± 3.1%
Malaysian Science and Technology Information Center,	Survey of the Public's Awareness of	2014	Interest, awareness, various knowledge and attitude items,	Face-to-face interviews	*n* = 2,653; ± 2.71%

Sponsoring organization	Title	Years used	Questions used	Data collection method	Respondents ***(n)*; margin of error of general population estimates**
Ministry of Science, Technology and Innovation	Science and Technology: Malaysia		visits to informal science institutions		
Pew Global Attitudes Project, Pew Research Center	Global Attitudes Survey	2013	Climate change concerns	(Varies by country) Face-to-face interviews Telephone interviews	(United States) *n* = 1,002; ± 3.5%; (38 other countries) *n* = 700–3,226; ± 3.1%– 7.7%
World Values Survey Association	World Values Survey Wave 6	2010-2014	Science, faith, environmental, and economics attitudes	Depending on country, face-to-face, mail, or online surveys; typically face-to-face	*n* = 1,000–2,500; ± 2.00%–3.20%

NOTES: EU = European Union; UK = United Kingdom.

All surveys are national in scope and based on probability sampling methods. Statistics on the number of respondents and margin of error are as reported by the sponsoring organization. When a margin of error is not cited, none was given by the sponsor.

Interest, Information Sources, and Involvement

Americans' understanding and attitudes about topics such as S&T depend, in part, on how much exposure they get to such content throughout their lives, as well as how much attention they pay to such content (Slater, Hayes, and Ford 2007). Exposure and attention to S&T can make residents more informed, shape their attitudes, and help them make decisions that are better for themselves, their families, and their communities. Media use itself may also foster a desire to seek and consider new information (Rimal, Flora, and Schooler 1999).

This section reviews overall expressed interest in media reports about S&T, the sources of material about S&T that are available to the public, and the type of S&T-related content the public uses. It concludes with indicators of personal involvement in S&T-related activities through visits to museums and other cultural institutions.

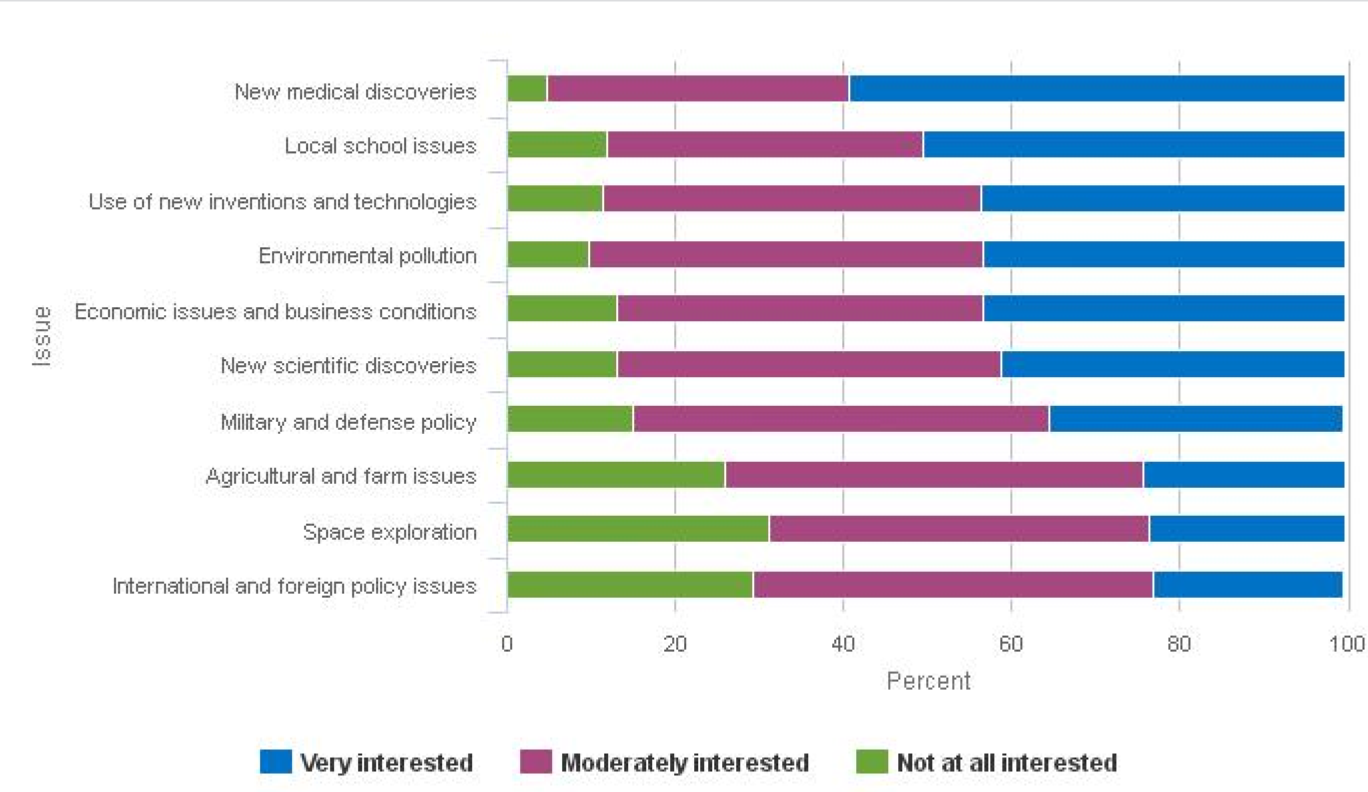
Public Interest in S&T

U.S. Patterns and Trends

Most Americans say they are interested in S&T. In 2014, 41% said they were "very interested" in new scientific discoveries, and 46% said they were "moderately interested" (Figure 7-3). Similarly, 43% said they were "very interested" in use of new inventions and technologies, and 59% said they were "very interested" in new medical discoveries. Medical discovery continues to be the subject included in the GSS in which Americans are most likely to express deep interest. About a quarter (24%) of respondents said they were "very interested" in space exploration. This puts space exploration near the bottom of the list of subjects asked about in the survey, similar to agricultural issues (24% "very interested" in 2014) and international policy (23% "very interested" in 2014).

Figure 7-3

Public interest in selected issues: 2014



NOTES: Responses to *There are a lot of issues in the news, and it is hard to keep up with every area. I'm going to read you a short list of issues, and for each one I would like you to tell me if you are very interested, moderately interested, or not at all interested.* Responses of "don't know" are not shown.

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2014). See appendix table 7-1.

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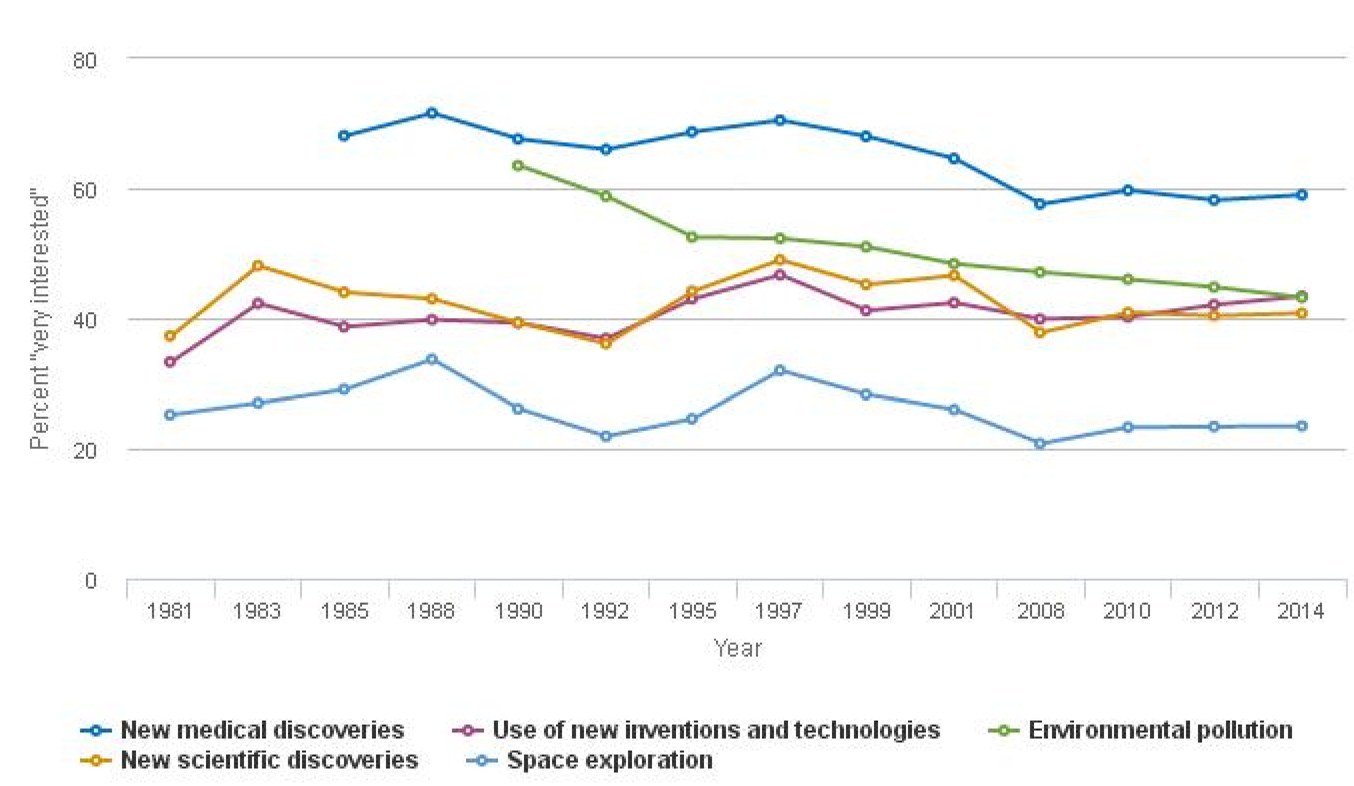
Although sometimes down from previous highs, these figures have been fairly stable in recent years, with the exception of interest in "environmental pollution," which has declined (Figure 7-4). In 2014, 43% said they were "very interested" in the topic, which represents a decline from 64% in 1990, the first year for which there are data. Interest in medical discoveries is also lower than it was in previous decades, although it has been relatively stable in recent years (Appendix Table 7-1 and Appendix Table 7-2). It is not clear in the data why respondents have been less likely to express interest in "environmental pollution" over time. The discussion of specific environmental issues later in this chapter notes, however, that concern about the environment is relatively low in historical terms. The term *pollution* may also have become less salient as public discussion has turned to issues such as climate change.

Figure 7-4

Public interest in selected science-related issues: 1981–2014



NA = not available.

NOTES: Responses to *There are a lot of issues in the news, and it is hard to keep up with every area. I'm going to read you a short list of issues, and for each one I would like you to tell me if you are very interested, moderately interested, or not at all interested.* Figure shows only "very interested" responses. Survey results in 1981, 1983, 1985, 1988, 1990, 1992, 1995, 1997, 1999, 2001, 2008, 2010, 2012, and 2014.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (1981–2001); University of Chicago, National Opinion Research Center, General Social Survey (2008–14). See appendix table 7-1.

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Interest in the various science topics—and most other topics—is associated with education levels and mathematics and science course taking. Women tend to be more interested in medical discoveries, whereas men are more interested in S&T topics. There is little difference between the sexes on interest in the environment (Appendix Table 7-2).

Questions about interest may depend a great deal on the specific wording used to describe the subject and on the type of response that survey participants are allowed to select. Although "new scientific discovery" ranks in the middle of a group of issues in the GSS data (41% "very interested"), a public policy–focused survey by the Pew Research Center (2014c) found that 58% of respondents chose "science and technology" as a topic they were "interested in." The only topic selected more often was "health and medicine" (66%). "Events in your community" (57%) and "government and politics" (57%) were also of substantial interest. When required to select only three topics of interest, "health and medicine" (37%) and "government and politics" (36%) were selected the most, although "science and technology" (32%) was ranked as third most popular. A later science-focused survey found that 37% of respondents said they "enjoy keeping up with news about science" "a lot." Another 35% said they get "some" enjoyment from keeping up with science news. About a quarter of Americans said they get either "not much" (18%) or no enjoyment "at all" (9%) from such coverage. These numbers were similar to those from a 2009 survey (Pew Research Center 2015b).

Another way that we can learn about what people think about S&T is to look at their behavior. New tools that allow users to explore online search habits, for example, can provide guidance on the topics that may be gaining or losing attention over time. The Using Google Trends to Examine American Attention to Science and Technology sidebar addresses this issue and provides two examples of what this type of data may be able to show those interested in how people are thinking about S&T.

Using Google Trends to Examine American Attention to Science and Technology

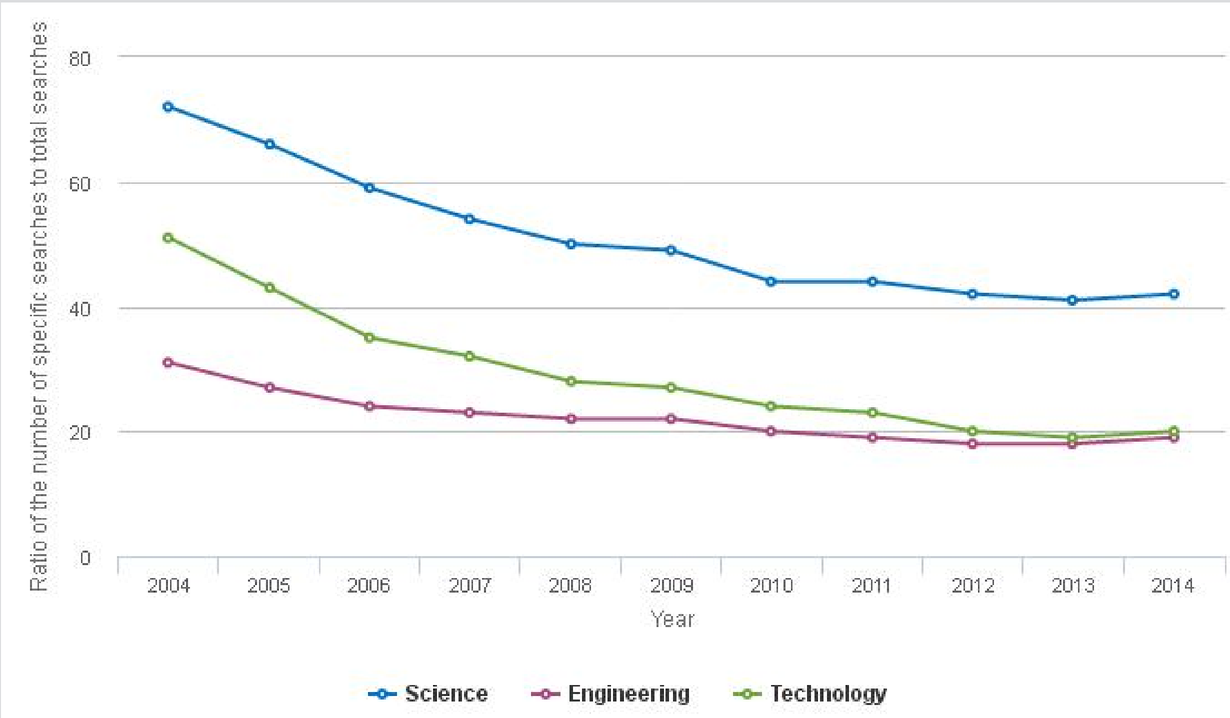
Another way to examine attention to science and technology (S&T) is to look at online search patterns using tools such as Google Trends (Segev and Baram-Tsabari 2012). Although specific data on the total number of searches for specific keywords are not publicly available, the Google Trends website provides data on Google search patterns back to 2004.

The findings for attention to S&T presented as follows are based on the number of Google searches for selected topics compared with the total number of Google searches at each time point. Therefore, a downward trend line means that the popularity of a search term is decreasing. It does not mean that the total number of searches for that search term is decreasing because the total number of Google searches has increased over time as the Internet has become more widely available. Google Trends also adjusts the search results so that the most popular time for a given keyword is always scored as 100, and other results are adjusted so that they represent comparisons with that high point (Google 2015). This means that results need to be described in relative terms. A wide range of searches might be used to provide guidance on interest in various S&T topics. The following two examples are provided.

First, a combined Google Trends search for how often people search for "science," "engineering," and "technology" in the United States shows that "science" is the most common of the searches and that there has been less relative focus on all three topics over time (Figure 7-A).* The downward sloping trend line for all three search terms suggests that each has become a relatively less common Google search since 2004. One potential explanation is that, as Internet use became more common, a smaller proportion of searches were focused on education or academic topics. In other words, entertainment or social uses might have become relatively more common during the period in question.

Figure 7-A

Google trend data for science, engineering, and technology searches: 2004–14



NOTE: The numbers reflect how many Google searches have been done for a particular term, relative to the total number of searches over time. The results are also normalized so that the highest score in any search is 100.

SOURCE: Google, Google Trends, http://www.google.com/trends/, accessed 6 January 2015.

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A second combined Google Trends search seeks to compare how often Google users searched the various topics discussed in the "Public Attitudes about Specific S&T-Related Issues" section of this chapter.[†] In this case, the results suggest that genetically engineered food, initially the least common search term, had become relatively common by 2014 (Figure 7-B). In contrast, there were declines in the relative amount of searching for issues related to the environment and stem cells. The pattern of searches for climate change shows a large spike around 2007, but relative searches have declined since. It is noteworthy that 2007 marked a high point in concern about climate change in the United States according to survey research on the topic (see the "Climate Change" section in this chapter and Kahn and Kotchen 2011). The relative amount of searching for nuclear energy has, in contrast, stayed stable, except for a brief spike in searches in 2011 at the time of the Fukushima Daiichi nuclear power plant accident in Japan.

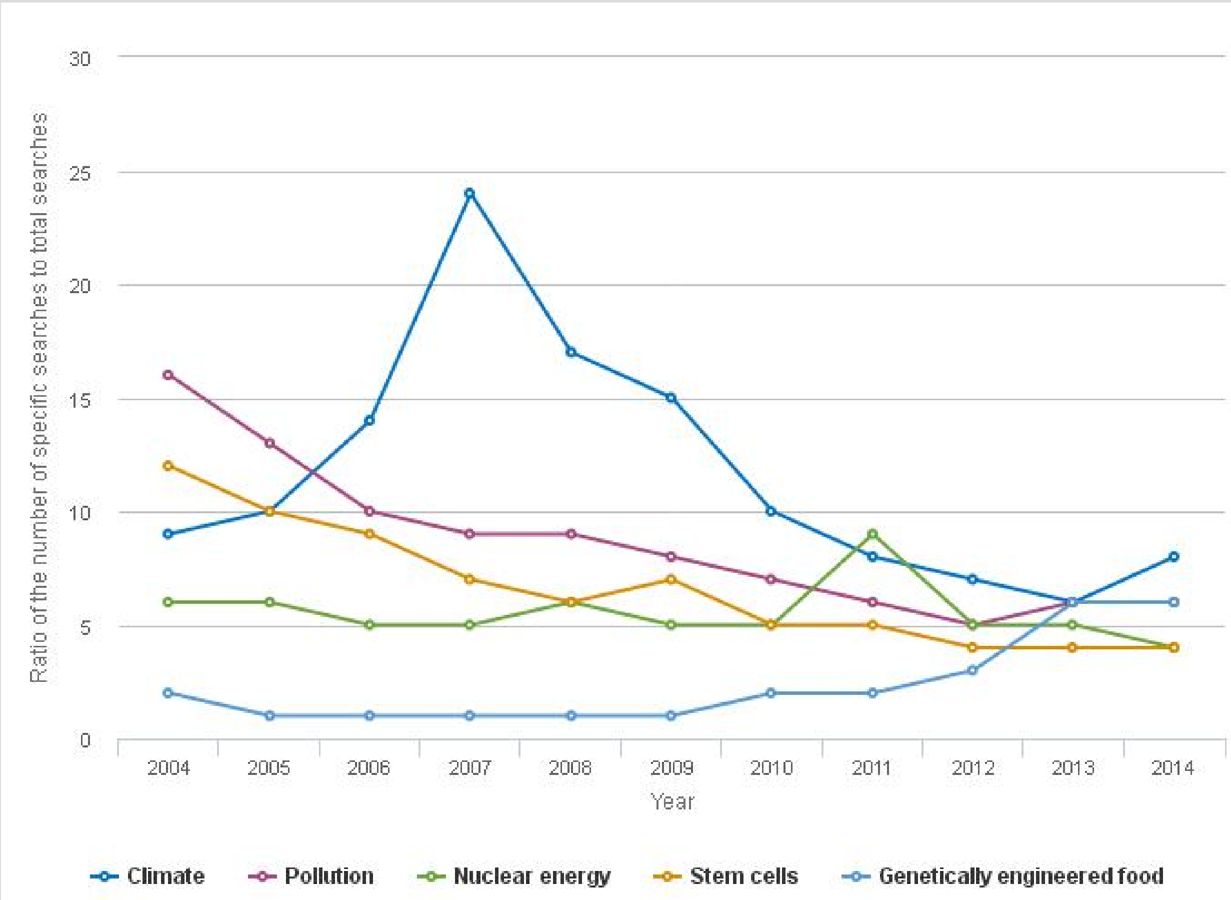
Tools such as Google Trends will likely become increasingly important to how we analyze behavior online. Other sources of online activity data from organizations such as Facebook or Twitter could also be used to assess interest in S&T topics, but data from such sources are not widely available. Google is a popular search engine in the United States; it accounted for about two-thirds (65%) of searches from desktop computers in January 2015 (comScore 2015). Focusing on these types of data, however, also means missing data on the behavior of those who are not online, including those with low levels of education and income. It will also become important to assess whether search patterns differ by language used (e.g., English versus Spanish). Although it is not shown here, the current Google Trends site also allows users to compare search patterns by location (e.g., country or state).

* Although various combinations were considered, the final search terms used were “science,” “engineering,” and “technology.” This search can be viewed, updated, or modified using the following link: http://www.google.com/trends /explore?q=#q=science%2C%20engineering%2C%20technology&geo=US&cmpt=q.

† Although various combinations were considered, the final search term used was: climate change +climate science +global warming +Kyoto protocol +UNFCC +Convention on Climate Change; pollution +environmental protection +environmental conservation +environmental issue; nuclear energy +nuclear power +nuclear reactor +nuclear plant +atomic energy +atomic power +atomic reactor +atomic plant; genetically engineered food +genetically engineered organism +genetically engineered crop +ge food +ge crop +genetically modified food +genetically modified organism +genetically modified crop +gm food +gm crop +gmo +agricultural biotechnology +agbiotech; STEM cell +STEM cells.”

Figure 7-B

Google trend data for specific science and technology issues searches: 2004–14



NOTE: The numbers reflect how many Google searches have been done for a particular term, relative to the total number of searches over time. The results are also normalized so that the highest score in any search is 100.

SOURCES: Google, Google Trends, http://www.google.com/trends/, accessed 6 January 2015.

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International Comparisons

Americans appear to report higher levels of interest in S&T issues than Europeans, although the level of expressed interest varies widely by country, and different question wordings require cautious comparisons. Overall, about 13% of Europeans said they were "very interested" in S&T in 2013, whereas another 40% said they were "fairly interested." That is, 53% were "very" or "fairly" interested versus 87% of Americans who were "very" or "moderately" interested. The 27 European countries surveyed display a broad range of interest levels, with a high of 77% in Sweden and lows of 34% and 35% in the Czech Republic and Bulgaria, respectively (European Commission 2013). Another factor that makes these numbers difficult to compare is that 2013 Eurobarometer respondents were asked about only their general interest in S&T and not issues such as local schools or agriculture, whereas Americans were asked about interest in a wide range of issues (Figure 7-3).

Although data for countries beyond the United States and Europe are limited, previous surveys suggest that a sizable majority of residents of China, Japan, and South Korea report substantial interest in S&T. The varied questions and survey structures used, however, prevent direct comparisons with the United States. In 2010, 72% of Chinese respondents said they were interested in "new scientific discoveries," and 68% said they were interested in "new inventions and technologies" (CRISP 2010). In Japan, the percentage saying they were interested in "science and technology" climbed from 63% in January 2010 to 76% in July 2011, before and after the major earthquake that damaged the nuclear power plant in Fukushima. It dropped back to 65% in December 2011 (NISTEP 2012). In South Korea, a 2012 survey found that 48% of respondents said they had an interest in "new inventions and technologies," 48% said they had an interest in "new medical information and discoveries," and 50% said they had an interest in "new scientific discoveries." These levels are generally similar to 2008 and 2010 South Korean surveys (KOFAC 2013).

Availability of S&T News in the Media

Americans' knowledge and attitudes about S&T, particularly on topics in which research and discovery are ongoing, partially depend on the availability of S&T news. Media coverage often sets the public agenda (Soroka 2002) and frames the debate related to scientific issues (Nisbet and Scheufele 2009). A range of social processes associated with journalism, science, and public decision making determine which issues get attention from journalists during particular periods (Nisbet and Huge 2006). For example, natural or human disasters may increase the likelihood that relevant S&T issues are covered by the news while decreasing the likelihood that unrelated issues are covered. Quantity and prominence of coverage may also affect topical knowledge within society (Barabas and Jerit 2009). Other research suggests that different types of media have different effects on attitudes, with newspaper reading and Internet use being associated with more favorable attitudes than television (e.g., Dudo et al. 2011). Given the potential impact of media use, indicators that address how much and what kinds of S&T news coverage are available in the media can be important for understanding the development of views about S&T.

The amount of science-focused news programming on the three major broadcast networks (ABC, CBS, and NBC) appears to have been relatively low compared with that of previous years. The Tyndall Report has tracked the content of the three major broadcast networks for more than 20 years. Tyndall tabulates the amount of air time devoted to different topics using 18 different categories (Tyndall Report 2015). Two categories with substantial science, engineering, and technology components are "science, space, and technology" and "biotechnology and basic medical research."[i] Neither category has ever occupied a large percentage of the approximately 14,500–15,000 minutes of annual nightly weekday newscast coverage on the networks. The airtime devoted to "science, space, and technology" has averaged about 2% of broadcast news between 2000 and 2012 (Figure 7-5). Time devoted to "biotechnology and basic medical research" was even lower, almost always 1% or less of broadcast news.

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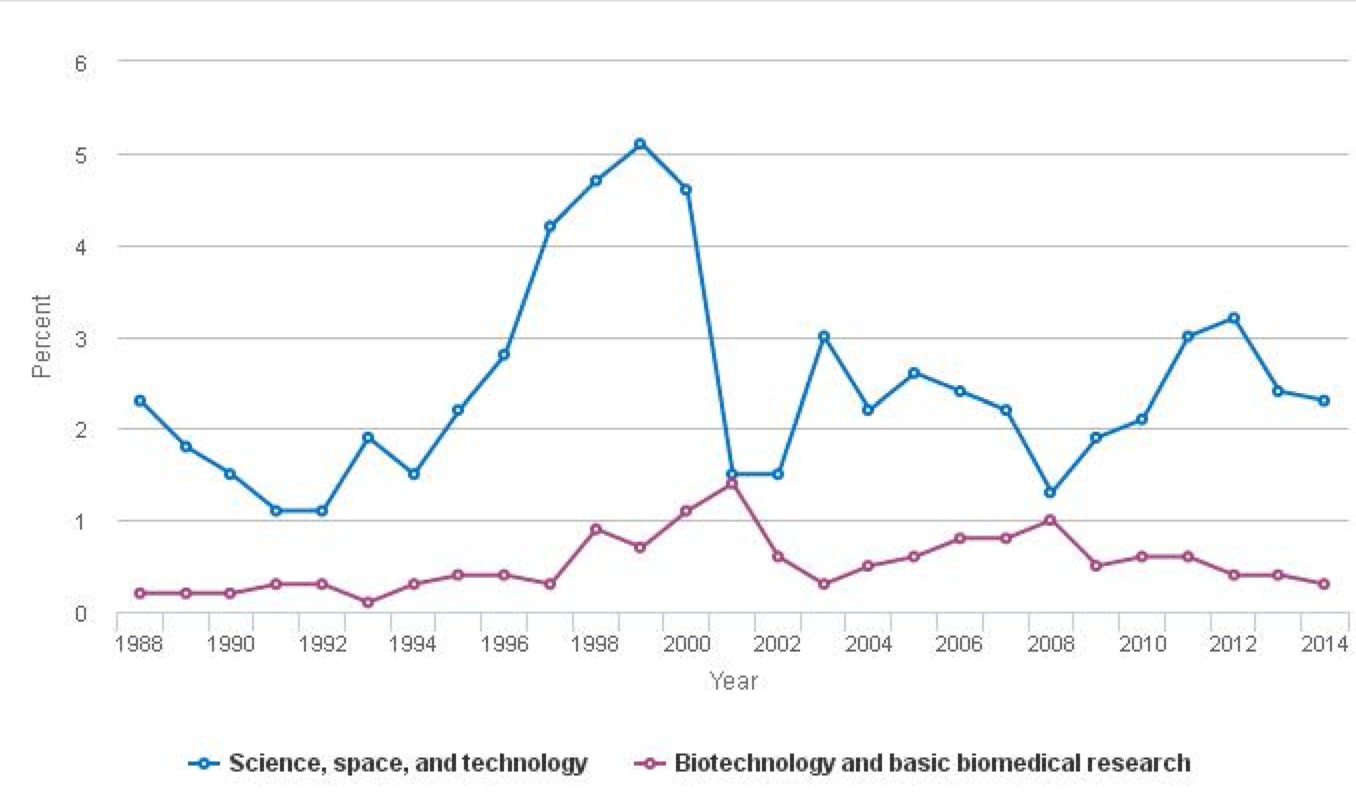
[i] "Science, space, and technology" includes stories on manned and unmanned space flight, astronomy, scientific research, computers, the Internet, and telecommunications media technology. It excludes forensic science and telecommunications media content. "Biotechnology and basic medical research" includes stem cell research, genetic research, cloning, and agribusiness bioengineering. It excludes clinical research and medical technology. Stories often do not fall neatly into a single category or theme. The coverage of health research in the Tyndall television

data represents only a small percentage of the overall health coverage on television. The coding of these data is done by Andrew Tyndall. Intercoder agreement statistics are not provided because the coding is done by a single individual.

Figure 7-5

Network nightly news coverage of science and technology: 1988–2014



NOTES: Data reflect percentage of approximately 15,000 total annual minutes of weekday nightly newscasts on ABC, CBS, and NBC that were spent on science, space, and technology and on biotechnology and basic medical research. Excluded from science, space, and technology are stories on forensic science. Excluded from biotechnology and basic medical research are stories on clinical research and medical technology.

SOURCE: Tyndall Report, special tabulations, http://tyndallreport.com, accessed 10 February 2015.

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It appears that, while the nature of science coverage varies from year to year, health coverage is relatively consistent. In 2013, the leading nightly news stories in the "science, space, and technology" category focused on the International Space Station and a Russian meteor strike. In 2014, the top stories were drone technology, space transportation, and space tourism. Cancer research garnered the most coverage in both 2013 and 2014 for the "biotechnology and basic medical research" category (Table 7-1). Since 2006, cancer research has received more attention than other medical research topics (NSB 2008, 2010, 2012, 2014).

Table 7-1 **Leading nightly news story lines on science and technology, by topic area: 2013 and 2014**

(Annual minutes of coverage)

Year and topic area/leading story line	Annual minutes of coverage
2013	

Year and topic area/leading story line	Annual minutes of coverage
Science, space, and technology	
International Space Station mission in orbit	38
Meteor explodes over Russia's Ural Mountains	25
Computer networks targeted by coordinated hackers	22
Drone technology: miniaturized, unmanned aircraft	19
Air safety: in-cabin use of electronic devices	18
Cellular telephone/computer combo: smart phones	15
Asteroids/astronomy: rocks pass close to Earth	12
Internet Twitter website makes public offering	9
Internet search engine Google monitors browsing	9
Science and mathematics education in schools	8
NASA *Voyager* probe is leaving solar system	8
Meteors are visible in night sky falling to Earth	8
NASA *Apollo* manned moon missions remembered	7
Solar-powered plane experiment has no engine	6
Mars astronomy: NASA *Curiosity* rover mission	6
Comet Ison may be heading for Earth	6
Internet used for social networking	6
Videogame title, design, development trends	6
BRAIN Initiative plans to map neurological activity	5
Computer systems are vulnerable to viruses, worms	5
Highway safety: drivers' cell phone use dangers	5
Space tourism planned by Virgin Galactic	5
Biotechnology and basic medical research	
War on cancer research efforts	36
Genetic DNA biotech analysis predicts diseases	9
Prosthetics technology for amputees goes bionic	5
2014	
Science, space, and technology	
Drone technology: miniaturized, unmanned aircraft	24
Space transportation uses privatized rockets	23
Space tourism planned by Virgin Galactic	21

Year and topic area/leading story line	Annual minutes of coverage
International Space Station mission in orbit	18
Comet astronomy: European satellite mission	18
Cellular telephone/computer combo: smart phones	15
Internet social networking: Facebook is popular	14
NASA manned missions to Mars planning	12
Wristwatch modernized: body-monitoring computer	11
Science and mathematics education in schools	10
Internet website security is vulnerable to hackers	9
Computer systems are vulnerable to viruses, worms	8
Video cameras miniaturized in HD by GoPro	8
Television broadcast networks' free signal diverted	8
Commercial bank databases targeted by hackers	7
Automobile research into smart-car technology	7
North Korea suffers cyberwarfare attack	6
Instant text messaging with worldwide WhatsApp app	6
Computer networks targeted by coordinated hackers	6
Internet account passwords hacked at Gmail	6
Highway safety: drivers' cell phone use dangers	5
Mars astronomy: NASA *Curiosity* rover mission	5
Asteroids/astronomy: rocks pass close to Earth	5
Bitcoin is virtual currency/commodity combination	5
Internet wireless networks targeted by hackers	5
Taxi fleet monopoly undercut by online services	5
Meteors are visible in night sky	5
Biotechnology and basic medical research	
War on cancer research efforts	12
Spinal cord injuries and paralysis research	10
Organs grown in laboratory for replacement implant	5

BRAIN = Brain Research through Advancing Innovative Neurotechnologies; HD = high definition; NASA = National Aeronautics and Space Administration.

NOTES: Data reflect annual minutes of story coverage on these topics by major networks ABC, CBS, and NBC, out of approximately 15,000 total annual minutes on weekday nightly newscasts. Story lines receiving at least 5 minutes of coverage in 2013 or 2014 are shown. Excluded from science, space, and technology are stories on forensic science and media content. Excluded from biotechnology and basic medical research are stories on clinical research and medical technology.

SOURCE: Tyndall Report, special tabulations, http://www.tyndallreport.com, accessed 10 February 2015.

Beyond Tyndall, data on media coverage of S&T is relatively scarce. The Project for Excellence in Journalism (PEJ 2012) conducted an extensive content analysis of news media coverage between January 2007 and May 2012, using 52 outlets in the following media sectors: traditional publications that have print editions, publications that are available online only, network television, cable television, and radio. Each week, stories were classified into 1 of 26 broad topic areas, including S&T, the environment, and "health and medicine."[ii] Special tabulations of PEJ data showed that S&T coverage made up a small percentage of all news in the traditional media—less than 2% annually—between 2007 and 2012, similar to the Tyndall findings. News coverage of the environment made up a similarly small percentage of the news in the 2007–12 period, ranging from a low of 1.0% in 2011 to a high of 1.6% in both 2007 and 2010. Coverage of health and medicine consistently made up a greater percentage of the news, ranging from 3.1% in 2011 to 8.9% in 2009 (NSB 2012).

Entertainment television can also shape views, although summary data in this area are even more limited. One of the more recent studies showed that, between 2000 and 2008, portrayals of scientists represented just 1% of characters on prime-time network shows. Of these scientists, 7 out of 10 were men, and almost 9 out of 10 were white. Medical professionals were 8% of the characters. Generic "professionals" were the most common type of character (21%). In general, about 8 of 10 scientists were coded as being "good" and not a villain (Dudo et al. 2011).[iii] Video games may also be a source of depictions of scientists; one research project suggests that such depictions are generally positive (Dudo et al. 2014).

[ii] The analysis is based on a purposive selection of five media sectors, outlets within each sector, and specific programs or articles for study. The index was designed to capture the main news stories covered each week. Coding of programs and articles was limited to the first 30 minutes of most radio, cable, and network news programs; the front page of newspapers; and the top five stories on websites. Each selected unit of study was coded on 17 variables, according to an established coding protocol. The team of individuals performing the content analysis was directed by a coding manager, a training coordinator, a methodologist, and a senior researcher. For variables that require little or no inference, intercoder agreement was 97% for 2010, the last year in which statistics were reported. For variables requiring more inference, intercoder agreement ranged from 78% to 85% in 2010. Intercoder agreement was similar in earlier years. For more details, see http://www.journalism.org /about_news_index/methodology.

[iii] In general, it is difficult to obtain information about S&T content within entertainment programming, although substantial evidence suggests that the entertainment people view shapes their attitudes about a range of issues, including S&T (Brossard and Dudo 2012).

S&T Information Sources

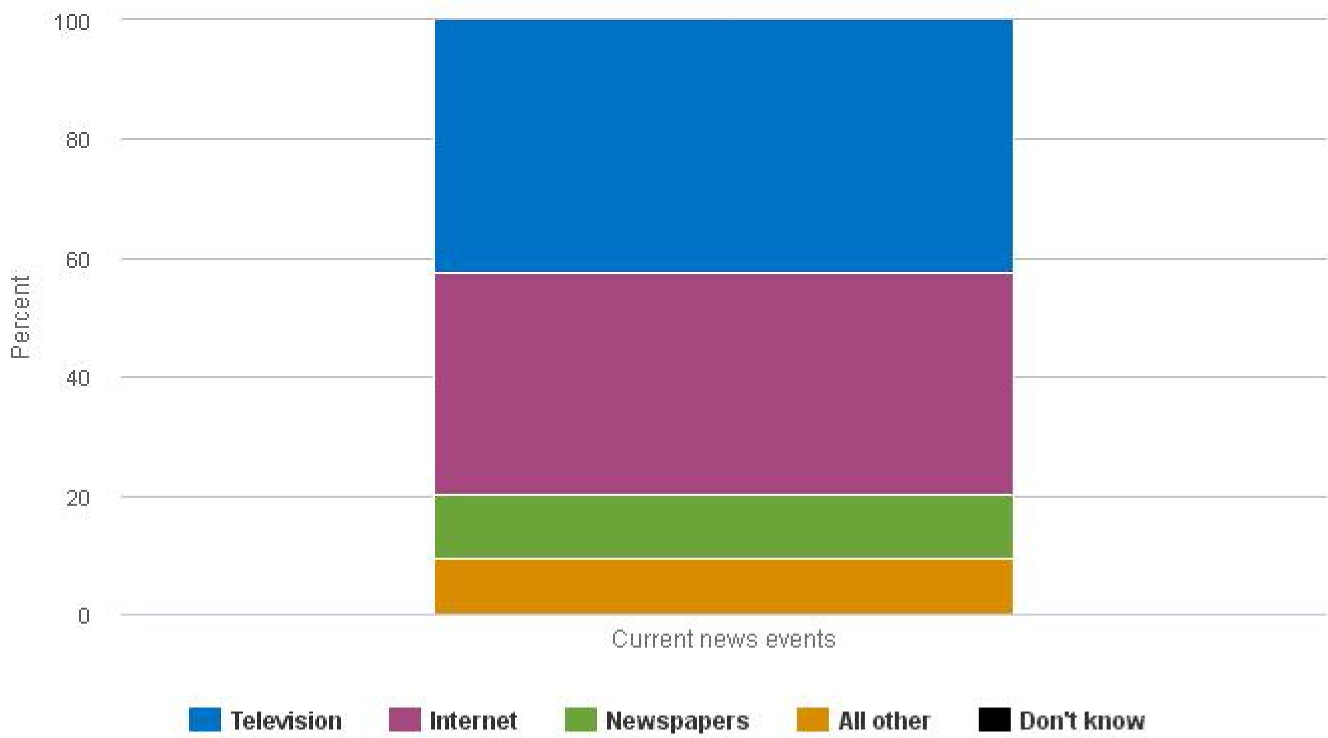
U.S. Patterns and Trends

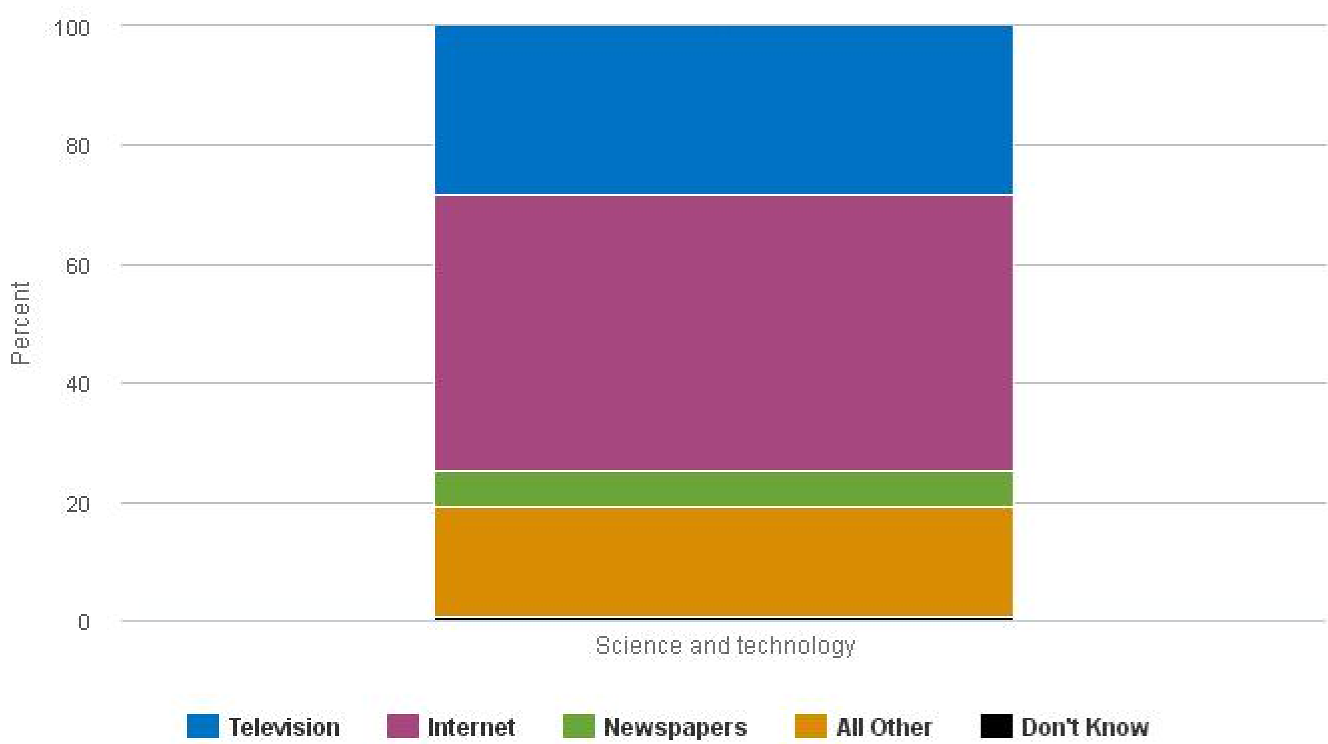
The news media environment continues to change as new organizations emerge; existing organizations disappear or merge; and journalistic routines change in response to economic, social, and technological forces. The available data show clear trends in what sources Americans say they use to get news about current events and S&T, as well as where they would look for new S&T information. The Pew Research Center (2012) previously reported that Americans said they spent a little more than an hour reading or watching the news per day in 2012. This figure was similar to that in previous years, but as the following data suggest, Americans are shifting to different media, increasingly spending time online. Caution is warranted when analyzing these results, however, because the distinction between news media is sometimes unclear. For example, as discussed subsequently, respondents may say they use newspapers for science information, but they use an online edition of the newspaper, or vice versa.

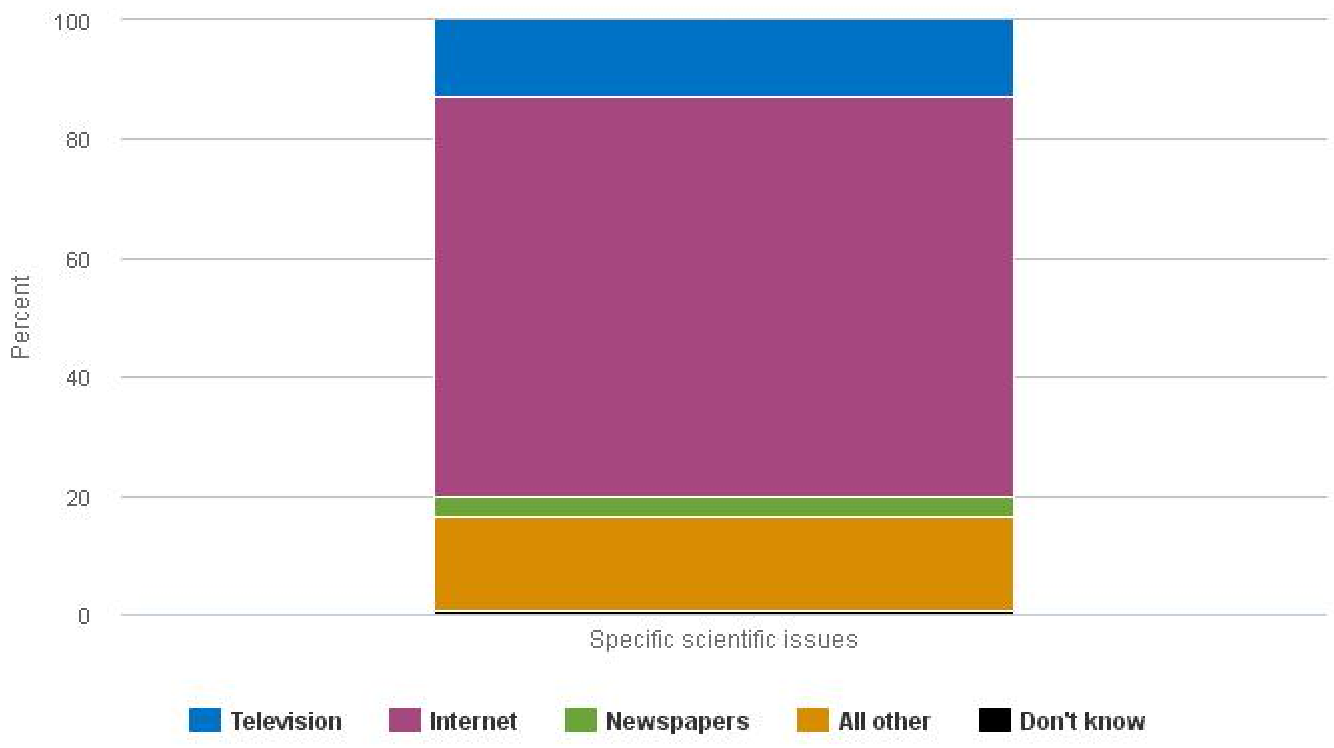
For news about general current events, television remains the primary source of information for 43% of Americans according to the GSS. Substantial percentages also reported in 2014 that their current event news comes primarily from the Internet (37%) or newspapers (11%) (Figure 7-6; Appendix Table 7-3). The percentage of Americans who report getting information about current events from the Internet has increased steadily since about 2001, and the percentages using newspapers and television for current events have declined (Figure 7-7).

Figure 7-6

Primary source respondents used to learn about current news events, science and technology, and specific scientific issues: 2014







NOTE: "All other" includes radio, magazines, books, government agencies, family, and friends/colleagues.

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2014). See appendix tables 7-3–7-5.

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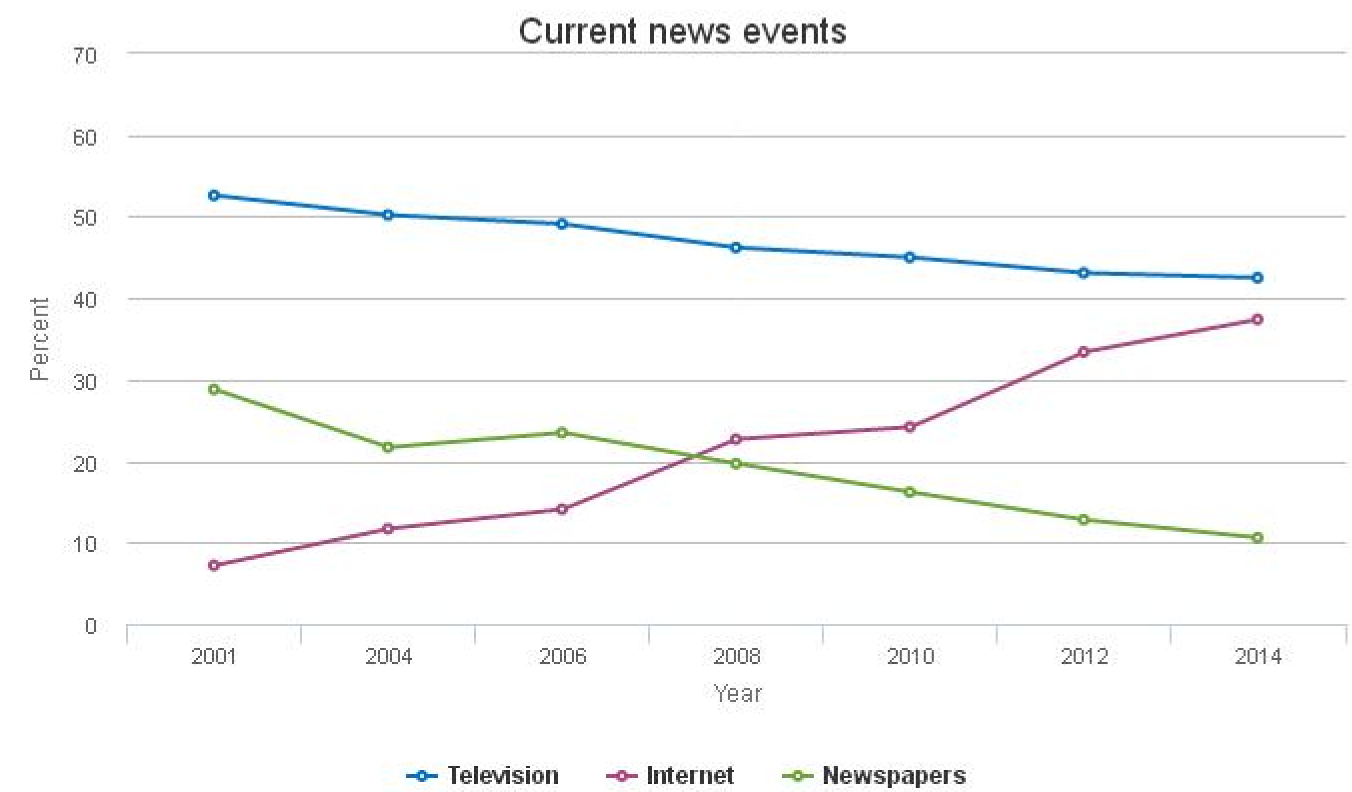
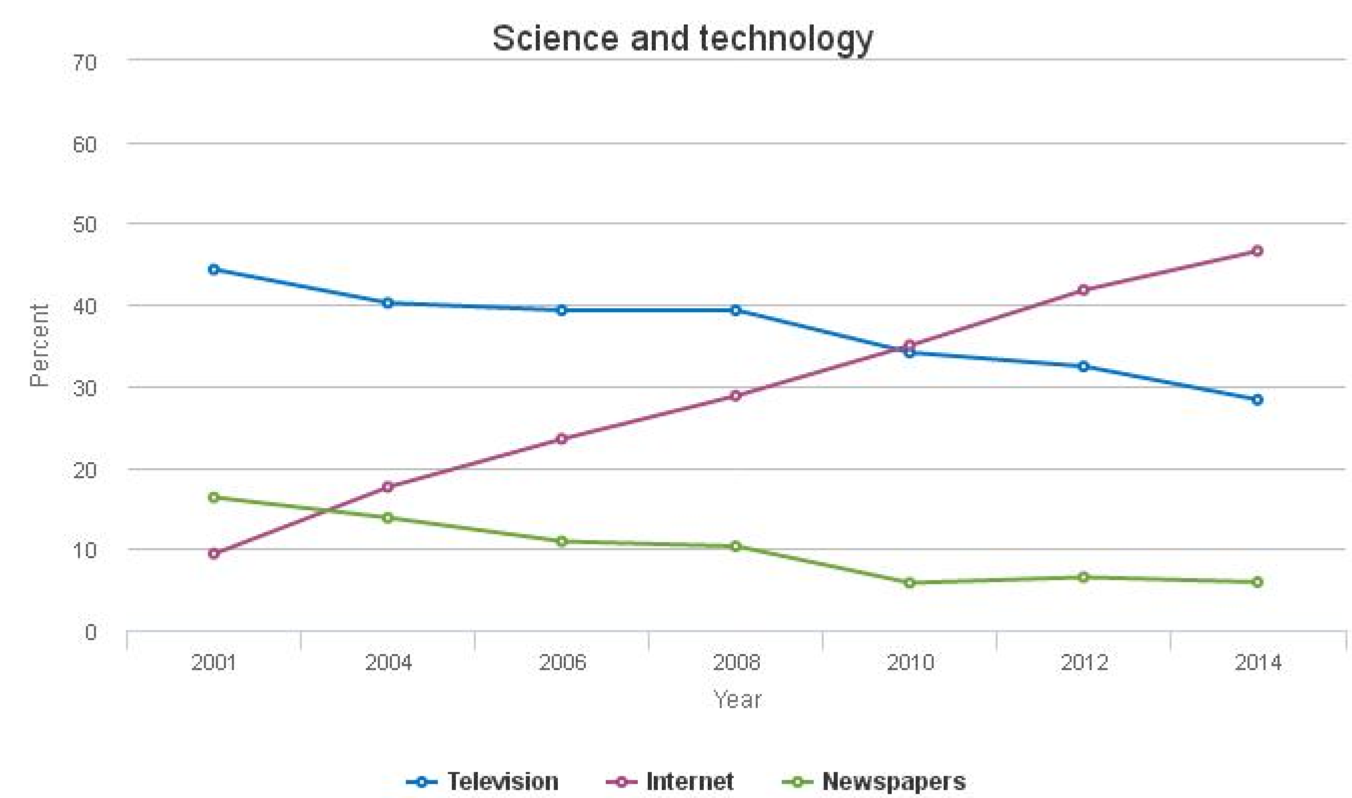
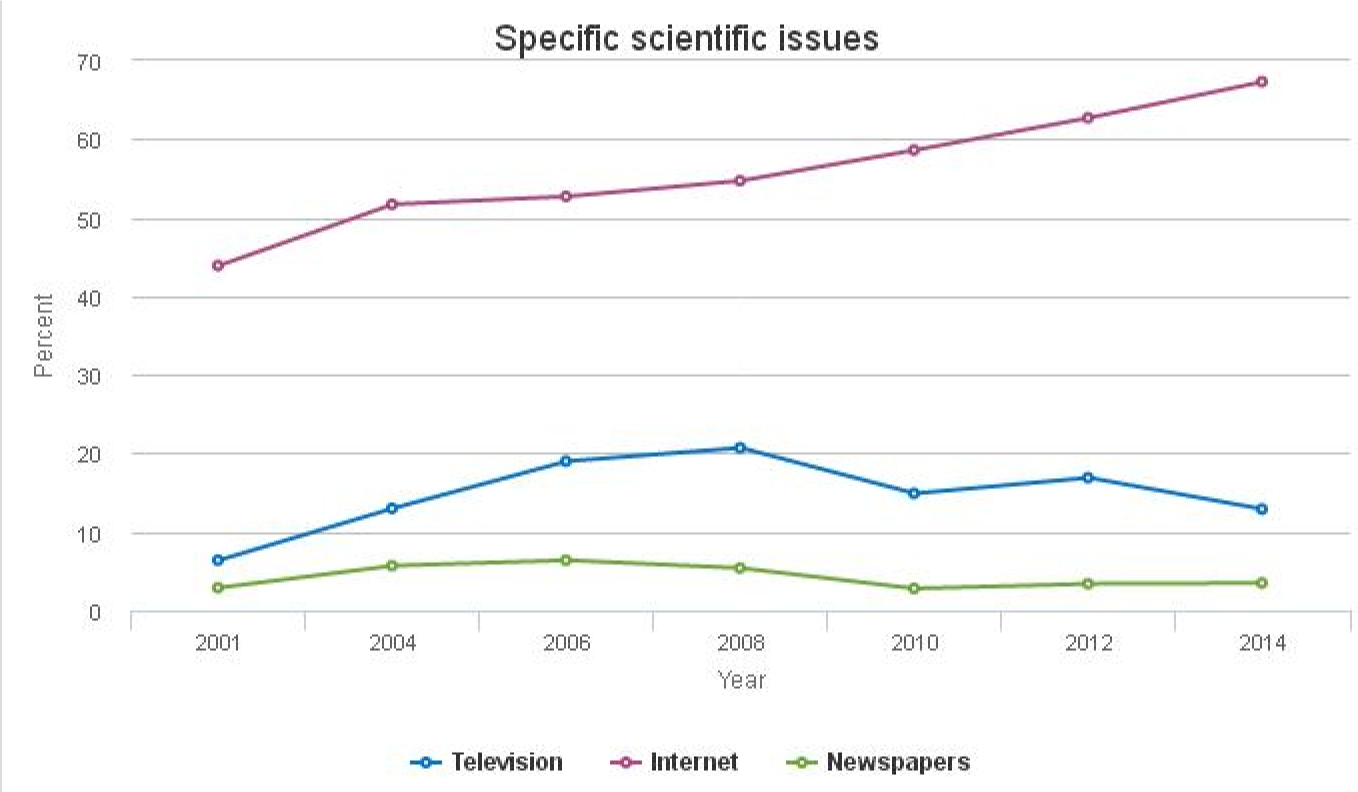
Figure 7-7

Primary source respondents used to learn about current news events, science and technology, and specific scientific issues: 2001–14







SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (2001); University of Michigan, Survey of Consumer Attitudes (2004); University of Chicago, National Opinion Research Center, General Social Survey (2006–14). See appendix tables 7-3–7-5.

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For news specifically about S&T, Americans are now more likely to rely on the Internet than on television. In 2014, 47% of Americans cited the Internet as their primary source of S&T information, up from 42% in 2012. This percentage has grown steadily since 2001 when 9% of respondents named the Internet as their primary source of S&T news. Conversely, reliance on television has dropped; about 28% of Americans reported that television was their primary source of S&T news in 2014, down from 32% in 2012. Some 6% said they get their S&T information from newspapers in 2014 (Figure 7-6 and Figure 7-7; Appendix Table 7-4). Of the 47% who go online for S&T information, 36% (i.e., 15% of all respondents) said that they use a search engine such as Google to seek information, whereas 45% said they use online newspapers (23%), online magazines (15%), or other online news sites (7%). Just 8% (3% of all respondents) said they rely on a science-focused site as their primary source of S&T news.

The Internet has also been the most common resource that respondents say they would use to seek information about specific scientific issues (Figure 7-6), and it has held this position since at least 2001 (Figure 7-7). In 2014, the highest ever percentage of Americans (67%) said they would go online to find information about a specific S&T issue. Another 13% said they would turn to television, and just 3% said they would use newspapers (Appendix Table 7-5).

Different subgroups of Americans tend to rely on different sources of information. Generally, higher levels of education and income are associated with relatively higher levels of Internet and newspaper use, whereas respondents with lower levels of education and income are more likely to say they rely on television. Newspaper reliance is more common for relatively older respondents, and Internet reliance is more common for relatively younger and higher-earning respondents. Television use is also somewhat less common for younger respondents, although the pattern is not nearly as pronounced (Appendix Table 7-3– Appendix Table 7-5).

International Comparisons

European and Asian patterns of media sources for news appear to differ from those in the United States, especially in the continuing importance of television. Television and traditional newspapers, in this regard, appear to remain the most commonly cited source for S&T news in many countries. However, many of the available data sources are several years old, and the rapid shift toward online sources seen in the United States suggests that older data, in particular, should be treated with caution.

Within Europe, a 2013 Eurobarometer survey found that television remains the dominant source of "information about developments in science and technology" (European Commission 2013). Overall, about 65% of Europeans said they "get information" from television, whereas 33% named newspapers, and 32% said "on websites." However, the way that the Eurobarometer survey asked this question allowed respondents to name multiple sources (whereas Americans select only one source in response to the similar GSS question).

Responses also vary substantially by country. Swedes were the most likely to say that they get S&T information from television (84%), newspapers (74%), magazines (51%), radio (45%), books (25%), and "social media or blogs" (23%). Swedes were also among the most likely to say they get S&T information "on websites" (54%), although Danes were slightly more likely to name websites as an information channel (57%). About one-third of residents of Portugal (34%) and a quarter of respondents in Malta (29%), Hungary (27%), Poland (27%), Italy (24%), and Ireland (24%) stated that they did not look for information about S&T. These countries were also typically among the least likely to name a specific channel for S&T information.

Outside of Europe and North America, older research has also suggested that television remains the leading source of S&T information; newspapers generally come in second, and relatively fewer survey respondents cite the Internet as an important source of S&T information. This was true in countries such as Malaysia (Malaysian Science and Technology Information Centre 2010) and India (Shukla 2005). A 2010 Chinese survey allowed respondents to choose up to three sources of information. About 88% of Chinese respondents indicated that television was a primary source of their S&T information, 59% said newspapers, and 27% said the Internet (CRISP 2010). However, in more widely connected South Korea, a 2012 survey found that, similar to 2010, a greater proportion of respondents named the Internet (21%) as their primary source of S&T information rather than newspapers (12%). About 58% said television was their primary source of S&T information (KOFAC 2013). Overall, it appears that, as Internet use has become more common, the Internet has also become an increasingly important source of S&T information.

Involvement

U.S. Patterns and Trends

As reported in 2012, U.S. residents may also come in contact with S&T through America's rich and diverse informal science and cultural institutions (Bell et al. 2009).[i] Some research suggests that informal science participation, along with media use, is a key source of perceived knowledge about S&T (Falk and Needham 2013). Although specific questions about informal science participation were not asked in the 2014 GSS, the 2012 GSS showed that reported attendance at informal science and cultural institutions was down slightly from 2008 (NSB 2014).[ii] In 2012, zoos and aquariums were the most popular type of informal science institutions, with 47% of Americans saying they had visited such an organization in the previous year. This represented a drop from 52% in 2008 and

58% in 2001. Americans with more years of formal education were more likely than others to engage in these informal science activities. Those in higher income brackets were also more likely to have visited a zoo or aquarium, a natural history or S&T museum, or an art museum, but they were just as likely as those in the lowest income bracket to have visited a public library. In general, visits to informal science institutions are less common among Americans aged 45 or older.

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[i] People become involved with S&T through many kinds of nonclassroom activities beyond attending informal science institutions. Examples of such activities include participating in government policy processes, going to movies that feature S&T, attending talks or lectures, bird watching, and building computers. *Citizen science* is a term used for activities by citizens with no specific science training who participate in the research process through activities such as observation, measurement, or computation. Nationally representative data on this sort of involvement with S&T are unavailable.

[ii] In the 2008 GSS, respondents received two different introductions to this set of questions. Response patterns did not vary depending on which introduction was given.

Another important factor that affects citizens' ability to take part in informal science activities is the availability of relevant opportunities. Recent research has thus focused on how members of the scientific community think about engagement. The Scientists and Public Engagement sidebar addresses this issue.

International Comparisons

The available data—some of which are relatively dated—suggest that Americans are particularly active in the degree to which they use a range of informal science and cultural institutions. Within the available data, China and Japan are the only countries in which zoo and aquarium attendance levels are similar to those in the United States. China also has similar levels of S&T and natural history museum attendance. Chinese attendance at these types of institutions also appears to be growing, with average attendance up about an average of 8% from 2007 across the five types of cultural institutions measured (NSB 2012).

Scientists and Public Engagement

Scientists' willingness to get involved in informal science and technology (S&T) activities and engage with their fellow citizens on S&T topics represents an important way for the scientific community to communicate and broaden its contributions to society. Many science leaders have long called for such "public engagement" as a way to ensure that the scientific community stays connected with the broader community (e.g., Royal Society 1985; Leshner 2003). Recent research by the Pew Research Center (2015a) found that U.S.-based members of the American Association for the Advancement of Science (AAAS), the world's largest general scientific society and publisher of the influential academic journal *Science*, were broadly supportive of having scientists contribute to public discussions about scientific issues. This willingness is consistent with academic work that has also shown substantial willingness by scientists to engage the public (e.g., Peters et al. 2008; Dudo 2013).

Specifically, 87% of AAAS respondents said that scientists should "take an active role in public policy debates" related to S&T. In contrast, 13% said that scientists need to "focus on establishing sound scientific facts and stay out of public policy debates."*

Reported engagement itself was also common, with 86% of AAAS respondents saying that they “often” (37%) or “occasionally” (49%) talk with nonscientists about science or research findings. Furthermore, 21% say they “often” (3%) or “occasionally” (18%) speak with reporters about their work.

Online channels are also being used. About 23% of respondents said they “often” (7%) or “occasionally” (16%) use social media to talk about science, whereas 13% said they “often” (5%) or “occasionally” (8%) tweet about research in their specialty area. When it comes to blogging, 8% said they “often” (2%) or “occasionally” (6%) write blog posts about science, and identical numbers of respondents said that they write blog posts about their “research and specialty” area.

The data do not address how often AAAS members directly discuss S&T with policy makers.

The Pew Research Center (2015a) also reports that engagement is higher in fields in which respondents report feeling that there is more public debate in the news media and more interest among the public. For example, 44% of those AAAS respondents who said that there was “a lot” or “some” debate about their field said that they often talk with other citizens, whereas only 29% of respondents who said that they see “not too much” or “no debate” in the media said that they often talk to other citizens. Respondents who described their discipline as “earth science” (53%) and those with a focus on social science, history, or science policy (50%) were the most likely to say that they “often” talk with citizens about their work. Respondents from other disciplines, including those with a focus on physics or astronomy (40%), biomedical science (35%), engineering (34%), mathematics and computer science (32%), and chemistry (24%), also said that they talked with their fellow citizens to varying degrees.

[*]It is possible that members of AAAS could have unique views about public engagement inasmuch as the organization has an “advancement of science” mission. However, the AAAS is also the publisher of one of the world’s highest impact journals, and the AAAS annual meetings often feature announcements of breaking science news. Also, because AAAS members tend to be relatively senior scholars, they might represent a key group whom other scientists might look to as examples.

Public Knowledge about S&T

Science and Engineering Indicators has been assessing Americans' knowledge about S&T since 1979. Initial questions focused on the proper design of a scientific study and whether respondents viewed pseudoscientific belief systems, such as astrology, as scientific. The questions also examined understanding of probability, and questions meant to assess an understanding of basic scientific facts were added in the late 1980s and early 1990s (Miller 2004). These later factual questions—called here the *trend factual knowledge questions*—remain the core of the best available data on trends in adult Americans' knowledge of science.

Although tracking knowledge trends is an important part of this chapter, it is also important to recognize that many researchers question the degree to which scientific literacy has a substantial impact on how people make decisions in their public and private lives (see, for example, NSB 2012:7–27; Bauer, Allum, and Miller 2007) and whether a short battery of questions can assess scientific literacy. Although all indicators have weaknesses and strengths, most evidence suggests that knowledge about science, as measured by the current GSS questions, has a small but meaningful impact on attitudes about science (Allum et al. 2008). It is also, however, clear that such knowledge need not result in accepting the existence of a scientific consensus or a policy position that such a consensus might suggest (Kahan et al. 2012). With regard to the limited number of questions included in the survey, adult responses to an expanded list of knowledge questions drawn from tests given to students nationwide indicate that people who "answered the additional factual questions accurately also tended to provide correct answers to the trend factual knowledge questions included in the GSS" (NSB 2010:7–20). This finding suggests that the trend questions used in this report represent a reasonable indicator of basic science knowledge, such as what might be needed to understand a newspaper science section (Miller 2004). At the same time, in light of the limitations of using a small number of questions largely keyed to knowledge taught in school, generalizations about Americans' knowledge of science should be made cautiously. Similar challenges confront attempts to study health literacy (Berkman, Davis, and McCormack 2010) and political literacy (Delli Carpini and Keeter 1996). Another issue is that, although the focus in *Indicators* is on assessing knowledge about scientific facts and processes, it could also be important to assess knowledge about the institutions of science and how they work—such as peer review and the role of science in policy discussions (Toumey et al. 2010). Others have similarly argued that the knowledge needed for citizenship might be different from what might be needed to be an informed consumer or to understand the role of science in our culture (Shen 1975, in Miller 2004).

More generally, in developing measures for what is often termed *scientific literacy* across nations, the Organisation for Economic Co-operation and Development (OECD 2003) emphasizes that scientific literacy is a matter of degree and that people cannot be classified as either literate or not literate.

The OECD noted that literacy had several components:

> Current thinking about the desired outcomes of science education for all citizens emphasizes the development of a general understanding of important concepts and explanatory frameworks of science, of the methods by which science derives evidence to support claims for its knowledge, and of the strengths and limitations of science in the real world. It values the ability to apply this understanding to real situations involving science in which claims need to be assessed and decisions made…
>
> Scientific literacy is the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity. (OECD 2003:132–33)

The degree to which respondents demonstrate an understanding of basic scientific terms, concepts, and facts; an ability to comprehend how S&T generates and assesses evidence; and a capacity to distinguish science from pseudoscience are widely used indicators of basic scientific literacy.

The 2014 GSS continues to show that many Americans provide multiple incorrect answers to basic questions about scientific facts and do not apply appropriate reasoning strategies to questions about selected scientific issues. Residents of other countries, including highly developed ones, rarely appear to perform better when asked similar questions.

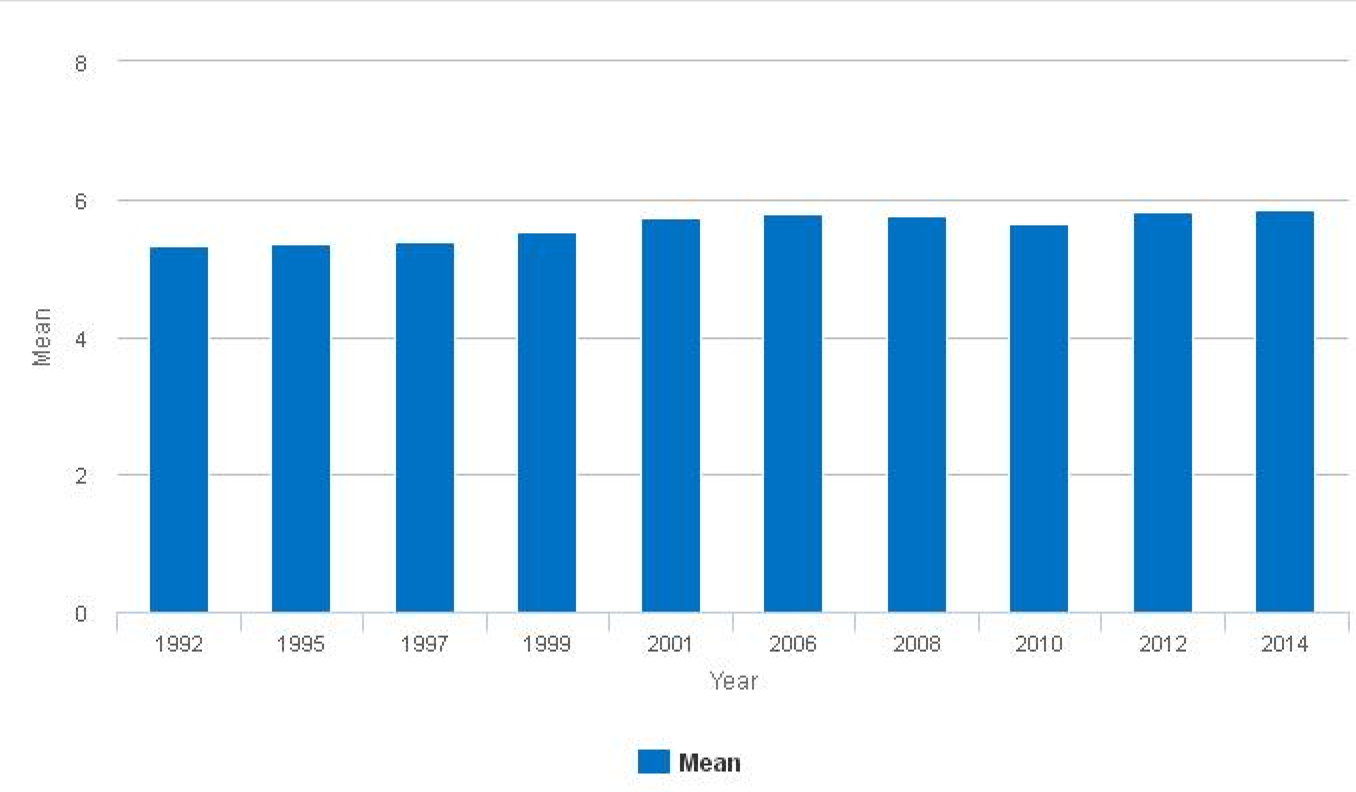
Understanding Scientific Terms and Concepts

U.S. Patterns and Trends

In 2014, Americans were able to correctly answer an average of 5.8 of the 9 items (65%) of NSF's factual knowledge questions. This score has remained nearly identical in recent years (Figure 7-8; Appendix Table 7-6). Two additional true-or-false questions about evolution and the big bang are also discussed subsequently.

Figure 7-8

Mean number of correct answers to trend factual knowledge of science scale: 1992–2014



NOTES: Mean number of correct answers to nine questions included in trend factual knowledge of science scale; see appendix table 7-2 for explanation and list of questions. See appendix table 7-6 for percentage of questions answered correctly. See appendix tables 7-7 and 7-8 for responses to individual questions.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (1992–2001); University of Chicago, National Opinion Research Center, General Social Survey (2006–14).

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The public's level of factual knowledge about science has not changed much over the past two decades. Since 2001, the average number of correct answers to a series of 9 questions for which fully comparable data have been collected has ranged from 5.6 to 5.8 correct responses, although scores for individual questions have varied somewhat over time (Figure 7-8; Appendix Table 7-7 and Appendix Table 7-8).[i] The Pew Research Center (2013c) used several of the same questions in a 2013 survey and received nearly identical results.

Within the GSS data, trend factual knowledge of science is strongly related to people's level of formal schooling and the number of science and mathematics courses completed (Appendix Table 7-6). For example, those who had not completed high school answered 47% of the nine questions correctly, whereas those for whom a bachelor's degree was their highest academic credential answered 77% of the questions correctly (Figure 7-9). The average percentage correct rose to 81% for those with a graduate degree. Similarly, Americans who took 5 or fewer high school or college science or mathematics courses answered 57% of the questions correctly, whereas those who had taken 9 or more courses answered 82% correctly. Those with higher verbal ability scores, a measure of cognitive ability (Miner 1961), also provided more correct responses. The 2014 version of *Indicators* (NSB 2014) showed that education is also associated with attending informal science institutions such as museums.

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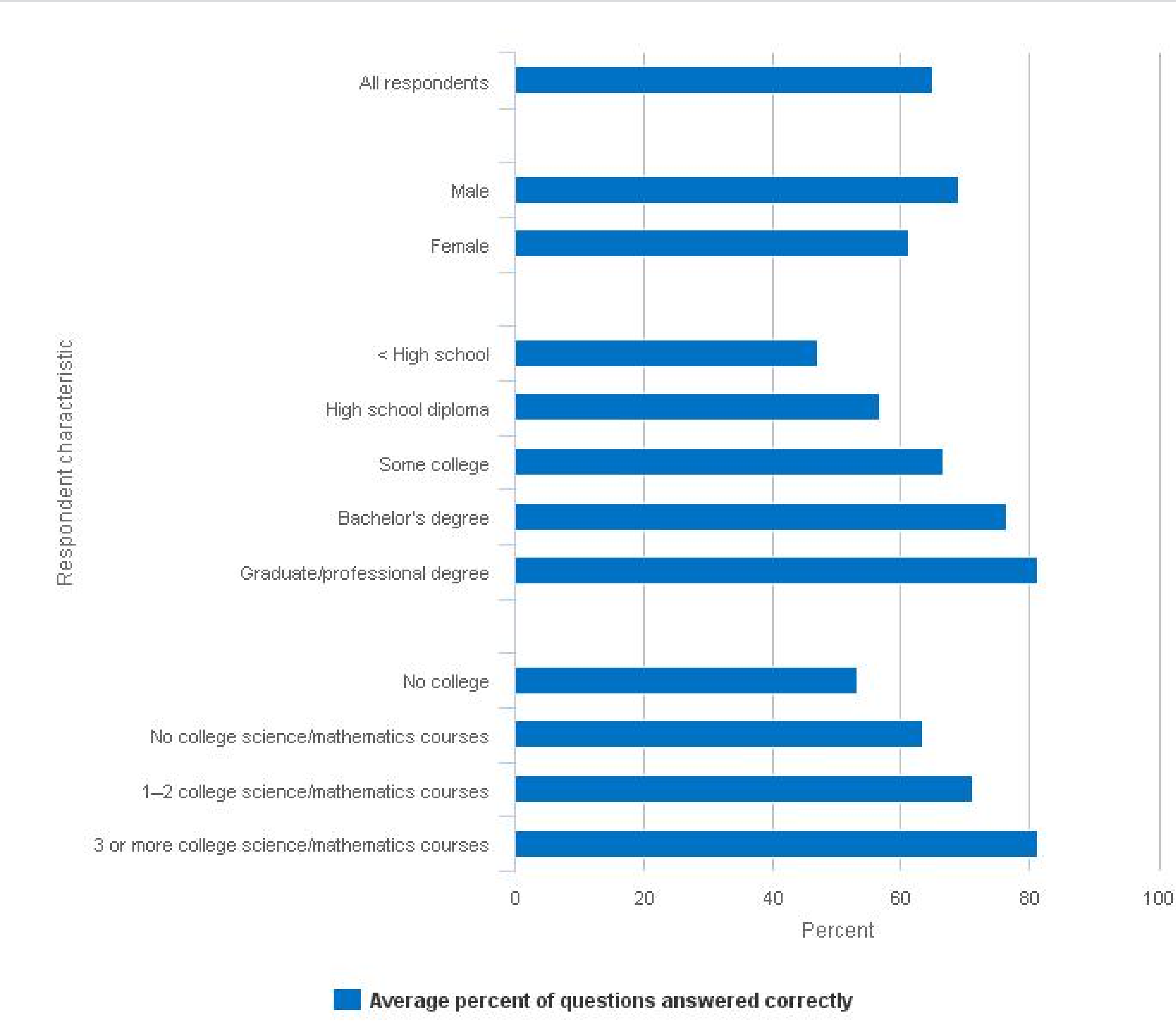
[i] Survey items that test factual knowledge sometimes use easily comprehensible language at the cost of scientific precision. This may prompt some highly knowledgeable respondents to believe that the items blur or neglect important distinctions, and in a few cases may lead respondents to answer questions incorrectly. In addition, the items do not reflect the ways that established scientific knowledge evolves as scientists accumulate new evidence. Although the text of the factual knowledge questions may suggest a fixed body of knowledge, it is more accurate to see scientists as making continual, often subtle modifications in how they understand existing data in light of new evidence.

Figure 7-9

Correct answers to trend factual knowledge of science scale, by respondent characteristic: 2014



NOTES: Data reflect average percentage of nine questions answered correctly. "Don't know" responses and refusals to respond counted as incorrect. See appendix table 7-6 for explanation, list of questions, and additional respondent characteristics. See appendix tables 7-7 and 7-8 for responses to individual questions.

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2014).

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The current data also suggest interesting patterns in the relationship between age and science knowledge. Although there used to be a large gap in scientific knowledge between the top-performing age group and those in the older age groups, this gap has narrowed or disappeared (Appendix Table 7-6). For example, in 1992, those aged 25–34 answered 64% of the questions correctly, whereas those older than age 65 answered 47% of the questions correctly (a 17% gap). In 2014, those aged 25–34 answered 66% of the science questions correctly, whereas 59% of those older than age 65 answered the questions correctly (a 7% gap). The gap between those aged 55–64 and other high-performing groups had substantially declined by 2006. Younger generations have had more formal education, on average, than Americans coming into adulthood some 50 years ago; these long-term societal changes make it difficult to know whether the association between age and factual knowledge is primarily due to aging processes, cohort differences in education, or other factors. Analyses of surveys conducted between 1979 and 2006 concluded that public understanding of science has increased over time and by generation, even after controlling for formal education levels (Losh 2010, 2012).

Factual knowledge about science, at least as measured in the current GSS, is also associated with respondents' sex. Men (69%) tend to answer somewhat more factual science knowledge questions in the GSS correctly than women do (61%) (Figure 7-9). However, men's overall better average score depends on the specific science questions asked. Among the questions asked, men do better in physical science, whereas women do better in biology. Men have typically scored higher than women on questions in the physical sciences on the trend factual knowledge index. Women have tended to score at least equally as high as men on the biological science questions and often a bit higher (Table 7-2; Appendix Table 7-8); however, men did better than women on an expanded set of biology questions in the 2008 survey, which suggests that respondents' sex differences may depend on the specific questions asked. Some evidence also suggests that men might be more likely to guess, rather than say they do not know. This could partly account for men's slightly higher science knowledge score (Mondak 2004).

Table 7-2 **Correct answers to factual knowledge and scientific process questions in physical and biological sciences, by sex: 1999–2014**

(Percent)

Science topic/sex	1999	2001	2004	2006	2008	2010	2012	2014
Physical science index[a]								
Male	72	73	73	74	74	73	75	74
Female	57	59	55	59	61	60	61	63
Biological science index[b]								
Male	59	61	62	63	60	62	59	63
Female	61	65	65	66	64	64	62	67

[a] Physical science index includes five questions:

•*The center of the Earth is very hot.* (True)

•*All radioactivity is man-made.* (False)

•*Lasers work by focusing sound waves.* (False)

•*Electrons are smaller than atoms.* (True)

•*The continents have been moving their location for millions of years and will continue to move.* (True)

[b] Biological science index includes six questions (questions 3 and 4 have two parts):

•*It is the father's gene that decides whether the baby is a boy or a girl*. (True)

•*Antibiotics kill viruses as well as bacteria.* (False)

•*A doctor tells a couple that their genetic makeup means that they've got one in four chances of having a child with an inherited illness*. (1) *Does this mean that if their first child has the illness, the next three will not?* (No); (2) *Does this mean that each of the couple's children will have the same risk of suffering from the illness?* (Yes). Data represent a composite of correct responses to both questions.

•*Two scientists want to know if a certain drug is effective against high blood pressure. The first scientist wants to give the drug to 1,000 people with high blood pressure and see how many of them experience lower blood pressure levels. The second scientist wants to give the drug to 500 people with high blood pressure and not give the drug to another 500 people with high blood pressure, and see how many in both groups experience*

	lower blood pressure levels. Which is the better way to test this drug? Why is it better to test the drug this way? (The second way because a control group is used for comparison.) Data represent a composite of correct responses to both questions.
NOTES:	Data reflect the average percentage of questions in the index answered correctly. "Don't know" responses and refusals to respond are counted as incorrect.
SOURCES:	National Science Foundation, National Center for Science and Engineering Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (1999, 2001); University of Michigan, Survey of Consumer Attitudes (2004); University of Chicago, National Opinion Research Center, General Social Survey (2006–14). See appendix tables 7-7 and 7-8 for factual knowledge questions. See appendix tables 7-9 and 7-10 for scientific process questions (probability and experiment).
	Science and Engineering Indicators 2016

Evolution and the Big Bang

The GSS includes two additional true-or-false science questions that are not included in the index calculation because Americans' responses appear to reflect factors beyond familiarity with basic elements of science. One of these questions is about evolution, and the other is about the origins of the universe. In 2014, 49% of Americans correctly indicated that "human beings, as we know them today, developed from earlier species of animals," and 42% correctly indicated that "the universe began with a big explosion" (Appendix Table 7-8). Both scores are relatively low compared with scores on the other knowledge questions in the survey.

To better understand Americans' responses, the 2012 GSS replicated an experiment first conducted in 2004 (NSB 2006). Half of the survey respondents were randomly assigned to receive the standard two questions focused on information about the natural world. The other half were asked the same questions with a preface that focused on conclusions that the scientific community has drawn about the natural world ("according to the theory of evolution, human beings, as we know them today, developed from earlier species of animals" and "according to astronomers, the universe began with a big explosion"). The results clearly showed that including the preface substantially improves scores (NSB 2014). This suggests that these items, as originally worded, may lead some people to provide incorrect responses based on factors other than their knowledge of what most scientists believe. The Survey-Based Experiments on Science Knowledge Question Format sidebar further examines whether the current response format for the science knowledge questions is as good as alternatives that have been suggested. An additional sidebar (Evaluation of the Human Evolution Question) presents survey experiment evidence regarding the soundness of the knowledge item question format in the *Indicators*.

Survey-Based Experiments on Science Knowledge Question Format

Researchers know that answers to survey questions are affected by the format of response options, raising the issue of whether *Indicators* science knowledge questions are being asked in the best possible way. For example, the true-or-false item "All radioactivity is man-made" can be reworded and tested as a so-called "forced-choice" item in which respondents are asked to select whether radioactivity is "All man-made" or "Some natural." Some researchers suggest that true-or-false items introduce more error because some respondents will reduce their effort by simply agreeing with most questions (Krosnick 1991, 1999; see also Krosnick and Presser 2010). However, this might not happen in this case because accurately answering brief factual science knowledge questions may take little effort.

Similarly, some researchers find that offering a "don't know" response encourages respondents to reduce their effort by selecting that option, increasing error in responding (Krosnick et al. 2002). Others, however, suggest that if respondents are sufficiently informed, a "don't know" option may reduce error (Tourangeau, Maitland, and Yan 2014).

Indicators science knowledge items are offered in a true-or-false format with “don’t know” responses allowed and encouraged in instructions. To determine the soundness of this format, an Internet panel-based survey experiment tested alternative formats of these items.* It concluded that the format in use was as sound as, or better than, alternative formulations (for details, see Tourangeau, Maitland, and Yan forthcoming).

The knowledge items were asked with different response formats, and the researchers examined the relative strength of the correlations among the items in each of these formats. The formats that best capture respondents’ knowledge of science, while reducing extraneous elements, should have items that are more strongly related to each other.

The strength of the correlations among questions in the true-or-false and forced-choice formats was about equal, suggesting that both formats are equally effective in capturing science knowledge.

The correlation among science knowledge questions was clearly higher for respondents encouraged to use “don’t know,” in contrast with those discouraged to do so. This indicates that the “don’t know” encouraged condition results in responses that may better measure knowledge.

Varying both formats simultaneously suggests an advantage for the combination of forced choice with a “don’t know” option over the currently used true-or-false option with “don’t know.” The advantage is modest, and the cost of changing to this option would include a break in a well-established time series.

The relationship of these alternative question formats was also examined against respondents’ reported number of science courses taken in high school and college. Respondents who have taken more science courses should do better on tests of science knowledge, particularly those that better capture such knowledge. A question format that better captures this knowledge should therefore show a larger gap in the number of correct answers between those who have taken many and those who have taken few science courses. For the true-or-false and forced-choice formats, there was little difference in this gap (1.8 versus 1.9 additional correct answers). This is consistent with the previous finding that these formats are not appreciably different from each other in capturing knowledge.

For respondents encouraged to use “don’t know,” the difference between high- and low-scoring course takers was 2.5 additional correct answers. This contrasts with a substantially lower difference of 1.4 for those who were discouraged from responding “don’t know.” This is also consistent with the aforementioned finding that encouraging “don’t know” responses is a superior technique because question responses are more correlated.

* Alternative response formats were tested using a survey experiment conducted in 2014 by Westat using GfK’s online KnowledgePanel. Because of the limitations of the KnowledgePanel, findings here are meant to be suggestive rather than representative of the U.S. population. GfK KnowledgePanel seeks to be nationally representative and recruits participants using well-established methods. However, the ultimate response rate for a given survey, relative to all people in the population asked to participate in the panel, can be in the single digits. People drop out at various stages, may refuse to participate in the panel, and as panelists, may choose not to answer a particular survey. Whether this affects survey results depends on whether nonrespondents would give different responses to questions than respondents. A few prior studies on specific KnowledgePanel surveys indicated little difference between respondents and nonrespondents (see http://www.knowledgenetworks.com/ganp/docs/KnowledgePanelR-Statistical-Methods-Note.pdf).

Evaluation of the Human Evolution Question

U.S. respondents have scored lower than people in other developed countries on a true-or-false question about evolution: "Human beings, as we know them today, developed from earlier species of animals." Prior research provided tentative evidence that many U.S. respondents did poorly not because they did not know about the theory of evolution but because they did not believe in human evolution. If respondents' personal beliefs prevent them from giving the scientifically correct answer to this question about human evolution, then it is possible that the question may not have adequately captured people's general knowledge of science.

A 2014 survey experiment sought to provide more compelling evidence that personal belief reduced correct responses to the human evolution question. The experiment compared the human evolution item with an alternative item about the evolution of elephants (for details, see Maitland, Tourangeau, and Yan 2014; Maitland, Tourangeau, Yan, Bell, and Muhlberger 2014; Roos 2014 presents related findings). The elephant version of the evolution question received more correct responses than did the original version: 75% versus 52%. More correct responses are consistent with the supposition that the elephant version of the evolution question allows people who are skeptical about human evolution to reveal that they know about the theory of evolution.

The elephant version is also better correlated with general scientific knowledge, as measured by the nine-item *Indicators* knowledge battery. Among individuals who do not believe in human evolution, the elephant version is also better correlated with overall knowledge of evolution, measured by a battery of questions. This indicates that the elephant version ameliorates the effects of such disbelief.

Correct responding to the elephant version also turned out to be less related to whether respondents believed in human evolution. For the original version, the difference in correct responses between believers and nonbelievers was 78 percentage points, whereas for the elephant version, the difference was 41 percentage points.

The elephant version proves better than the original version in capturing scientific knowledge, evidently by permitting those who are personally skeptical of human evolution to show that they are aware of the theory of evolution. Adding the elephant version to the nine-item knowledge scale, however, improves the average knowledge score only marginally: from 73% to 76% correct. This improvement would come at the cost of a well-established time series.

These findings suggest that belief in human evolution is not a reliable indicator of general knowledge of evolution or science. That is, many people know basic facts about evolution and science without believing in human evolution.

International Comparisons

Knowledge scores for individual items vary from country to country, and it is rare for one country to consistently outperform others across all items in a given year (Table 7-3). One exception is a 2013 Canadian survey that has Canadians scoring as well as or better than Americans and residents of most other countries on the core science questions (CCA 2014). For the physical and biological science questions, knowledge scores are relatively low in China, Russia, and Malaysia. Compared with scores in the United States and the European Union overall, scores in Japan are also relatively low for several questions. Science knowledge scores have also varied across Europe, with northern European countries, led by Sweden, scoring the highest on a set of 13 questions.

Scores on a smaller set of four questions administered in 12 European countries in 1992 and 2005 show each country performing better in 2005 (European Commission 2005), in contrast to a flat trend in corresponding U.S. data. In Europe, as in the United States, men, younger adults, and more educated people tended to score higher on these questions (see also Wellcome Trust 2013).

Little international polling is done concerning evolution or the big bang. On evolution, the available evidence suggests that residents of other countries have typically been more likely than Americans to say they believe that "human beings, as we know them today, developed from an earlier species of animals." For example, although 49% of Americans gave the correct response to the evolution question in 2014, 70% of European respondents in 2005 (European Commission 2005), 74% of Canadian respondents in 2013 (CCA 2014), and 78% of Japanese respondents in 2011 (NISTEP 2012) gave this response (Table 7-3).

Table 7-3 **Correct answers to factual knowledge questions in physical and biological sciences, by country/region: Most recent year**

(Percent)

Question	United States[a] (2014)		Canada (2013)	China (2010)	EU (2005)	India (2004)	Japan[b] (2011)	Malaysia (2014)	Russia (2003)	South Korea (2004)
Physical science										
The center of the Earth is very hot. (True)	84		93	56	86	57	84	75	NA	87
The continents have been moving their location for millions of years and will continue to move. (True)	82		91	50	87	32	89	62	40	87
Does the Earth go around the Sun, or does the Sun go around the Earth? (Earth around Sun)	76		87	NA	66	70	NA	85	NA	86
All radioactivity is man-made. (False)	72		72	48	59	NA	64	20	35	48
Electrons are smaller than atoms. (True)	51		58	27	46	30	28	35	44	46

Question	United States [a] (2014)		Canada (2013)	China (2010)	EU (2005)	India (2004)	Japan[b] (2011)	Malaysia (2014)	Russia (2003)	South Korea (2004)
Lasers work by focusing sound waves. (False)	50		53	23	47	NA	26	30	24	31
The universe began with a huge explosion. (True)	42	c	68	NA	NA	34	NA	NA	35	67
Biological science										
It is the father's gene that decides whether the baby is a boy or a girl.[d] (True)	59		NA	58	64	38	26	45	22	59
Antibiotics kill viruses as well as bacteria.[e] (False)	55		53	28	46	39	28	16	18	30
Human beings, as we know them today, developed from earlier species of animals. (True)	49	f	74	66	70	56	78	NA	44	64

NOTES: NA = not available, question not asked.

EU = European Union.

See notes to table 7-2 for the full list of questions in the trend factual knowledge of science scale. EU data includes Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finalnd, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom, but does not include Bulgaria and Romania.

[a] See appendix table 7-7 for U.S. trends.

[b] Numbers for Japan are the average from two studies conducted in 2011.

[c] An experiment in the 2012 General Social Survey showed that adding the preface "according to astronomers" increased the percentage correct from 39% to 60% (NSB 2014).

[d]China and Europe surveys asked about "mother's gene" instead of "father's gene."

[e] Japan survey asked about "antibodies" instead of "antibiotics."

[f] An experiment in the 2012 General Social Survey showed that adding the preface "according to the theory of evolution" increased the percentage correct from 48% to 72% (NSB 2014).

SOURCES: United States—University of Chicago, National Opinion Research Center, General Social Survey (2014); Canada—Council of Canadian Academies, Expert Panel on the State of Canada's Science Culture, *Science Culture: Where Canada Stands* (2014); China—Chinese Association for Science and Technology/China

Research Institute for Science Popularization, Chinese National Survey of Public Scientific Literacy (2010); EU—European Commission, Eurobarometer 224/Wave 63.1: Europeans, Science and Technology (2005); India—National Council of Applied Economic Research, National Science Survey (2004); Japan—National Institute of Science and Technology Policy/Ministry of Education, Culture, Sports, Science and Technology, Survey of Public Attitudes Toward and Understanding of Science and Technology in Japan (2011); Malaysia—Malaysian Science and Technology Information Centre/Ministry of Science, Technology and Innovation, Survey of the Public's Awareness of Science and Technology: Malaysia (2014); Russia—Gokhberg L, Shuvalova O, *Russian Public Opinion of the Knowledge Economy: Science, Innovation, Information Technology and Education as Drivers of Economic Growth and Quality of Life*, British Council, Russia (2004), Figure 7; South Korea—Korea Science Foundation (now Korea Foundation for the Advancement of Science and Creativity), Survey of Public Attitudes Toward and Understanding of Science and Technology (2004).

Science and Engineering Indicators 2016

Reasoning and Understanding the Scientific Process

U.S. Patterns and Trends

Another indicator of the public understanding of science focuses on the public's understanding of how science generates and assesses evidence, rather than knowledge of particular science facts. Such measures reflect recognition that knowledge of specific S&T facts is conceptually different from knowledge about the overall scientific processes (Miller 1998), as well as the increased emphasis placed on process in science education (NRC 2012).

Data on three scientific process elements—probability, experimental design, and the scientific method—show trends in Americans' understanding of the process of scientific inquiry. One set of questions tests how well respondents apply the principles of probabilistic reasoning to a series of questions about a couple whose children have a 1 in 4 chance of suffering from an inherited disease. A second set of questions deals with the logic of experimental design, asking respondents about the best way to design a test of a new drug for high blood pressure. A third open-ended question probes what respondents think it means to "study something scientifically." Because probability, experimental design, and the scientific method are all central to scientific research, these questions are relevant to how respondents evaluate scientific evidence. These measures are reviewed separately and then as a combined indicator of public understanding about scientific inquiry.

With regard to probability, 84% of Americans in 2014 correctly indicated that the fact that a couple's first child has the illness has no relationship to whether three future children will have the illness (Table 7-4; Appendix Table 7-9). In addition, about 74% of Americans correctly responded that the odds of a genetic illness are equal for all of a couple's children. Overall, 66% got both probability questions correct. The public's understanding of probability has been fairly stable over time, with the percentage giving both correct responses ranging from 64% to 69% since 1999, and has been no lower than 62% dating back to 1992 (Appendix Table 7-9 and Appendix Table 7-10).[i]

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[i] Earlier NSF surveys used for the *Indicators* report used additional questions to measure understanding of probability. Bann and Schwerin (2004) identified a smaller number of questions that could be administered to develop a comparable indicator. Starting in 2004, the NSF surveys used these questions for the trend factual knowledge scale. This scale does not include the questions aimed at studying scientific reasoning and understanding (e.g., questions about probability or the design of an experiment).

Table 7-4 **Correct answers to scientific process questions: Selected years, 1999–2014**

(Percent)								
Question	1999	2001	2004	2006	2008	2010	2012	2014
Understanding of scientific inquiry scale[a]	32	40	39	41	36	42	33	46
Components of understanding scientific inquiry scale								
Understanding of probability[b]	64	67	64	69	64	66	65	66
Understanding of experiment[c]	34	40	46	42	38	51	34	53
Understanding of scientific study[d]	21	26	23	25	23	18	20	26

[a] To be classified as understanding scientific inquiry, the survey respondent had to (1) answer correctly the two probability questions stated in footnote b, and (2) either provide a theory-testing response to the open-ended question about what it means to study something scientifically (see footnote d) or a correct response to the open-ended question about experiment (i.e., explain why it is better to test a drug using a control group [see footnote c]).

[b] To be classified as understanding probability, the survey respondent had to answer correctly *A doctor tells a couple that their genetic makeup means that they've got one in four chances of having a child with an inherited illness.* (1) *Does this mean that if their first child has the illness, the next three will not have the illness?* (No); and (2) *Does this mean that each of the couple's children will have the same risk of suffering from the illness?* (Yes).

[c] To be classified as understanding experiment, the survey respondent had to answer correctly (1) *Two scientists want to know if a certain drug is effective against high blood pressure. The first scientist wants to give the drug to 1,000 people with high blood pressure and see how many of them experience lower blood pressure levels. The second scientist wants to give the drug to 500 people with high blood pressure and not give the drug to another 500 people with high blood pressure, and see how many in both groups experience lower blood pressure levels. Which is the better way to test this drug?* and (2) *Why is it better to test the drug this way?* (The second way because a control group is used for comparison.)

[d] To be classified as understanding scientific study, the survey respondent had to answer correctly (1) *When you read news stories, you see certain sets of words and terms. We are interested in how many people recognize certain kinds of terms. First, some articles refer to the results of a scientific study. When you read or hear the term scientific study, do you have a clear understanding of what it means, a general sense of what it means, or little understanding of what it means?* and (2) (If "clear understanding" or "general sense" response) *In your own words, could you tell me what it means to study something scientifically?* (Formulation of theories/test hypothesis, experiments/control group, or rigorous/systematic comparison.)

NOTES: Data reflect the percentage of survey respondents who gave a correct response to each concept. "Don't know" responses and refusals to respond are counted as incorrect and are not shown. See appendix table 7-9 for more detail on the probability questions and for years before 1999.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (1999, 2001); University of Michigan, Survey of Consumer Attitudes (2004); University of Chicago, National Opinion Research Center, General Social Survey (2006–14).

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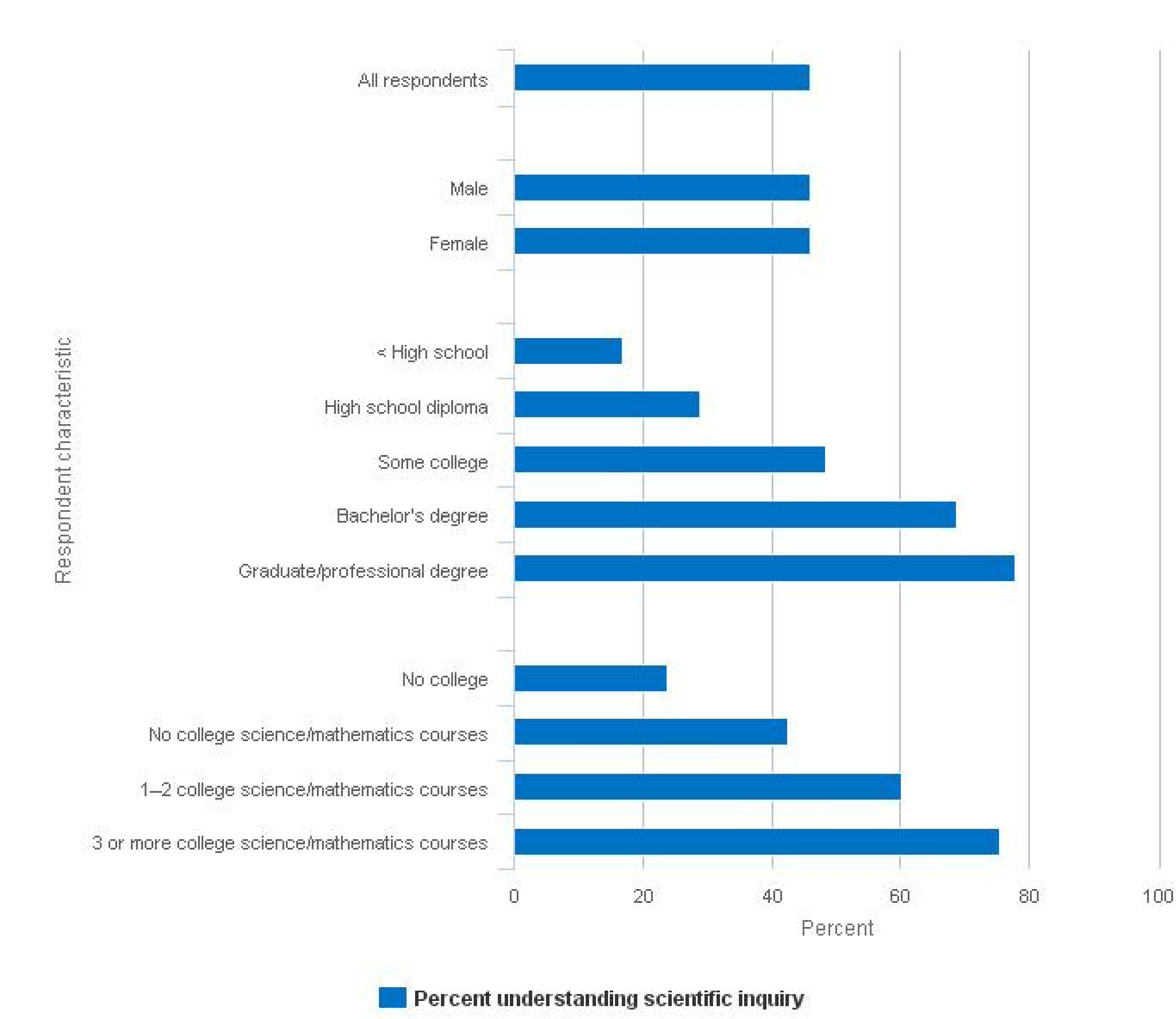
With regard to understanding experiments, more than half (53%) of Americans were able to answer a question about how to test a drug and then provide a correct response to an open-ended question that required them to explain the rationale for an experimental design (i.e., giving 500 people a drug while not giving the drug to 500 additional people, who then serve as a control group) (Table 7-4). The 2014 results are a substantial improvement over the unusually low 2012 results that had only 34% answering correctly. Indeed, the 2014 results are the highest they have ever been, although they are similar to the previous high (51%) seen in 2010 (Appendix Table 7-9). Also, although there has been an average increase in the percentage of correct responses over the previous two decades, there has also been substantial year-to-year variation. The changes observed for this question should be treated with particular caution because of the way these types of survey responses rely on human coders to categorize responses.[ii]

When all of the scientific reasoning questions are combined into an overall measure of "understanding of scientific inquiry" (Figure 7-10), the 2014 results were found to be the highest they have been for the 10 surveys for which NSF has data, dating back to 1995 (Appendix Table 7-9). About 46% of Americans could both correctly respond to the two questions about probability and provide a correct response to at least one of the open-ended questions about experimental design or what it means to study something scientifically (Table 7-4). The previous high was in 2010 when 42% correctly answered all of the questions. In general, respondents with more education, higher incomes, and greater verbal ability (Miner 1961) did better on the scientific inquiry questions. Men and women did equally well, whereas both younger and older age groups did relatively less well compared with those in the middle of the age range (Appendix Table 7-10).

[ii] Declines such as those seen in 2012 need to be regarded with caution. In that case, the percentage of Americans who correctly answered the initial multiple-choice question about how to conduct a pharmaceutical trial stayed stable between 2010 and 2012. It was only the follow-up question that asked respondents to use their own words to justify the use of a control group that saw a decline. For this question, interviewers record the response and then trained coders use a standard set of rules to judge whether the response is correct. Although the instructions and training have remained the same in different years, small changes in survey administration practices can sometimes substantially affect such estimates.

Figure 7-10

Understanding scientific inquiry, by respondent characteristic: 2014



NOTES: See appendix table 7-9 for explanation of understanding scientific inquiry and questions included in the index. See appendix table 7-10 for additional respondent characteristics.

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2014).

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International Comparisons

Reasoning and understanding have not been the focus of surveys from most other countries in recent years. In Asia, a 2010 Chinese survey reported that 49% understood the idea of probability, 20% understood the need for comparisons in research, and 31% understood the idea of "scientific research" (CRISP 2010). In a July 2011

Japanese survey, 62% correctly answered a multiple-choice question on experiments related to the use of a control group, whereas 57% answered correctly in a follow-up December 2011 survey (NISTEP 2012). As noted previously, 66% of Americans provided a correct response to a similar question in 2014.

Pseudoscience

Another indicator of public understanding about S&T comes from a measure focused on the public's capacity to distinguish science from pseudoscience. One such measure, Americans' views on whether astrology is scientific, has been included in *Indicators* because of the availability of data going back to the late 1970s. Other examples of pseudoscience include the belief in lucky numbers, extrasensory perception, or magnetic therapy. Because astrology is based on systematic observation of planets and stars, respondents might believe that this makes it "sort of scientific." As such, the results on astrology should be interpreted with caution.[i]

In 2014, two-thirds of Americans (65%) said astrology is "not at all scientific," a value at the higher end of the historical range. A quarter (26%) said they thought astrology was "sort of scientific," and 6% said it was "very scientific." About 3% said they did not know. In contrast, the 2012 survey suggested that only 55% said that astrology is unscientific—a result that was relatively low in comparison with previous surveys. The percentage of Americans seeing astrology as unscientific has ranged between 50% (1979) and 66% (2004) since the NSF science survey began, with an increasing number of respondents saying astrology is "not at all scientific" and fewer saying that it is "sort of scientific."

Respondents with more years of formal education and higher income were less likely to see astrology as scientific. For example, in 2014, 84% of those with graduate degrees indicated that astrology is "not at all scientific," compared with 51% of those who did not graduate from high school. Age was also related to perceptions of astrology. Younger respondents, in particular, were the least likely to reject astrology, with only 48% of the youngest age group (18–24) saying that astrology is "not at all scientific" (Appendix Table 7-11).

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[i] The fact that those with more formal education and higher factual science knowledge scores are consistently more likely to fully reject astrology suggests that this nuance has only a limited impact on results. Another problem is that some respondents may also confuse astrology with astronomy, and such confusion seems most likely to occur in some of the same groups (i.e., relatively lower education and factual knowledge) that might be predicted to get the question wrong. This could artificially inflate the number of wrong responses, although the fact that the question rebounded between 2012 and 2014 to within a more normal range also suggests that this question continues to assess something meaningful about how people perceive astrology. Also noteworthy is the fact that a Pew Forum on Religion & Public Life study (2009) using a different question found that 25% of Americans believe in "astrology, or that the position of the stars and planets can affect people's lives." Gallup found the same result with the same question in 2005 (Lyons 2005). In contrast, similar to 2014, the 2010 GSS found that 6% saw astrology as "very scientific," and 28% said they saw astrology as "sort of scientific" (34% total).

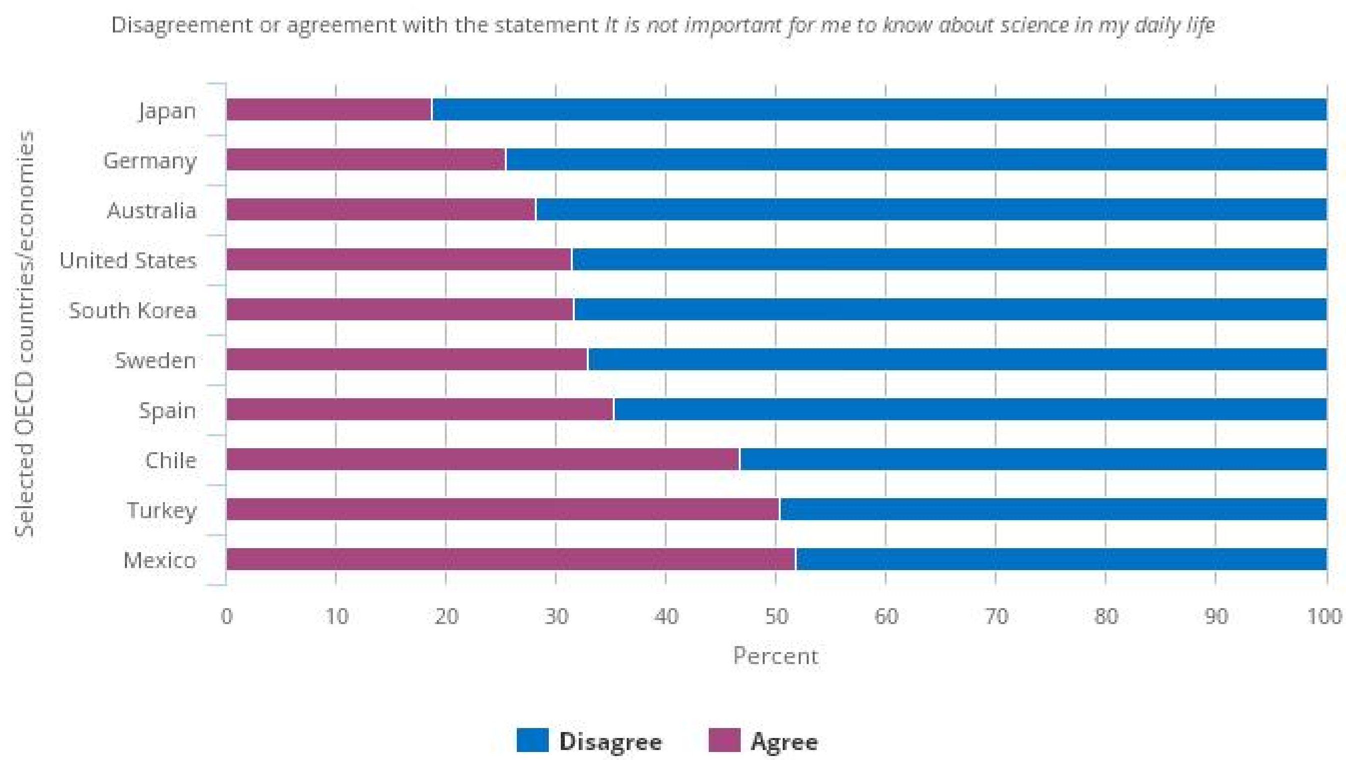
Perceived Knowledge Importance

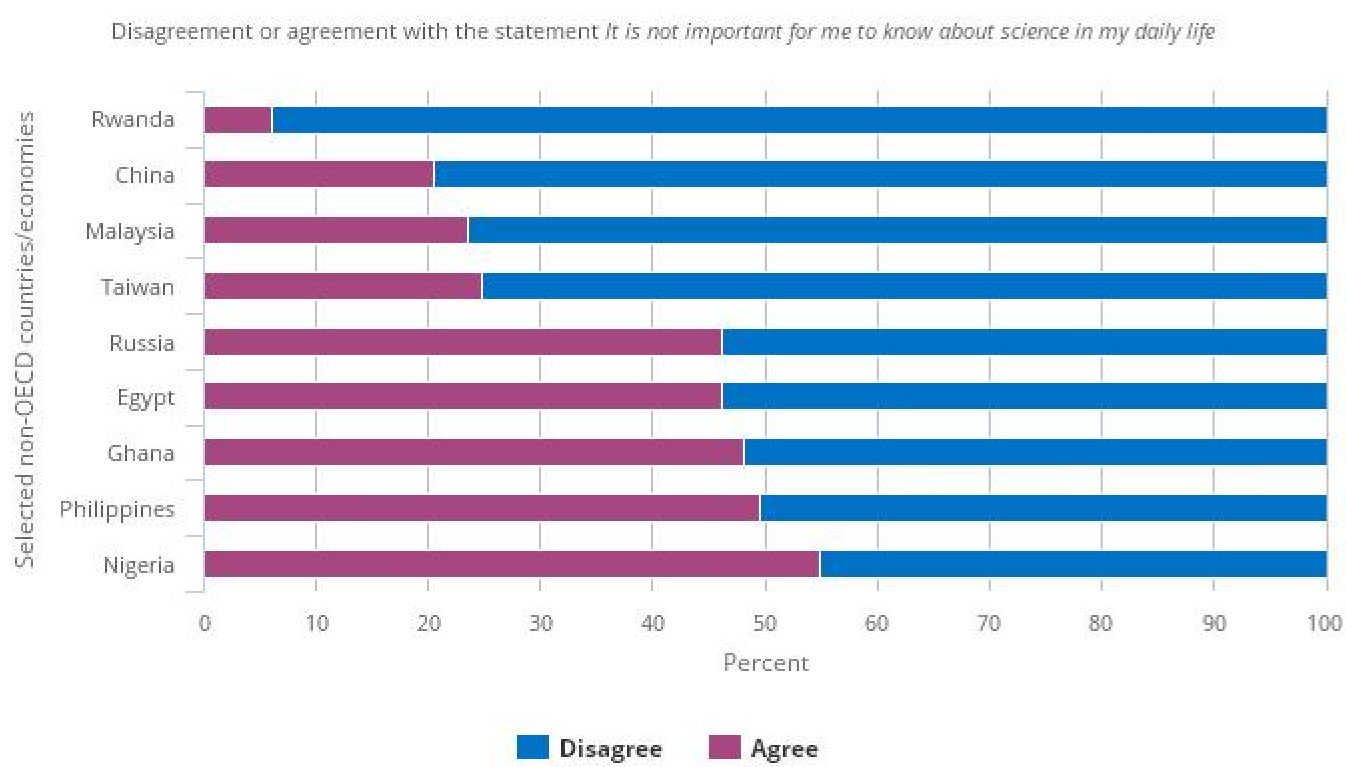
International Comparisons

A 2010–14 international survey also asked about people's perceptions of the importance of scientific knowledge to their daily lives. The study found that 32% of Americans said that it was "not important … to know about science in [his or her] daily life" by choosing between 6 and 10 on a 10-point scale where 1 represented complete disagreement and 10 represented complete agreement (WVS 2014). The United States is similar to many other OECD countries, although residents of Japan (19%) and Germany (26%) were less likely to agree that scientific knowledge is unimportant (Figure 7-11). Outside of the OECD, there were also countries in which relatively few residents indicated that they thought scientific knowledge was unimportant, including Rwanda (6%), China (21%), and Malaysia (24%). In general, about half of the residents of some OECD and non-OECD countries also said they thought scientific knowledge was unimportant.

Figure 7-11

Perceived importance of knowledge about science, by country/economy: 2014





OECD = Organisation for Economic Co-operation and Development.

NOTES: Responses to *It is not important for me to know about science in my daily life.* Respondents were asked to rate from 1 (completely disagree) to 10 (completely agree). Disagreement is the aggregation of responses from 1 to 5, agreement is the aggregation of responses from 6 to 10.

SOURCE: World Values Survey, WVS Wave 6 (2010–14), http://www.worldvaluessurvey.org/WVSDocumentationWV6.jsp, accessed 17 February 2015.

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Public Attitudes about S&T in General

Scientific knowledge is only one limited aspect of how people think about S&T. How people perceive science and scientists can also matter considerably. Such attitudes could affect the public's willingness to fund S&T through public investment (Miller, Pardo, and Niwa 1997; Muñoz, Moreno, and Luján 2012), as well as young people's willingness to enter into S&T training and choose jobs in S&T. Committing resources—whether time or money—to S&T means trusting that such commitments will pay off over the long term for individuals, families, and society. Such general views about S&T may also shape opinions about specific technologies and research programs that could enhance lives or pose new risks.

This section presents general indicators of public attitudes and orientations toward S&T in the United States and other countries. It covers perceptions of the promises and reservations about S&T, overall support for government funding of research, and confidence in scientific community leaders. Overall, the data make it clear that Americans support both S&T and the people involved in S&T.

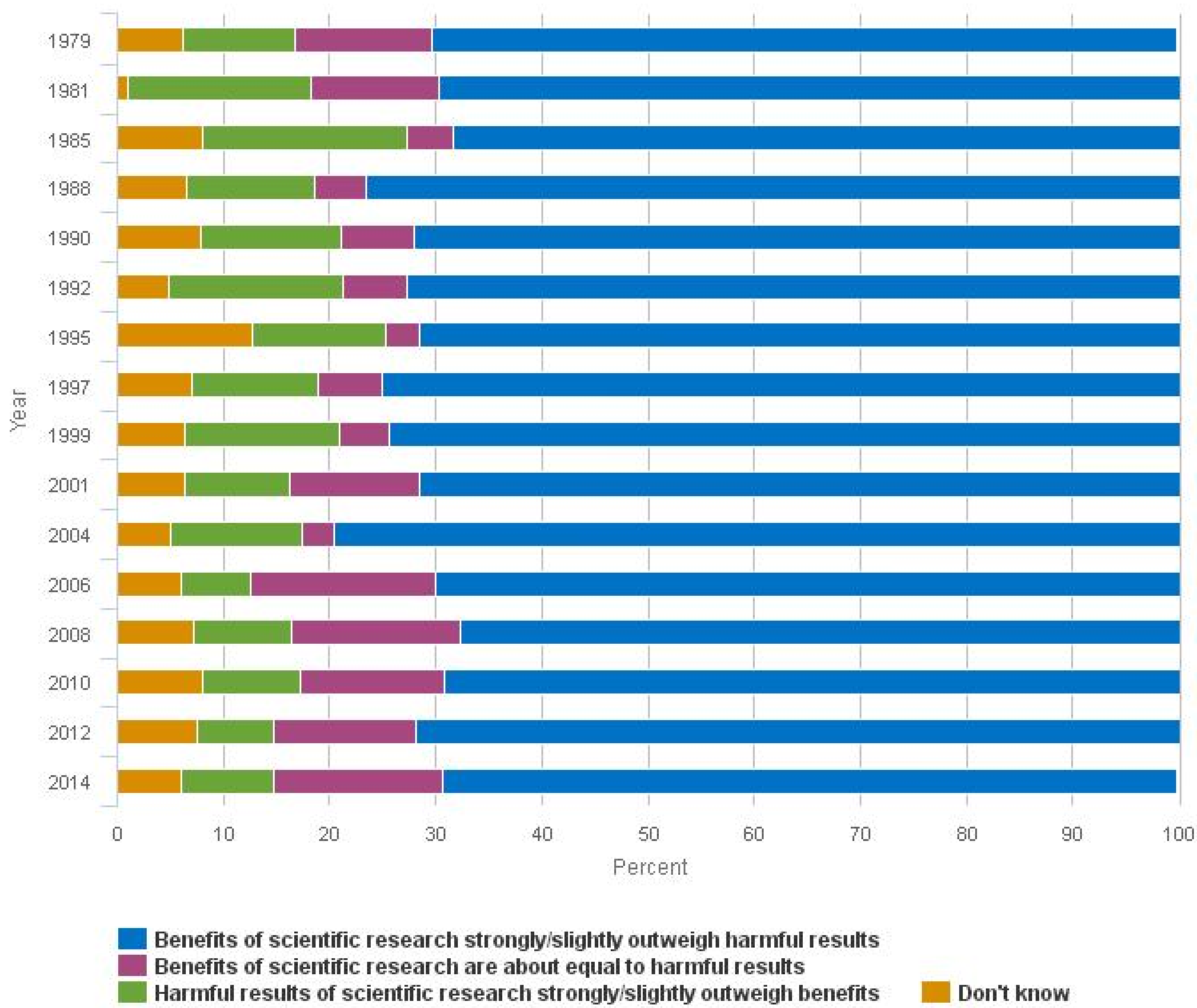
Promises and Reservations about S&T

U.S. Patterns and Trends

Overall, Americans remain strong believers in the benefits of S&T even while seeing potential risks. Surveys since at least 1979 show that roughly 7 in 10 Americans believe the effects of scientific research are more positive than negative for society (Figure 7-12; Appendix Table 7-12). In the 2014 GSS, this included 43% who said they believed the benefits "strongly" outweigh the negatives and 26% who said the benefits only "slightly" outweigh the potential harms (Appendix Table 7-13). Only 9% said science creates more harms than benefits, including 7% who indicated that they thought science caused "slightly" more harm and 2% who thought the balance was "strongly" toward harm. These numbers are generally consistent with earlier surveys; Americans saying the benefits strongly or slightly outweigh the harmful results have ranged from 68% to 80% since this question was initially asked in the 1970s.

Figure 7-12

Public assessment of scientific research: 1979–2014



NOTES: Responses to *People have frequently noted that scientific research has produced benefits and harmful results. Would you say that, on balance, the benefits of scientific research have outweighed the harmful results, or have the harmful results of scientific research been greater than its benefits?* In this figure, "benefits ... outweigh harmful results" and "harmful results ... outweigh benefits" each combine responses of "strongly outweigh" and "slightly outweigh." Figure includes all years for which data were collected. Percentages may not add to total because of rounding.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (1979–2001); University of Michigan, Survey of Consumer Attitudes (2004); University of Chicago, National Opinion Research Center, General Social Survey (2006–14). See appendix tables 7-12 and 7-13.

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Older respondents and those with more education, income, and scientific knowledge hold a stronger belief in the benefits of science than others (Appendix Table 7-12). For example, 44% of those who had not completed high school said they believe science does more good than harm, but 84% of those with bachelor's degrees and 91% of those with graduate degrees expressed this view. Similarly, 49% of those in the lowest income quartile expressed that they saw more benefits than harms from science as compared with 83% of those in the top income quartile. Men were more likely than women to say that benefits "strongly" outweigh harms (49% versus 38%), whereas women were more likely to indicate that the benefits "slightly" outweigh harms; overall, however, 70% of men and 68% of women agreed that science provided more benefits than harms.[i]

Americans also overwhelmingly agree that S&T will foster "more opportunities for the next generation." In the 2014 GSS, 89% of Americans "strongly agreed" (33%) or "agreed" (56%) that S&T will create more opportunities (Appendix Table 7-14). This is up slightly from 2012 but consistent with surveys between 2006 through 2010 during which time 89%–91% agreed about the relative value of S&T (Appendix Table 7-15). Pew Research Center (2015b) data further confirm that most Americans see science as having positive impacts in a range of areas. Overall, 79% of respondents to a 2014 survey by the organization said they thought science has "made life easier," whereas just 15% said they thought it has made life more difficult.

Although Americans may be generally positive about science, concern about the speed at which science may be changing "our way of life" is also close to high levels not seen in more than 30 years. In the 2014 GSS, 51% of Americans "strongly agreed" (11%) or "agreed" (40%) that "science makes our way of life change too fast," with demographic patterns corresponding to those found for the question addressing benefits and harms (Appendix Table 7-16). For example, those with less education and less income were more likely to express worry about the pace of change. Age, however, was not substantially associated with concerns about the pace of change. The current high level of concern is similar to that found in 1979 when 53% agreed that they were concerned about the pace of change. It is, however, difficult to know if there is an underlying trend because the main increase in concern occurred at the same time (between 2004 and 2008) that the underlying survey switched from a telephone survey to a face-to-face survey. Concern about the pace of change was, nevertheless, lower during much of the 1980s and 1990s (Appendix Table 7-17).

International Comparisons

The 2013 special Eurobarometer on S&T found that, across Europe, large majorities see substantial benefits from S&T. More than three-quarters (77%) of respondents said they felt that S&T had a "very" (60%) or "fairly" (17%) positive influence on society in their home country. There was near consensus in Sweden (94% positive) and in the Baltic countries of Estonia (91% positive) and Lithuania (90% positive). Even respondents in the least favorable countries—Romania (68% positive) and Portugal (69% positive)—agreed on the value of S&T (European Commission 2013). The 2013 Eurobarometer survey, along with the WVS, also included several questions that are nearly identical to those asked in the GSS.

For the Eurobarometer, Europeans were asked whether they believe S&T would "provide more opportunities for future generations." Three-quarters of Europeans (75%) agreed, and several northern European countries were again among the most favorable, led by the Netherlands (88%), Estonia (87%), Denmark (85%), and Sweden (85%). There were still substantial positive attitudes about S&T in countries in which residents were least likely to agree that S&T would provide future opportunities. The least positive attitudes were in Southern and Eastern Europe, including Slovenia (64%), Romania (67%), and Italy (67%). Belief in future benefits from science is also widespread, although Americans may be relatively less likely to say they see such benefits than residents of many other countries. In this regard, the 2010–14 WVS also included a question about perceived future opportunities from science. This question used a 10-point scale anchored by "completely disagree" to "completely agree" with no neutral response option (i.e., no middle category). Among OECD countries in the survey, the 79% of Americans who said they believe S&T will ensure more opportunities for future generations is similar to results from the Netherlands (84%), South Korea (80%), and Australia (74%). The OECD countries that see the most hope from S&T are Estonia (93%) and Poland (86%). Beyond the OECD, the countries in which there appears to be the most hope for S&T include Libya (97%), Qatar (93%), Uzbekistan (93%), and Armenia (91%) (WVS 2014). A separate 2013 survey indicated that 74% of Canadians agreed that S&T would create more opportunities (CCA 2014).

Another past GSS question used in the 2013 Eurobarometer survey on science asked respondents to consider the role of faith and science in society. A total of 39% of Europeans agreed that "we depend too much on science and not enough on faith." The highest proportion of agreement came from Southern and Eastern Europe, including Bulgaria (66%), Cyprus (66%), and Montenegro (64%), and the least amount of agreement came from the Netherlands (23%), Denmark (24%), and France (25%) (European Commission 2013). A 2013 Canadian survey found that Canadians' responses were similar (25% agreed) to those of respondents in the latter European countries (CCA 2014). About 41% of Americans agreed that "we depend too much on science and not enough on faith" when the question was last asked in the 2010 GSS (NSB 2014), similar to the European average.

The 2010–14 WVS also included a version of the faith versus science question, which used a 10-point scale anchored by "completely disagree" to "completely agree" described previously (WVS 2014). Among OECD countries, the WVS found that residents of Sweden (20%), Slovenia (21%), and the Netherlands (25%) were the least likely to agree that "we depend too much on science and not enough on faith" (i.e., give a response that was between 6 and 10 on the scale) (Figure 7-13). In contrast, Americans were evenly divided (50%). Beyond the OECD, the respondents least likely to say their society puts too much emphasis on science were from a group of Middle Eastern countries, including Yemen (20%) and Iraq (19%). Respondents from a group of Central and South American countries were among the most likely to agree that their society puts too much emphasis on science, including Ecuador (75%) and Colombia (70%).[ii]

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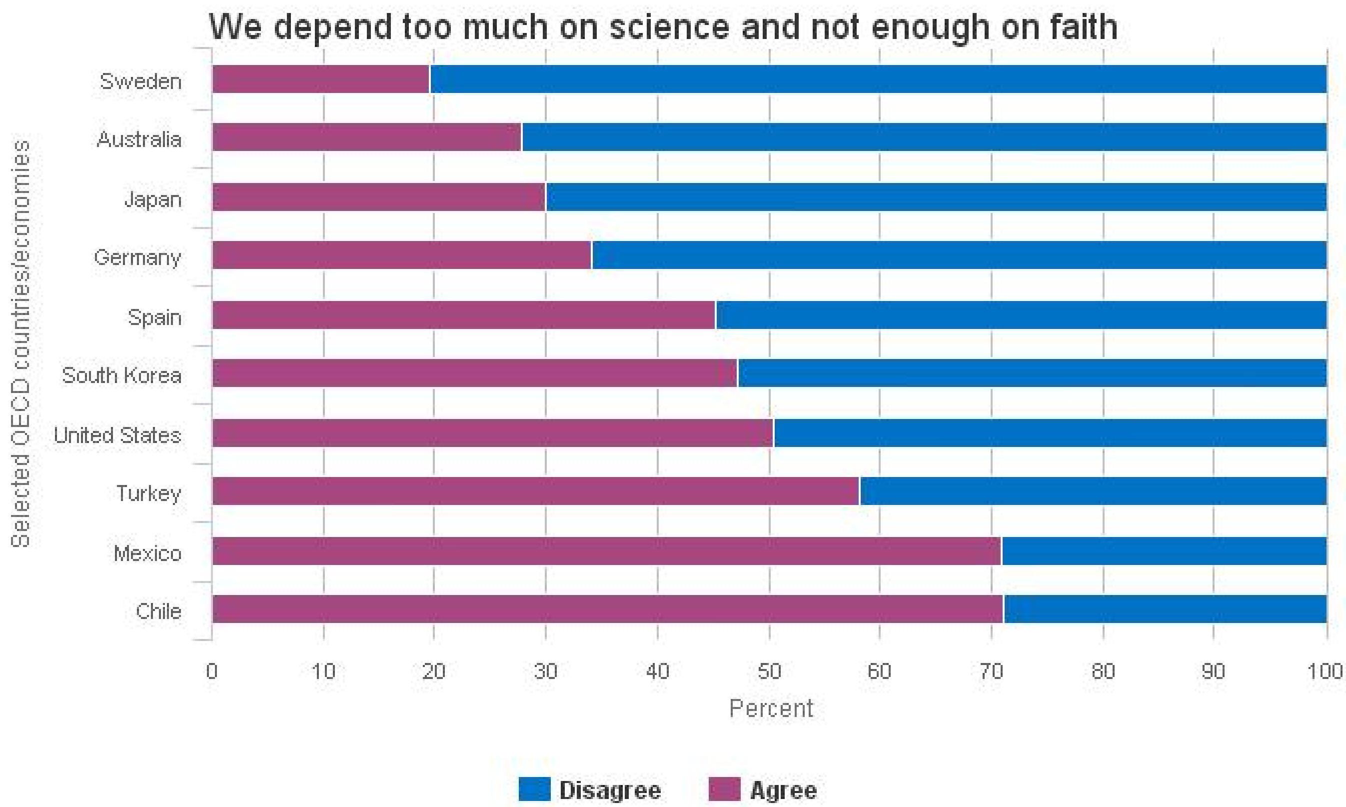
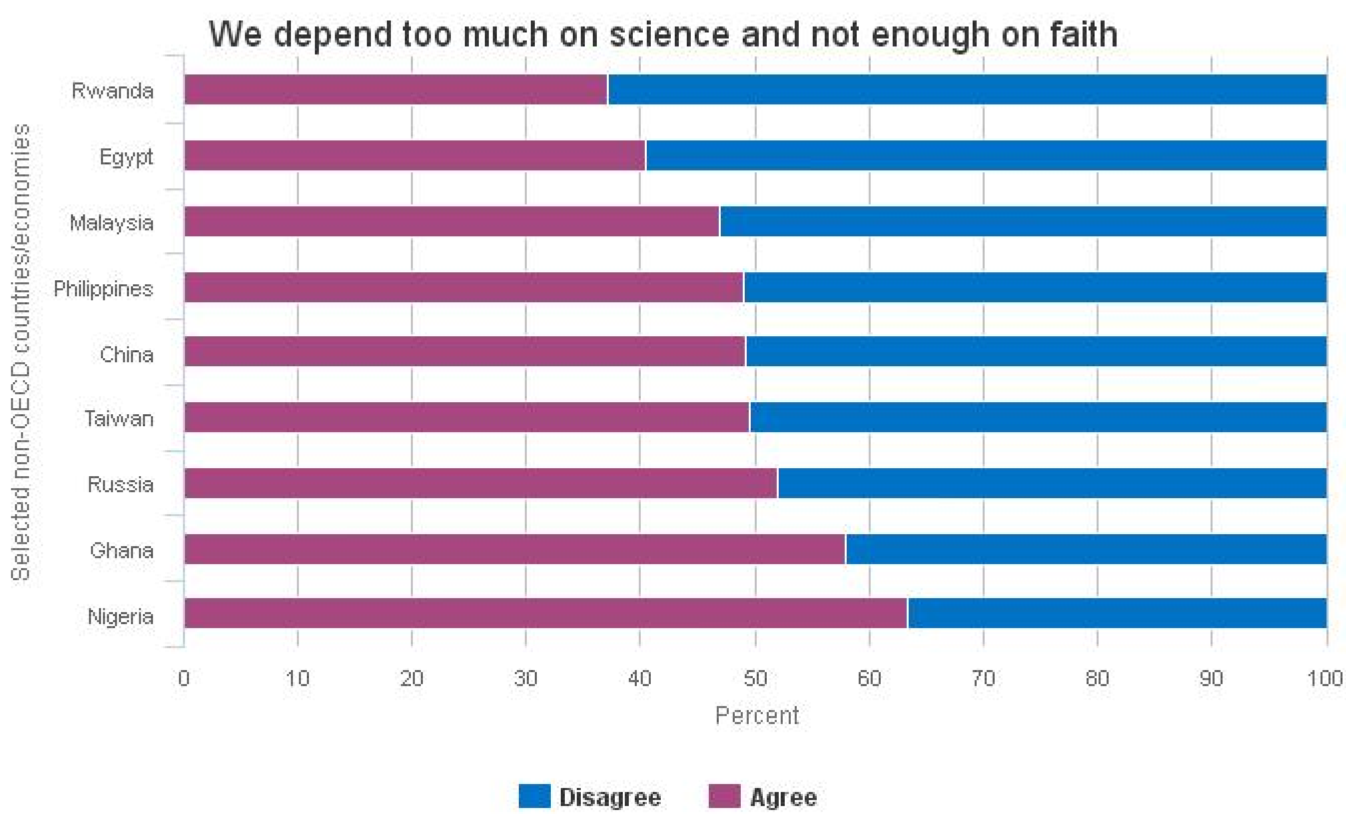
[i] Methodological issues make fine-grained comparisons of data from different survey years particularly difficult for this question. For example, although the question content and interviewer instructions were identical in 2004 and 2006, the percentage of respondents who volunteered "about equal" (an answer not among the choices given) was substantially different. This difference may have been produced by the change from telephone interviews in 2004 to in-person interviews in 2006 (although telephone interviews in 2001 produced results that are similar to those in 2006). More likely, customary interviewing practices in the three different organizations that administered the surveys affected their interviewers' willingness to accept responses other than those that were specifically offered on the interview form, including "don't know" responses.

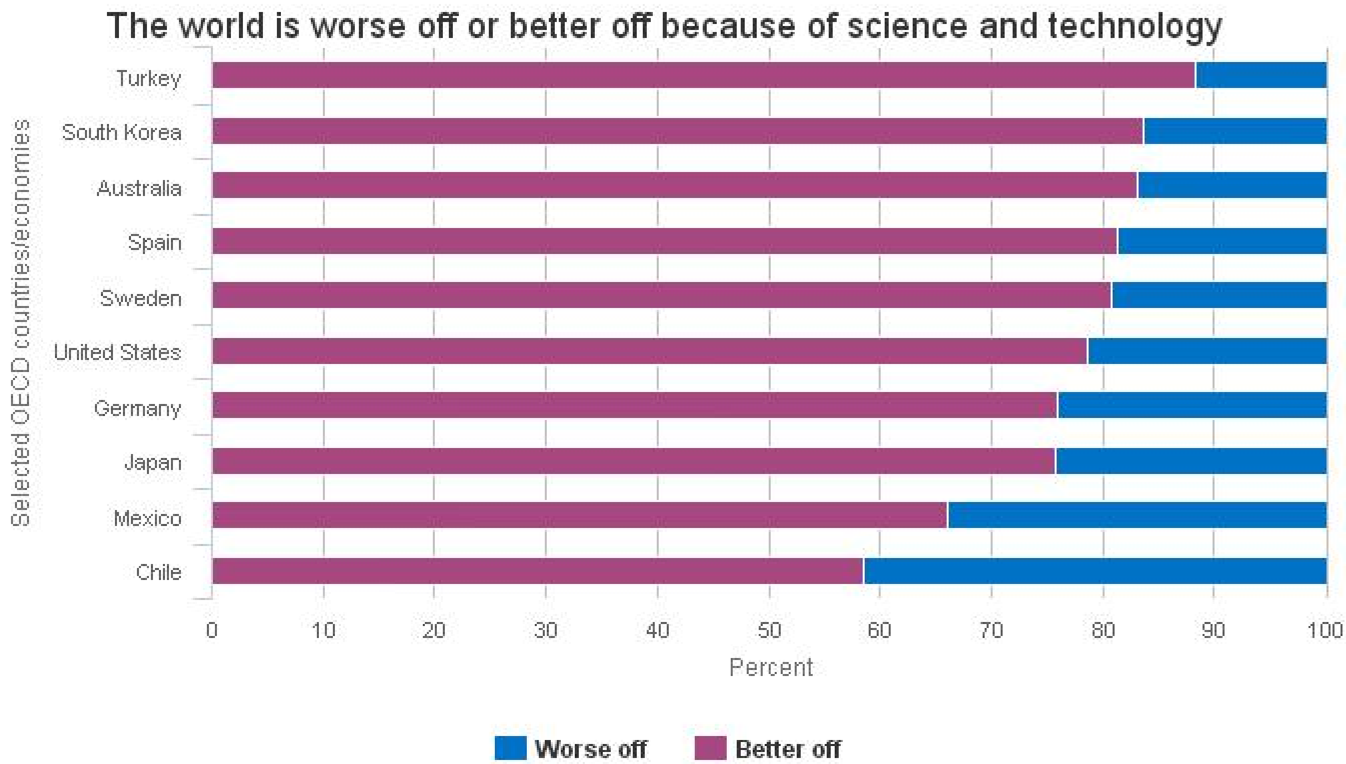
[ii] Interpreting this response is difficult because agreement could mean that a respondent thinks either that his or her country relies too much on science or not enough on science. For example, if the respondent felt that his or her country relied too much on faith, then he or she might disagree with the question. It should thus be understood that the respondent is unhappy with the current balance, not that he or she wants more emphasis on either faith or science. Also, the difference between the two data points from the United States is not readily interpretable because of the different response options provided to those taking the survey.

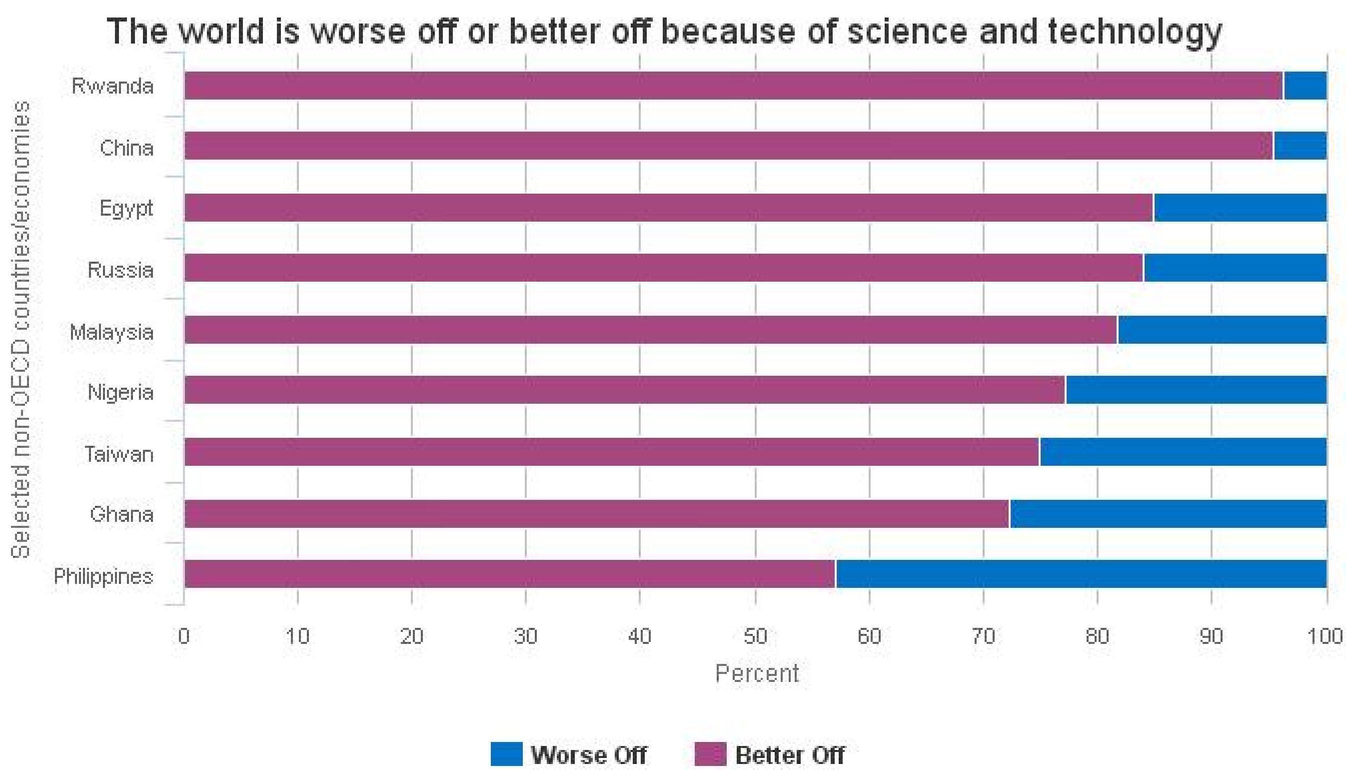
Figure 7-13

Public assessment of belief in science versus faith and of whether science does more harm than good, by country/economy: 2014









OECD = Organisation for Economic Co-operation and Development.

NOTES: Response to *We depend too much on science and not enough on faith.* Respondents were asked to rate from 1 (completely disagree) to 10 (completely agree). Disagreement is the aggregation of responses from 1 to 5; agreement is the aggregation of responses from 6 to 10. Response to *All things considered, would you say that the world is worse off, or better off, because of science and technology*. Respondents were asked to rate from 1 (Much worse off) to 10 (Much better off). Worse off is the aggregate of responses from 1 to 5; better off is the aggregate of responses from 6 to 10.

SOURCE: World Values Survey, WVS Wave 6 (2010–14), http://www.worldvaluessurvey.org/WVSDocumentationWV6.jsp, accessed 17 February 2015.

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Another WVS question addressing general views about S&T addressed whether respondents said they believed that science had made the world better off or worse off (again, using a 10-point scale). In this case, most respondents agreed that the world was "better off" because of science. Within the OECD, Turkey (88%), South Korea (84%), and Australia (83%) were the most likely to say the world was better off, although most residents of the United States (79%) also held this view (Figure 7-13). Within the OECD, residents of Chile (59%) and Mexico (66%) were the least likely to say that science has made the world better off. Outside of the OECD, residents of Rwanda (96%) and China (96%) were particularly likely to say that science had made the world better off. Residents of the Philippines (57%) were the least likely to give this view, although most non-OECD countries were positive about science.

A third GSS question that was included in the 2013 special Eurobarometer focused on whether respondents agreed or disagreed that "science makes our way of life change too fast." Although 51% of Americans agreed with this statement in 2014, about 62% of Europeans agreed, with residents of Cyprus (93%) and Greece (89%) being the most likely to agree and residents of the Netherlands (45%) and Denmark (45%) the least likely to agree (European Commission 2013). The 2013 Canadian survey suggested that just 35% of Canadians thought science makes life "change too fast" (CCA 2014).

Within Asia, different question wording makes comparisons difficult, but most respondents appeared to support S&T. In 2010, 75% of Chinese respondents "fully" or "basically" agreed that S&T brings more advantages than disadvantages, whereas only one-fifth (20%) said they thought that "we are too dependent on science such that we overlook belief" (CRISP 2010). In 2011, 54% of Japanese respondents said that S&T development has more advantages than disadvantages (NISTEP 2012). South Koreans were asked separate questions about the risks and benefits of S&T. In 2012, about 83% "agreed" or "somewhat agreed" that S&T promotes a healthy and convenient life, and 72% agreed that S&T "helps in everyday life." However, 60% also agreed that S&T "creates problems" (KOFAC 2013).

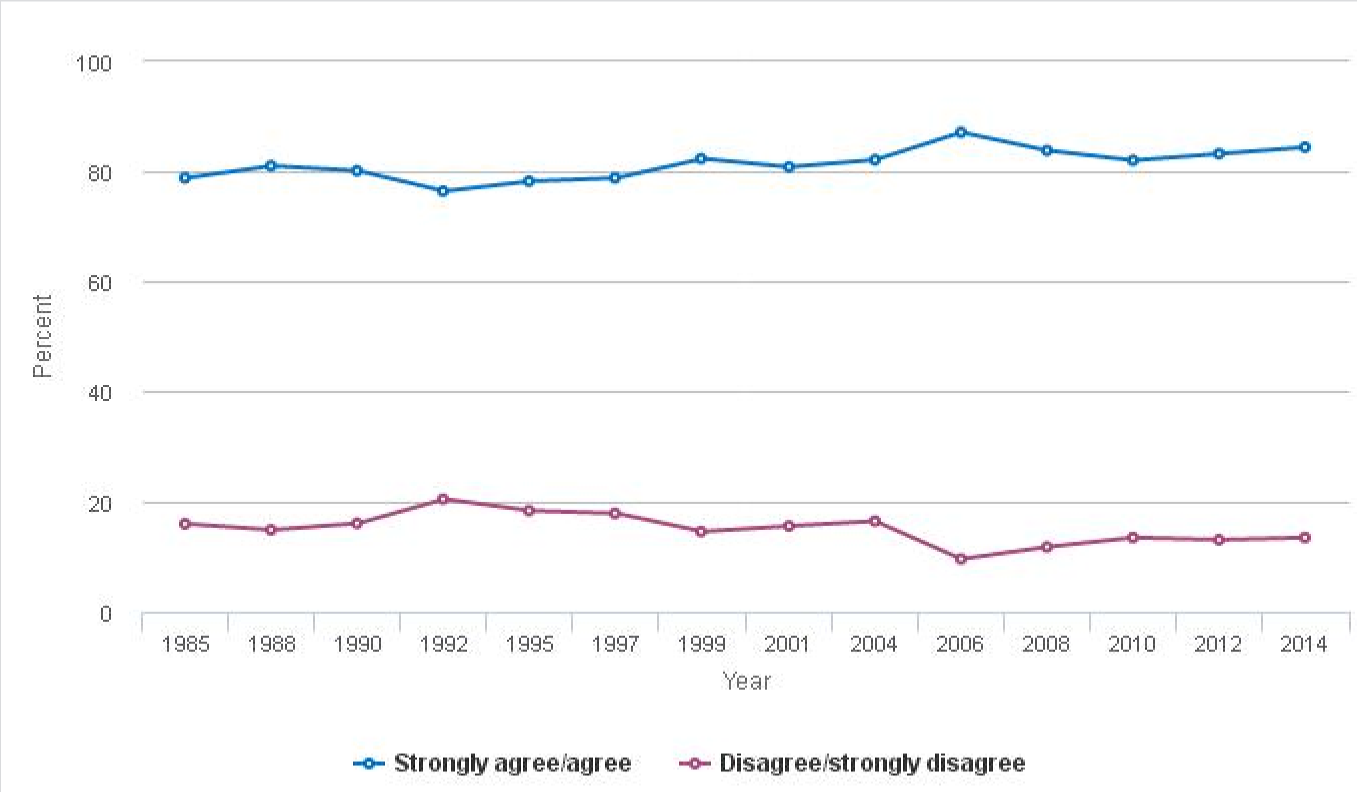
Federal Funding of Scientific Research

U.S. Patterns and Trends

U.S. public opinion has consistently and strongly supported federal spending on basic scientific research. In the 2014 GSS, 85% of Americans "strongly agreed" (25%) or "agreed" (60%) that "even if it brings no immediate benefits, scientific research that advances the frontiers of knowledge is necessary and should be supported by the federal government" (Figure 7-14 and Appendix Table 7-18). This is similar to the percentage in recent years, although it has risen from that in the 1985–2001 NSF surveys, when the value ranged between 77% (1992) and 82% (1999) (Appendix Table 7-19).

Figure 7-14

Public opinion on whether government should fund basic scientific research: 1985–2014



NOTES: Responses to *Even if it brings no immediate benefits, scientific research that advances the frontiers of knowledge is necessary and should be supported by the federal government. Do you strongly agree, agree, disagree, or strongly disagree?* Responses of "don't know" are not shown.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (1985–2001); University of Michigan, Survey of Consumer Attitudes (2004); University of Chicago, National Opinion Research Center, General Social Survey (2006–14). See appendix tables 7-18 and 7-19.

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Americans with relatively higher levels of education, more income, and more science knowledge are particularly likely to support funding scientific research. For example, 76% of those who had not completed high school agreed that funding was needed, but 90% of those with graduate degrees expressed this view (Appendix Table 7-18).

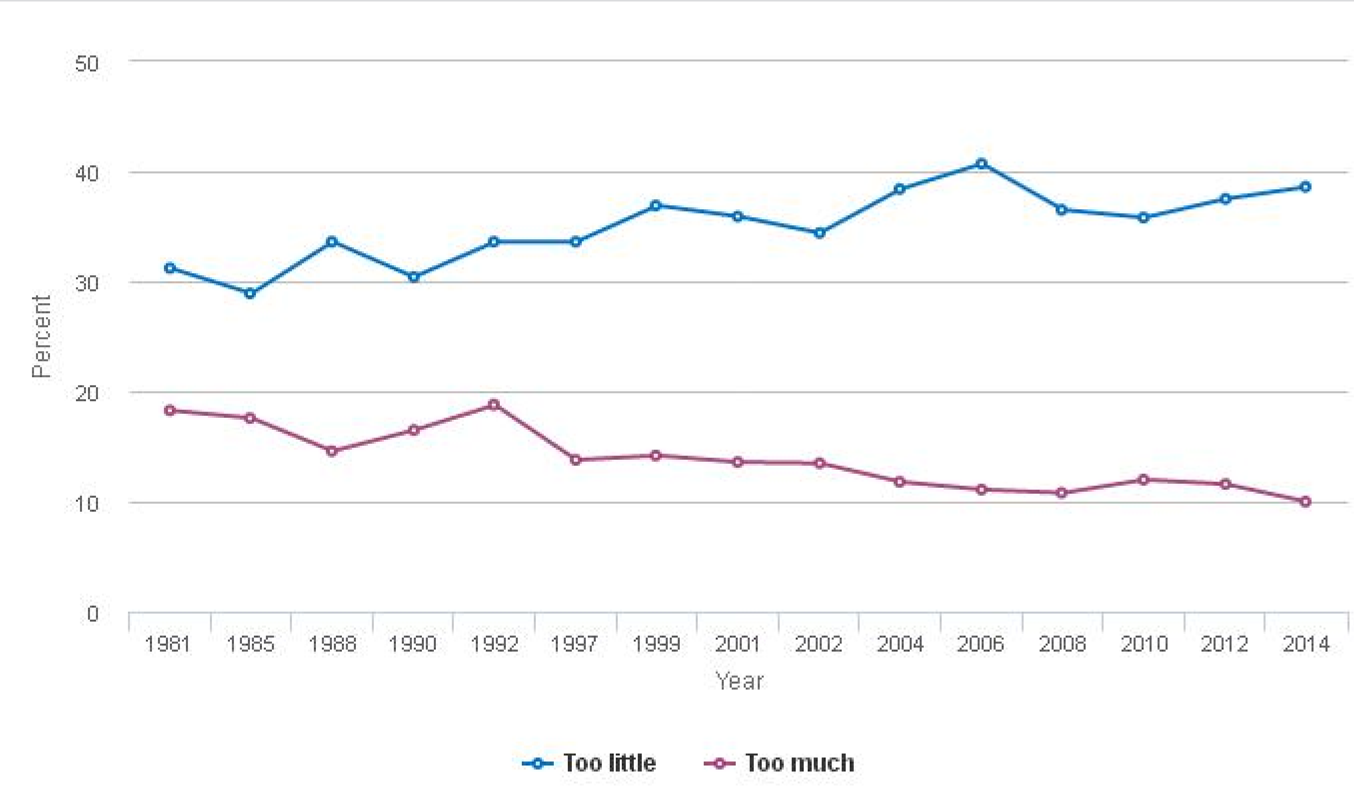
The Pew Research Center (2015b) also found that, in 2014, most Americans said they think that "government investments" in both basic scientific research (71%) and engineering and technology (72%) "pay off in the long run." Overall, 61% of Americans told the Pew Research Center that they thought "government investment in research is essential for scientific progress." These results were also similar to what the Pew Research Center found in 2009 (Pew Research Center 2015b).

Another indicator of views about S&T is the percentage of Americans who say they "think we're spending too little money" on "supporting scientific research." The 2014 GSS found that 39% of respondents said we are spending "too little," 45% said the amount was "about right," and 10% said it was "too much." In other words, 84% of Americans say they would like to see similar or increased funding for S&T in the years ahead, although the question does not specify who is responsible for this spending.

The percentage who said they thought we spend too little on science gradually increased from 1981 to 2006, fluctuating between 29% and 34% in the 1980s, between 30% and 37% in the 1990s, and then varying between 34% and 41% in the 2000s and 2010s (Figure 7-15; Appendix Table 7-20 and Appendix Table 7-21). Also, as noted previously, older residents, those with more education, and those with more income were more likely to say that they believe too little is being spent on science.

Figure 7-15

Public assessment of amount of government spending for scientific research: 1981–2014



NOTES: Responses to *We are faced with many problems in this country, none of which can be solved easily or inexpensively. I'm going to name some of these problems, and for each one, I'd like you to tell me if you think we're spending too little money on it, about the right amount, or too much: [scientific research].* Responses of "right amount" and "don't know" not shown.

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (1981–2001); University of Michigan, Survey of Consumer Attitudes (2004); University of Chicago, National Opinion Research Center, General Social Survey (2006–14). See appendix table 7-21.

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Compared with support for spending in other areas, however, support for spending on scientific research may not be especially strong. In the 2014 GSS, Americans were more likely to say several other policy domains need spending more than S&T (Figure 7-16). Although 39% of Americans say they would like more funding for scientific research, education has consistently been the domain that Americans are most likely to say receives too little funding, with 74% giving this response in 2014. Other S&T domains in which Americans consistently think there is too little spending according to the 2014 GSS include improving the environment (60%) and health (57%) (Appendix Table 7-21).[i]

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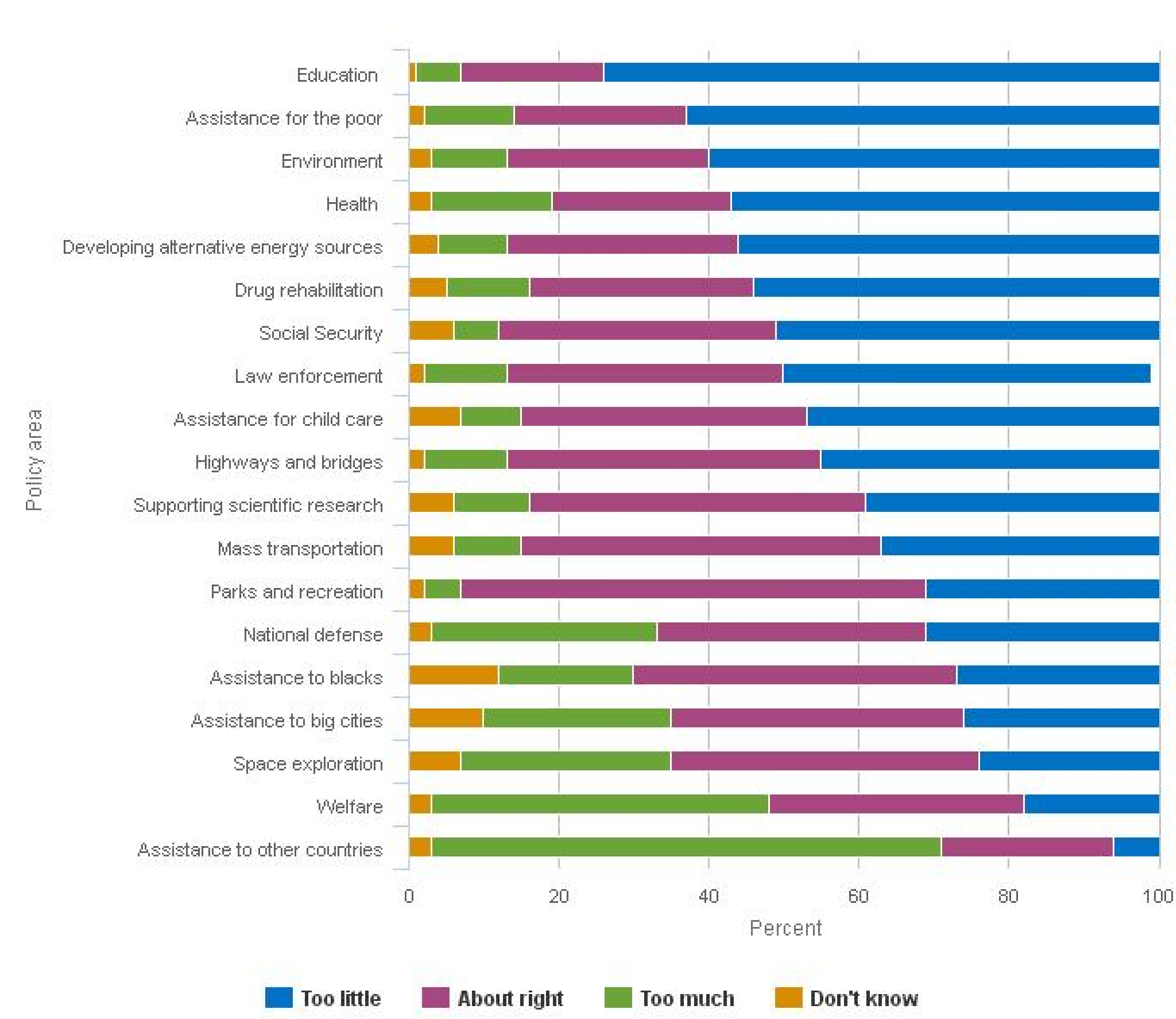
[i] This type of survey question asks respondents about their assessment of government spending in several areas without mentioning the possible negative consequences of spending (e.g., higher taxes, less money available for higher-priority expenditures). A question that focused respondents' attention on such consequences might yield response patterns less sympathetic to greater government funding.

Figure 7-16

Public attitudes toward government spending in various policy areas: 2014



NOTE: Responses to *We are faced with many problems in this country, none of which can be solved easily or inexpensively. I'm going to name some of these problems, and for each one I'd like you to tell me if you think we're spending too little money on it, about the right amount, or too much.*

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2014). See appendix table 7-21.

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International Comparisons

Citizens of many other countries have also generally expressed strong support for spending on scientific research. In 2010, 72% of Europeans and 77% of Chinese agreed that scientific research should be supported even in the absence of immediate benefits (European Commission 2010a; CRISP 2010). A 2013 survey of Canadians similarly found that 76% of respondents said they thought government should support scientific research (CCA 2014). Levels of agreement in South Korea, Malaysia, Japan, and Brazil have also been similar to those in the United States and Europe (NSB 2012).

According to a 2014 Eurobarometer survey, Europeans also think that scientific and technological innovation will have positive impacts in the coming years in a range of policy domains. These include health and medical care (65%), education and skills (60%), transportation (59%), energy (58%), environmental protection (57%), climate change (54%), and housing (50%). Optimism was consistently higher in those who said they had studied S&T (European Commission 2014). In South Korea in 2012, 29% of respondents said they thought that the government and industry needed to invest more in S&T research; this percentage has fallen from 37% in 2008 and 35% in 2010 (KOFAC 2013). The South Korean survey asked about S&T topics only.

Confidence in the Science Community's Leadership

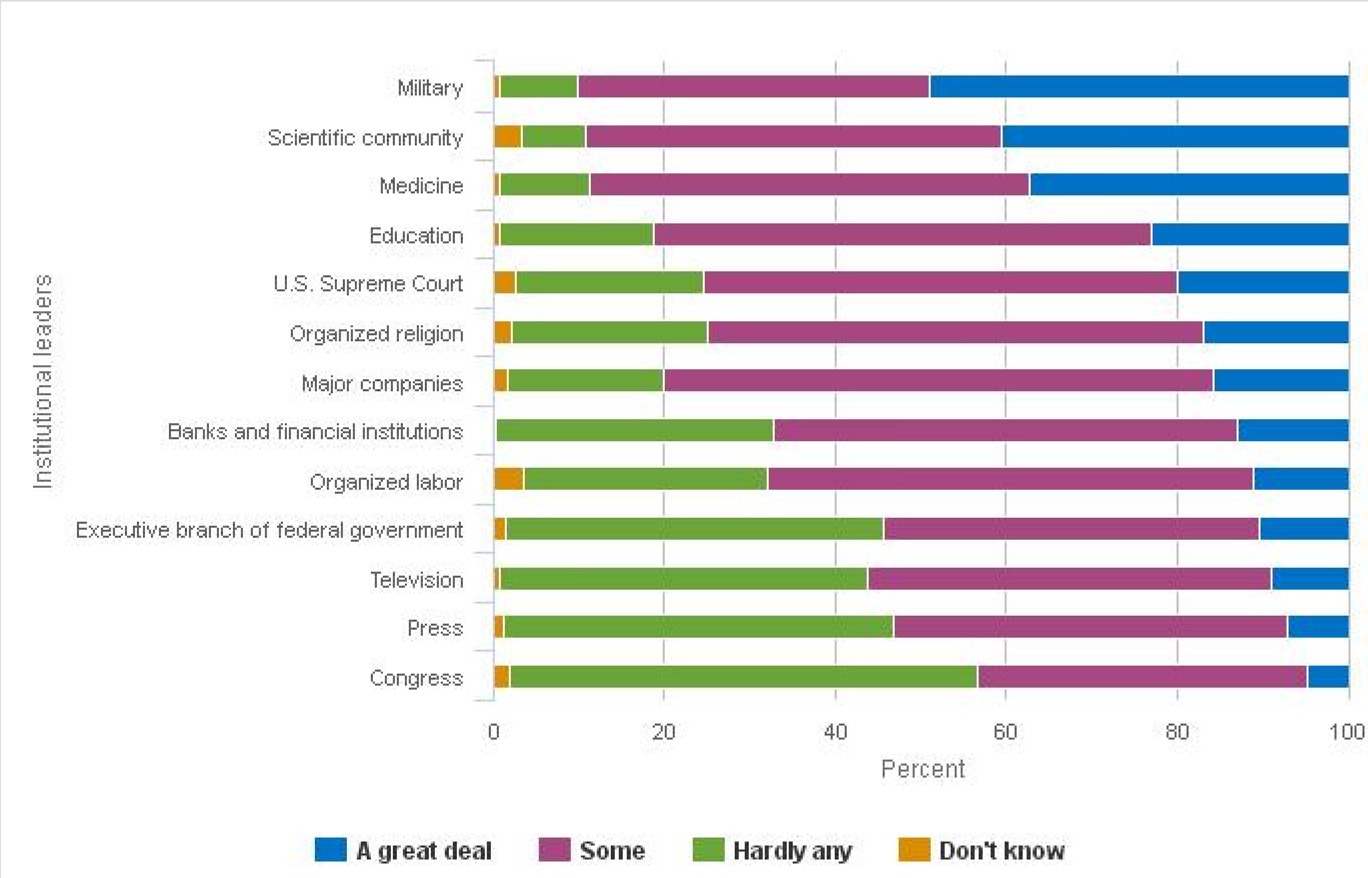
U.S. Patterns and Trends

Few members of the public have the background knowledge or resources to fully evaluate evidence related to scientific questions in the public sphere. People, therefore, often rely on how they perceive decision makers and other cues as decision aids (Fiske and Dupree 2014). Public confidence in leaders of the scientific community can therefore affect public acceptance of findings and conclusions based on scientific research.

Since 1973, the GSS has tracked public confidence in the leadership of various institutions, including the scientific community. The GSS asks respondents whether they have “a great deal of confidence,” “only some confidence,” or “hardly any confidence at all” in the leaders of different institutions. In 2014, 41% of Americans expressed “a great deal of confidence” in leaders of the scientific community, 49% expressed “only some confidence,” and 8% expressed “hardly any confidence at all” (Figure 7-17). These results are nearly identical to 2012 and are similar to previous years (NSB 2014). In general, men (45%) are more confident in the scientific community than women (37%). Also, those with more education and income are more confident than those with less, and young respondents are more confident than older respondents (Appendix Table 7-22). Some recent research suggests that political views are increasingly related to confidence in science (Gauchat 2012; McCright et al. 2013).

Figure 7-17

Public confidence in institutional leaders, by type of institution: 2014



NOTE: Responses to *As far as the people running these institutions are concerned, would you say that you have a great deal of confidence, only some confidence, or hardly any confidence at all in them?*

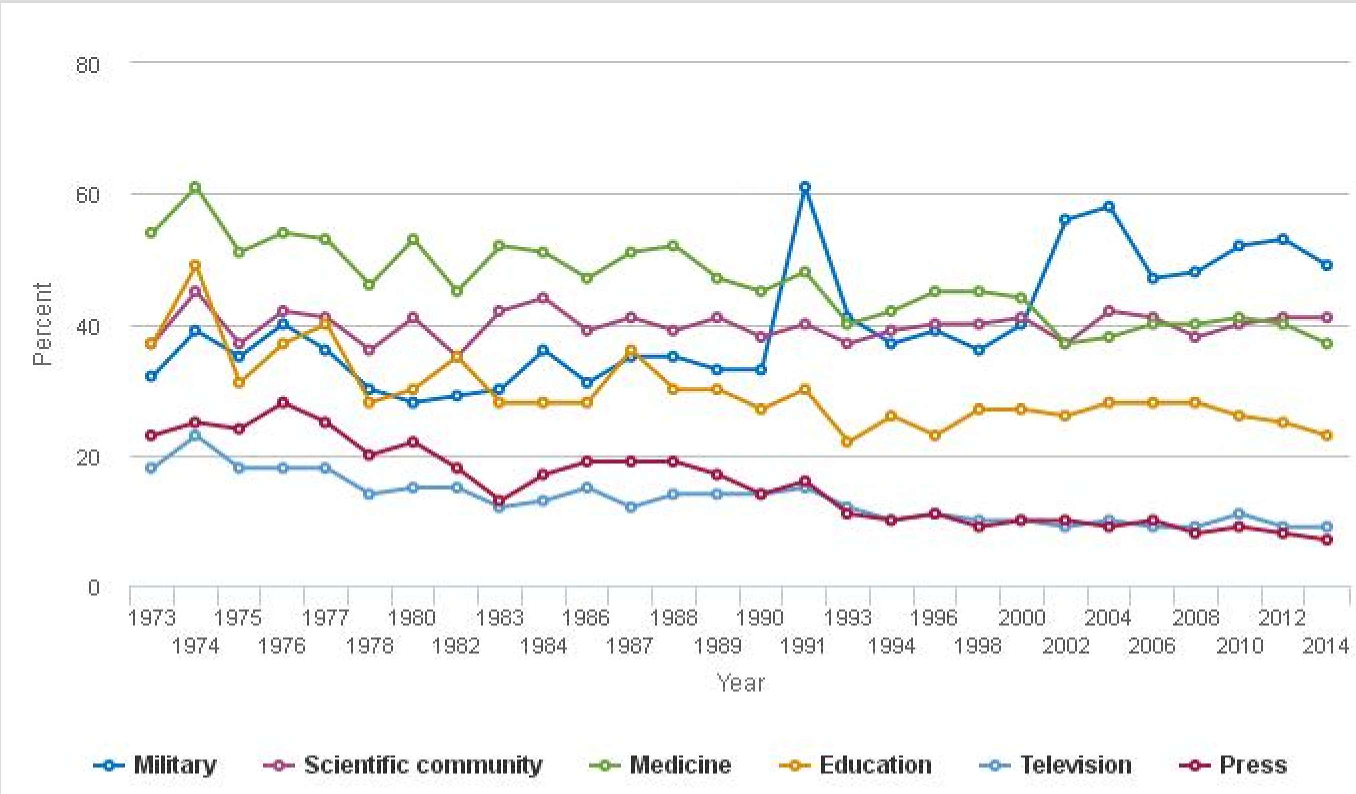
SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (2014). See appendix table 7-23.

Science and Engineering Indicators 2016

These results also suggest that leaders of the scientific community compare well with leaders of other institutions in America. Only military leaders held greater public confidence in 2014, with 49% of Americans saying they had a "great deal of confidence" in them (Figure 7-18). In recent years, the percentage of Americans who express high levels of confidence in the scientific community (41%) has also remained similar to the percentage of Americans who have high confidence in the medical community (37%). However, whereas the percentage of Americans saying they place a "great deal of confidence" in the scientific community has been relatively stable since the 1970s, the percentage saying this about the medical community has fallen from consistently above 50% in the 1970s and 1980s to 37% in 2014 (for a discussion, see Zheng forthcoming) (Appendix Table 7-23).

Figure 7-18

Public confidence in institutional leaders, by selected institution: 1973–2014



NOTE: Responses to *As far as the people running these institutions are concerned, would you say that you have a great deal of confidence, only some confidence, or hardly any confidence at all in them?* Figure shows only responses for "a great deal of confidence."

SOURCE: University of Chicago, National Opinion Research Center, General Social Survey (1973–2014). See appendix table 7-23.

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The GSS results are mostly consistent with a Pew Research Center (2013b) survey that showed that military leaders were the group that Americans were most likely to say contribute “a lot” to society (78%). Teachers were the second highest ranked (72%), followed by medical doctors (66%), scientists (65%), and engineers (63%). Americans were least likely to view lawyers (18%), business executives (24%), and journalists (28%) as contributing “a lot” to society. The survey also noted that opinions about most groups became less positive between 2009 and 2013, although this pattern was not universal. The percentage of Americans saying that scientists contribute “a lot” dropped somewhat from 70% to 66%, and medical doctors dropped from 69% to 66%. In contrast, engineers stayed essentially the same.

A later 2014 Pew Research Center (2015b) survey similarly found that most Americans think their country’s scientific achievements are relatively special, with 15% labeling them as among the “best in the world” and 39% labeling them as “above average”—that is, 54% viewed these achievements as at least “above average.” The military was again the only group seen more positively, with 76% seeing it as at least “above average” in the world. The quality of available “medical treatment” was ranked similarly to science—51% saw it as at least “above average.” The overall “healthcare” system, however, was ranked more poorly, with only 25% considering it as at least “above average.” Similarly, only about one-third of Americans rated America’s kindergarten through grade 12

(K–12) "science, technology, engineering, and math" (STEM) education "best in the world" (7%) or "above average" (22%). In all cases, these numbers declined from those in a 2009 survey. A companion survey of scientists found that scientists were much more likely than the general public to see America's scientific research as good, with 92% ranking it at least "above average." Scientists were also less likely to consider America's K–12 STEM education as successful, with just 16% ranking it as at least "above average."

International Comparisons

The 2013 special Eurobarometer on S&T examined views about scientists by asking residents to select up to three types of people from a list that they considered as "best qualified to explain the impact of scientific or technological development." University and government scientists (66%) were the most frequently selected group in every country, followed by corporate scientists (35%). Other groups were selected less frequently, including environmental protection associations (21%), television journalists (20%), consumer organizations (20%), medical doctors (19%), and newspaper journalists (15%). Near the bottom of the list were groups such as industry (9%), politicians (4%), and the military (3%). In Europe, perceptions about the top-ranked groups varied substantially by country. University and government scientists ranged from a high of 92% in Cyprus to a low of 54% in Portugal and 55% in Hungary. Similarly, corporate scientists ranged from a high of 57% in Cyprus to a low of 19% in Hungary. For environmental groups, the range was between 29% (Sweden) and 9% (Poland and Lithuania) (European Commission 2013).

Levels of reported trust varied in two Asian surveys that used different questions. A 2012 South Korean survey found that 36% "strongly agreed" or "agreed" that scientists can always be trusted (KOFAC 2013). In contrast, a 2011 survey in Japan found that 69% of respondents said scientists could be trusted or "somewhat trusted." Even more respondents (77%) said engineers could be trusted (NISTEP 2012).

Public Attitudes about Specific S&T-Related Issues

In addition to general views about S&T, people also develop views about specific issues and topics, and these views can shape behavior. Such specific attitudes are often based on general attitudes and knowledge, but this is not always the case. In the current context, attitudes about emerging areas of research and new technologies may influence innovation activity in important ways. For example, the climate of opinion about research areas such as biotechnology, energy, or other topics can shape public and private investment in these areas. Ultimately, such views might affect the individual or societal adoption of new technologies and the growth of industries based on these technologies.

Nevertheless, public opinion about new S&T developments rarely translates directly into actions or policy. Instead, institutions attempt to assess what the public believes and may magnify or minimize the effects of divisions in public opinion on policy (Jasanoff 2005). It is noteworthy that the public's attitudes about specific S&T issues such as climate change and biotechnology can differ markedly from the views of scientists (Pew Research Center 2015b). This is partly because attitudes toward S&T involve a multitude of factors, not just knowledge or understanding of the relevant science. Values, attitudes, and many other factors come into play, and judgments about scientific facts may become secondary or even shaped by those values or attitudes (Kahan, Jenkins-Smith, and Braman 2011).

This section describes views on environmental issues, including global climate change, nuclear power, and energy development; GE food; nanotechnology; synthetic biology; cloning and stem cell research; and teaching evolution in schools. It concludes with recent data on attitudes toward scientific research on animals and toward STEM education. As with the rest of *Indicators*, the focus is on descriptive statistics for key indicators, including trends and between-group differences. Where appropriate, academic research on the origins of opinions or their effects is cited to provide context.

Environment

Environmental issues—especially climate change and energy technologies—are often the subject of public policy debate and news interest. A review of general public views about the environment, specific environmental issues, energy technologies, and climate follows.

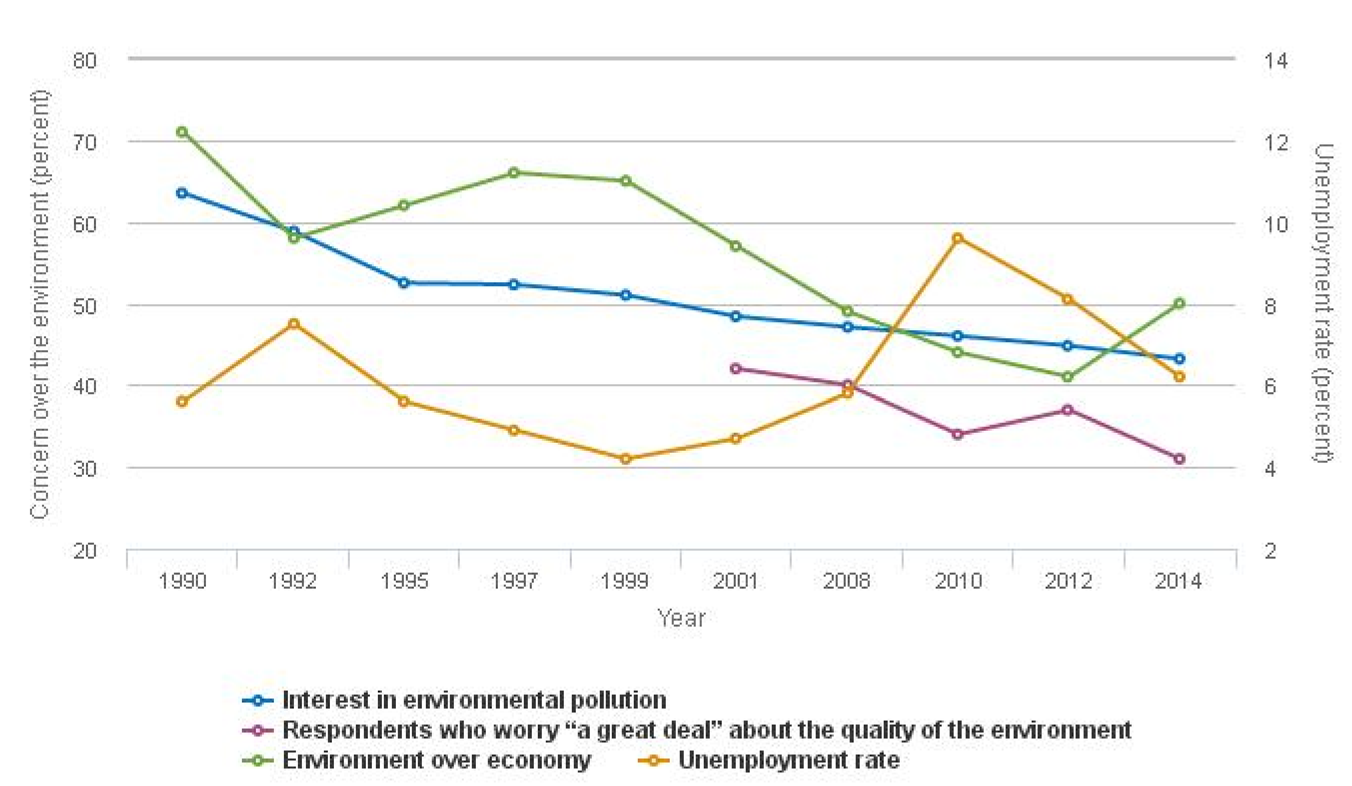
Overall Concern about Environmental Quality

U.S. patterns and trends. Annual Gallup surveys show that pro-environmental attitudes may be at a relative low point compared with historical averages. Nevertheless, environmental issues remain important to many Americans, with about half of the respondents expressing concern about the current state of the environment in the various questions discussed subsequently.

The proportion of Americans who say that they worry "a great deal" about the quality of the environment was at 34% in 2015 (Gallup 2015a), up slightly from the low point of 31% in 2014, but still low compared with other years since 2001 (Figure 7-19). As noted previously, the 2014 GSS also found that interest in environmental pollution is at a relative low, with 43% saying they are "very interested" in the subject in 2014, compared with 63% in 1990.

Figure 7-19

Relation between the economy and concern over the environment: 1990–2014



NA = not available; question not asked.

NOTES: Responses to the following:

• *There are a lot of issues in the news, and it is hard to keep up with every area. I'm going to read you a short list of issues, and for each one I would like you to tell me if you are very interested, moderately interested, or not at all interested.* Figure shows only responses for "very interested."

• *How much do you personally worry about the quality of the environment: a great deal, a fair amount, only a little, or not at all?* Figure shows only responses for "a great deal." Poll conducted annually in March.

• *With which one of these statements about the environment and the economy do you most agree: protection of the environment should be given priority, even at the risk of curbing economic growth (or) economic growth should be given priority, even if the environment suffers to some extent?*

SOURCES: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (1990–2001); University of Chicago, National Opinion Research Center, General Social Survey (2008–14); Gallup, Climate Change: Environment, http://www.gallup.com/poll/1615 /environment.aspx#, accessed 10 August 2015; Bureau of Labor Statistics, Local Area Unemployment Statistics (various years).

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At the same time, however, Gallup data indicate that the proportion of Americans who say that the environment should be given priority over economic growth increased to 50% in 2014 and 46% in 2015 from a low of 36% in 2011. This is still below previous highs of 57% (2001) and 55% (2007) (Gallup 2015a). A similarly worded 2014 *New York Times*/CBS poll put the proportion choosing the environment at 58% (Dutton et al. 2014). The proportion who rated the country's environment as "only fair" (40% in 2015) or "poor" (9% in 2015), who think the country's environment is "getting worse" (51% in 2015), and who think the U.S. government does "too little" to protect the environment (48%) was either similar or down slightly in 2015 relative to recent years. This was, however, a decrease from higher levels of concern in the middle of the previous decade (i.e., 2007 and 2008) (Gallup 2015a).

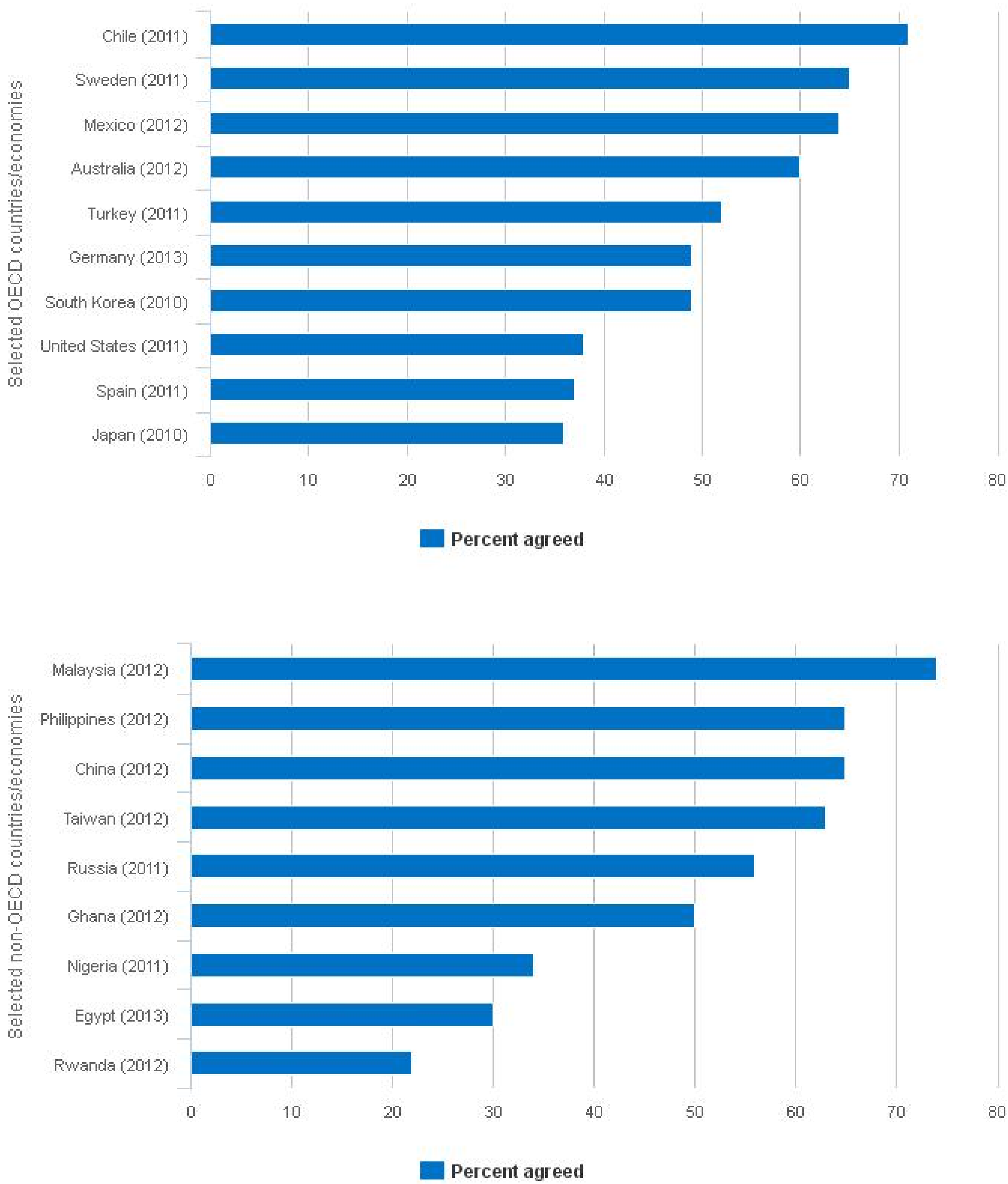
A series of Pew Research Center (2014b) surveys suggests a similar pattern of concern. Biennial pre-election surveys show that the proportion of respondents saying that "the environment" should be a "very important" election issue started at 55% in 2004 and climbed to a high of 62% in 2008 before falling back to 54% before the 2014 midterm election. This, nevertheless, put the environment relatively low on the list of issues about which respondents were asked. The economy (83%) and health care (77%) topped the list of issues that people said were important to them in the election.

Finally, although these numbers indicate that about half of Americans say they would choose the environment over the economy, recent polling consistently finds that less than 2% of respondents name the environment as the most important issue facing the nation when allowed to say what they think the most important problem facing the nation is in their own words. The economy, in contrast, is mentioned much more often. For example, 25% chose the economy or jobs as the most important problem in one recent survey focused on global warming (e.g., Dutton et al. 2014; see also Gallup 2015b).

International comparisons. The 2010–14 WVS allows for comparisons among countries and highlights wide variations in views around the globe. These data suggest that, in 2011 (the year Americans completed the WVS), about 38% of Americans said that "protecting the environment" should be a priority over economic growth (Figure 7-20) (WVS 2014). This was less than the average of 50% for the 50 countries included in the survey. Within the OECD, residents of Chile (71%), Sweden (65%), and Mexico (64%) were most inclined to give priority to the environment. Beyond the OECD, Malaysia (74%) and Uruguay (70%) were among the most likely to prioritize the environment. It should also be noted that, according to Gallup (2015a), the U.S. WVS data collection appears to have occurred at a point at which Americans were relatively less likely to choose the environment over economic growth.

Figure 7-20

Choose the environment over economic growth, by selected country/economy: Most recent year



OECD = Organisation for Economic Co-operation and Development.

NOTES: Respondents were asked to indicate which of two responses "comes closer to" their "own point of view." These were: *Protecting the environment should be given priority, even if it causes slower economic growth and some loss of jobs* and *Economic growth and creating jobs should be the top priority, even if the environment suffers to some extent*. Some respondents also volunteered a different answer.

SOURCE: World Values Survey, WVS Wave 6 (2010–14), http://www.worldvaluessurvey.org/WVSDocumentationWV6.jsp, accessed 17 February 2015.

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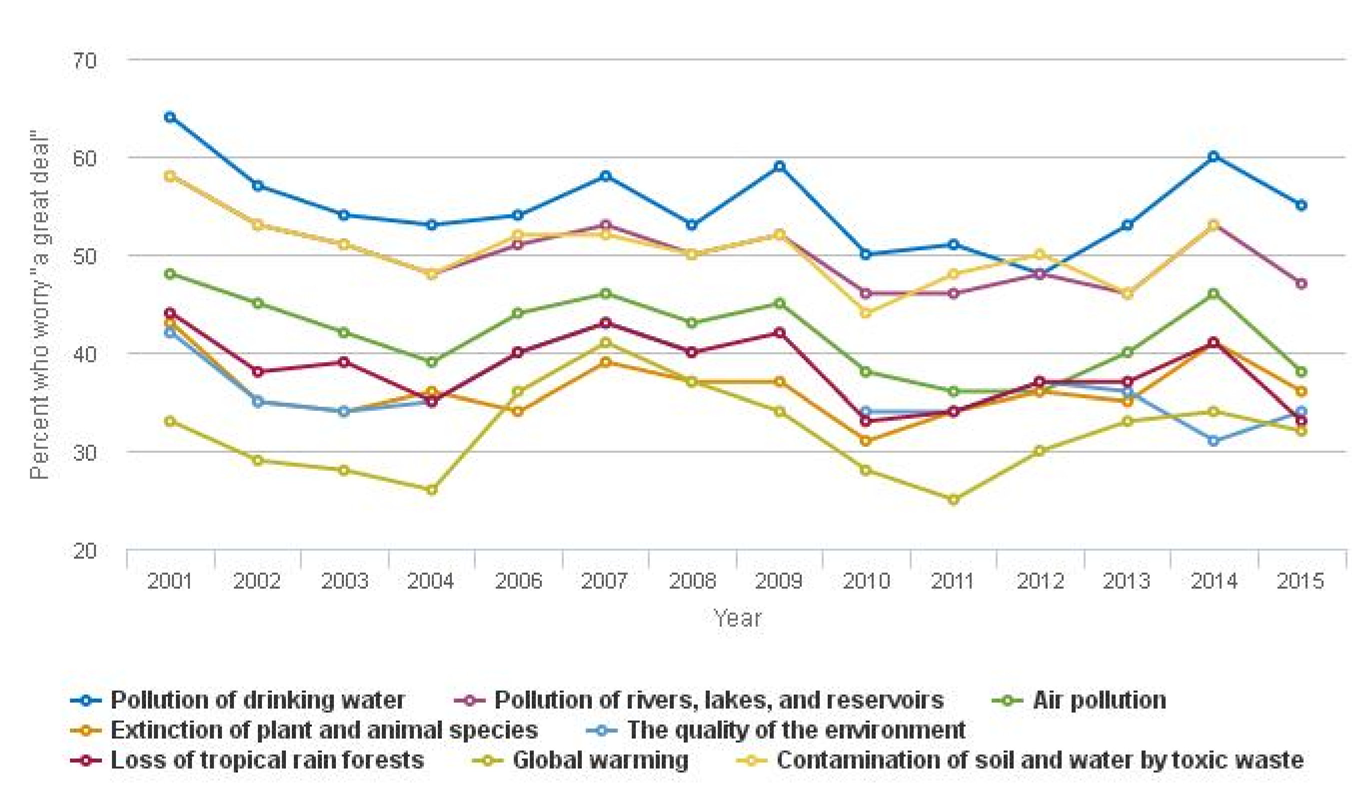
Within Europe, a 2014 Eurobarometer survey on the environment included a broad range of questions about attitudes and behavior. Overall, 95% of Europeans said that "protecting the environment" was "very important" (53%) or "fairly important" (42%), similar to 2011 (94%). About three-quarters of respondents (77%) also indicated that they "totally agreed" (35%) or "tend(ed)" to agree that "environmental issues have a direct impact" on their daily life. This was also stable from 2011 when 76% agreed. Respondents in southern European countries have the highest proportion of citizens with concerns about direct impacts. For example, residents of Cyprus (95%), Greece (93%), and Malta (90%) were the most likely to say they see an impact of environmental issues on their lives, whereas the least likely were residents of relatively affluent countries in Northern and Western Europe, including Denmark (56%), Austria (66%), the Netherlands (66%), Belgium (67%), and Germany (68%) (European Commission 2014). Although somewhat different from the Gallup and WVS questions that focused on overall economic versus environmental priorities, 59% of European respondents said that "public authorities" should favor "environmentally-friendly considerations over cost considerations" when "thinking about spending and investment." Respondents in Slovenia (78%) and Cyprus (76%) were the most likely to prioritize the environment, whereas those in Poland (36%) and Romania (44%) were the least likely (European Commission 2014).

Assessment of Specific Environmental Problems

U.S. patterns and trends. Gallup (2015a) also asks about a wide range of specific environmental concerns as part of its annual survey on the environment. The 2015 data suggest a sharp drop in concern from the relatively high rates in 2014. This drop brings levels of concern back to where they have been in recent years but below historical averages. As in most previous years, drinking water pollution topped the list of issues about which Americans were most likely to "worry" a "great deal" about (55%) in 2015. Worry was also relatively high for "pollution of rivers, lakes, and reservoirs" (47%) (Figure 7-21). Smaller proportions expressed a "great deal" of worry about "air pollution" (38%), "extinction of plant and animal species" (36%), and the "loss of tropical rainforests" (33%). Americans expressed relatively low levels of concern about "global warming" (32%), a topic discussed in more detail subsequently. Within the available data, worry about environmental problems was greatest in 2000 and then fell and rose through the previous decade, reaching low points for most measures in about 2010 or 2011. Worries about different issues tend to move together.

Figure 7-21

Concern about specific environmental issues: 2001–15



NOTES: Responses to *How much do you personally worry about [specific environmental issues]: a great deal, a fair amount, only a little, or not at all?* Figure shows only responses for "a great deal." Poll conducted annually in March.

SOURCE: Gallup, Climate Change: Environment, http://www.gallup.com/poll/1615/environment.aspx# , accessed 2 August 2015.

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International comparisons. The 2014 Eurobarometer on the environment asked respondents to indicate the 5 "main" environmental issues that they were "worried about" from a list of 14. Although water pollution was the issue most worried about in the United States, "air pollution" (56%) was the most commonly named issue in Europe. In Europe, "air pollution" was followed by "water pollution" (50%), "the growing amount of waste" (43%), the health impact of "chemicals used in everyday products" (43%), and the "depletion of natural resources" (36%). Climate change was not included on the list because it was the focus of a separate report earlier in 2014.

Climate Change

U.S. Patterns and Trends

Climate change (often referred to as *global warming, especially in past decades*) remains a central, and often divisive, environmental issue for the American public. The importance of this issue to national and international debates means that it has also been the subject of widespread polling over more than two decades.[i]

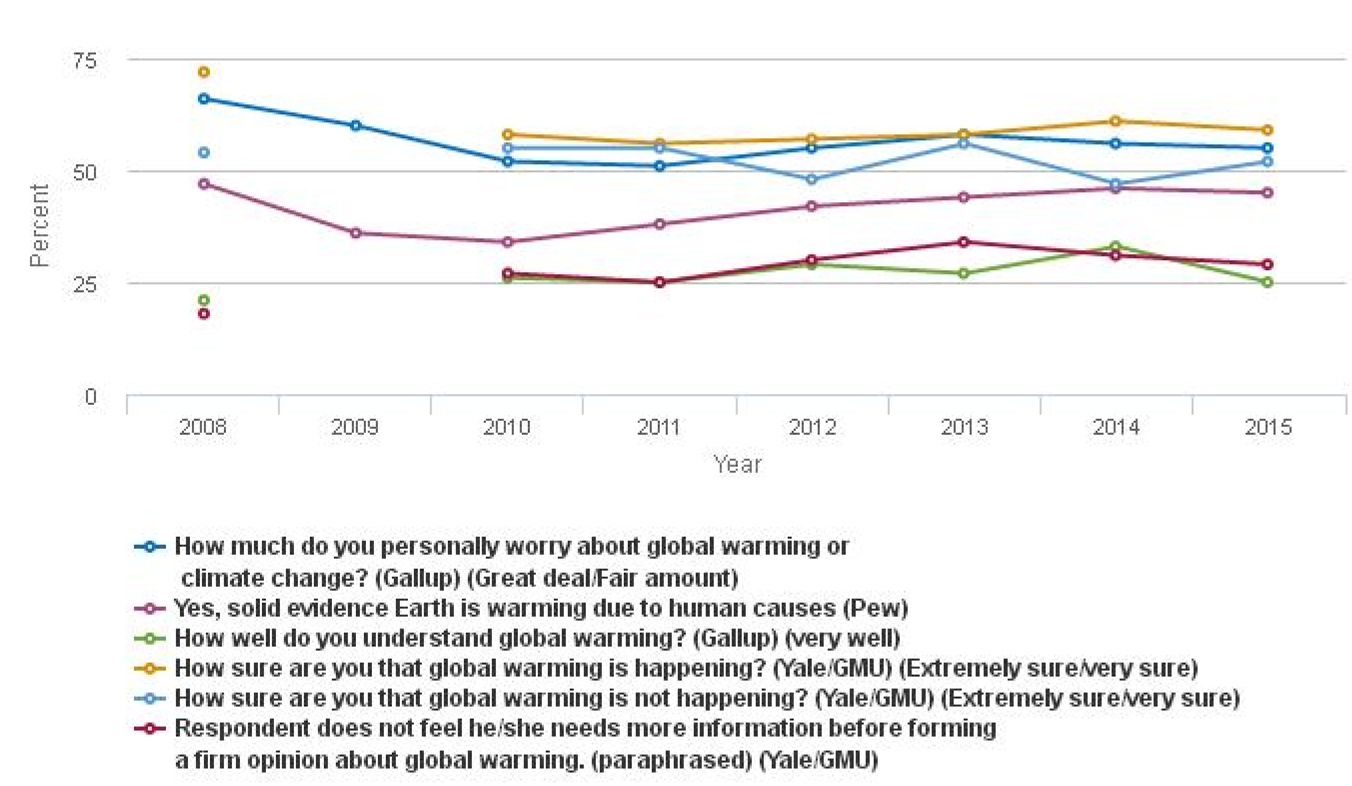
Gallup has polled on "global warming" since 1989, when it found that 63% of Americans worry a "great deal" (35%) or a "fair amount" (28%) about the issue (Saad 2015). In March 2015, the comparable statistic was 55%

(including 32% who worry a "great deal" and 23% who worry a "fair amount") (Figure 7-22). This indicator has fluctuated between a low of 51% (2004) and a high of 66% (2008) since 2001. Also, although more than half of Americans may say they worry about global warming, slightly more than one-third (37%) told Gallup in 2015 that they believed "global warming would pose a serious threat" to their "way of life" during their lifetime. As with the question about "worry," responses to this question have fluctuated over time, although it has stayed between 31% (2001) and 40% (2008) since 2001 (Jones 2014). Data from other sources show similar fluctuations. Researchers at Yale and George Mason University placed worry at 52% in early 2015 (Leiserowitz et al. 2015), whereas a survey from the *New York Times* and Stanford University (2015) indicated that 44% see "global warming" as a "very serious" future problem for the United States. Another 34% (78% in total) responded that the threat was at least "somewhat serious." Even more respondents (83%) said they thought global warming would be a threat to "the world."

[i] There is some evidence from a large-scale experimental study that the wording used in such questions ("global warming" or "climate change") can have an effect on reported beliefs about global climate change (Schuldt, Konrath, and Schwarz 2011). Other studies, however, suggested that such wording differences have limited effect (Dunlap 2014; European Commission 2008; Villar and Krosnick 2010).

Figure 7-22

Belief in global warming and confidence in that belief: 2008–15



NA = not available, question not asked.

GMU = George Mason University.

NOTE: Dots indicate years with data.

SOURCES: Pew Research Center, *Public and Scientists' Views on Science and Society*, (2015), http://www.pewinternet.org/files/2015/01/PI_ScienceandSociety_Report_012915.pdf, accessed 25 March 2015; Pew Research Center, *Catholics Divided Over Global Warming,* (2015), http://www.pewforum.org/files/2015/06/Catholics-climate-change-06-16-full.pdf, accessed 11 August 2015; Gallup, Climate Change: Environment, http://www.gallup.com/poll/1615/environment.aspx#, accessed 17 January 2015; Leiserowitz A, Maibach E, Roser-Renouf C, Feinberg, G, and Rosenthal S, Climate Change in the American Mind: *March, 2015*. Yale University and George Mason University (2015), https://environment.yale.edu/climate-communication/files/Global-Warming-CCAM-March-2015.pdf, accessed 11 August, 2015.

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The Yale/George Mason work from 2014 also showed that about one-third (36%) of Americans said they believed that climate change would personally hurt them, 42% said they thought harm would come to their family, 43% said their community, 53% said other Americans or people in other industrialized countries, and 55% said people in developing countries (Leiserowitz et al. 2014). Researchers who study risk perceptions have long known that people often optimistically see risks as more likely to harm others than themselves (Spence, Poortinga, and Pidgeon 2012).

Many Americans also indicate that they believe in climate change but do not believe humans are exclusively to blame. Among Americans who believe the Earth is getting warmer, the survey from the *New York Times* and Stanford (2015) showed that about 40% said they believed it was because of “things people did,” whereas 18% thought the cause was natural. An additional 41% said they thought both human and natural processes deserved equal blame. June 2015 research by the Pew Research Center (2015c) without a "both" response option showed that 45% blame the climate change "mostly" on "human activity such as burning fossil fuels" (Figure 7-22), 18% believed that "mostly" "natural patterns" are the cause of the changes, and 5% said they did not know the cause. Another 25% said they did not believe change was occurring. Overall, the Pew Research Center's data suggest that the percentage attributing perceived change to human activity reached a high of 50% in July 2006 but declined to a low of 34% in October 2010.

Existing surveys also suggest varying degrees of certainty about climate change. In 2015, the Yale/George Mason surveys showed that 63% believe that "global warming is happening," and of these, 59% are "extremely" (27%) or "very" sure (32%). Similarly, of the 18% who do not believe in "global warming," 52% are "extremely" (21%) or "very sure" (31%) of their views (Leiserowitz et al. 2015). However, in 2015, just a quarter (25%) of Americans said they understood global warming "very well" (Gallup 2015a). A similar small percentage (29%) of Americans indicated that they felt they had enough information on the subject "to form a firm opinion" and that they therefore did not "need any more" (Leiserowitz et al. 2015) (Figure 7-22).

Despite widespread concern, the Pew Research Center (2015d) also reports that "dealing with global warming" has been at or near the bottom of the public's priorities for the president and Congress since at least 2007. About 38% of Americans said it should be a priority in 2015, although this is up from a low of 25% in 2012 and similar to the previous high of 38% in 2007. Rather than ask about priorities, Yale/George Mason researchers asked about whose responsibility it was to act in 2015 and found that most Americans say they want key social actors to do more to address global warming (Leiserowitz et al. 2015). Specifically, 68% of Americans said they thought "corporations and industry" "should be doing much more" or "more," and large percentages also wanted more from members of Congress (59%), local government officials (56%), state governors (55%), and the president (52%).

Only a small majority of Americans say they believe that scientists have reached a consensus on climate change. Gallup, for example, reported that 60% of Americans said that "most scientists believe that global warming is occurring" in 2014 (Dugan 2014). Their research also shows that the percentage saying a consensus exists rose from 48% in 1998 to a high of 65% in 2006 and 2008 before falling again. Several other surveys report similar findings, with the Yale/George Mason researchers placing belief in consensus at 52% in the first half of 2015 (Leiserowitz et al. 2015) and the Pew Research Center placing belief in consensus at 57% in 2014 (Pew Research Center 2015b). All of this research suggests that reported belief in consensus is related to belief in the threat of climate change.

A review of high-quality longitudinal studies from around the world concluded that negative economic trends are the most likely driver of widespread declines in environmental concern, including climate change, that began in about 2007 after several decades of rising concern (Scruggs and Benegal 2012; Capstick et al. 2015). This research also noted that political trends may also have played a role in some cases. One piece of evidence pointing to the central role of the economy is that the declines in support of climate change occurred in both Europe and the United States, two regions that were hit hard by the 2007–08 financial crisis and its immediate aftermath but that did not share the same political trends (Scruggs and Benegal 2012). It is also clear, however, that political views continue to shape opinion about climate change in the United States (e.g., Hart, Nisbet, and Myers 2015).

International Comparisons

The most recent internationally comparable, representative data on public views about climate change suggest that Americans are relatively less concerned about the issue than residents of most other countries (Pew Research Center 2013a). For example, in 2013, 40% of Americans told the Pew Research Center that they thought "global climate change" was a "major threat" to the United States, in contrast to 54% of both Canadians and Europeans. The views of those in the United States were similar to the views of respondents in Middle Eastern countries surveyed, where 42% of respondents saw climate change as a major threat. Latin American respondents (65%) were the most concerned, whereas respondents in Asia (56%) and Africa (54%) had views similar to respondents in Europe and Canada (Pew Research Center 2013a).

Energy

U.S. Patterns and Trends

Public opinion about energy has fluctuated in recent years in response to accidents such as the 2010 *Deepwater Horizon* oil spill in the Gulf of Mexico; the 2011 nuclear accident in Fukushima, Japan; changing energy prices; and the emergence of issues such as hydraulic fracturing (sometimes termed *fracking*) as a technique to obtain natural gas. The range of energy events and issues, however, means that, although specific events may have short-term effects, consistent long-term trends in public opinion about energy are rare. Overall, it appears that 2014 saw increased support for alternative energy compared with recent years.

Gallup (2015a) reported that, in 2015, Americans were about equally divided over whether "protection of the environment should be given a priority, even at the risk of limiting the amount of energy supplies—such as oil, gas, and coal—which the U.S. produces" or whether the "development of U.S. energy supplies … should be given priority, even if the environment suffers to some extent." About 49% of respondents chose the environment in 2015, up from a low of 41% in 2011. Environment was chosen by the highest percentage of respondents in 2007 (58%).

Gallup respondents were also previously asked how they thought the country should deal with "the nation's energy problems" and then were asked to choose between emphasizing production of "oil, gas and coal supplies" or "conservation by consumers." The percentage choosing to "emphasize conservation" rose to 57% in 2014 after hovering between 48% and 51% since 2010. The year in which the highest percentage of Americans chose conservation was also 2007 (64%) (Moore and Nichols 2014). An alternative question asked respondents to choose between fossil fuel production and "the development of alternative energy such as wind and solar power." With this question, Gallup found that 64% of Americans chose alternative energy in 2014, up from 59% in both 2012 and 2013 but similar to the 66% who chose alternative energy in 2011. A similar question asked by the Pew Research Center in recent years found that prioritizing alternative energy sources such as "wind, solar, and hydrogen" started at 63% in 2011 and then dipped to 47% in 2012 before climbing back to about 60% in late 2014, having reached a high of 65% in early 2014 (Pew Research Center 2014a).

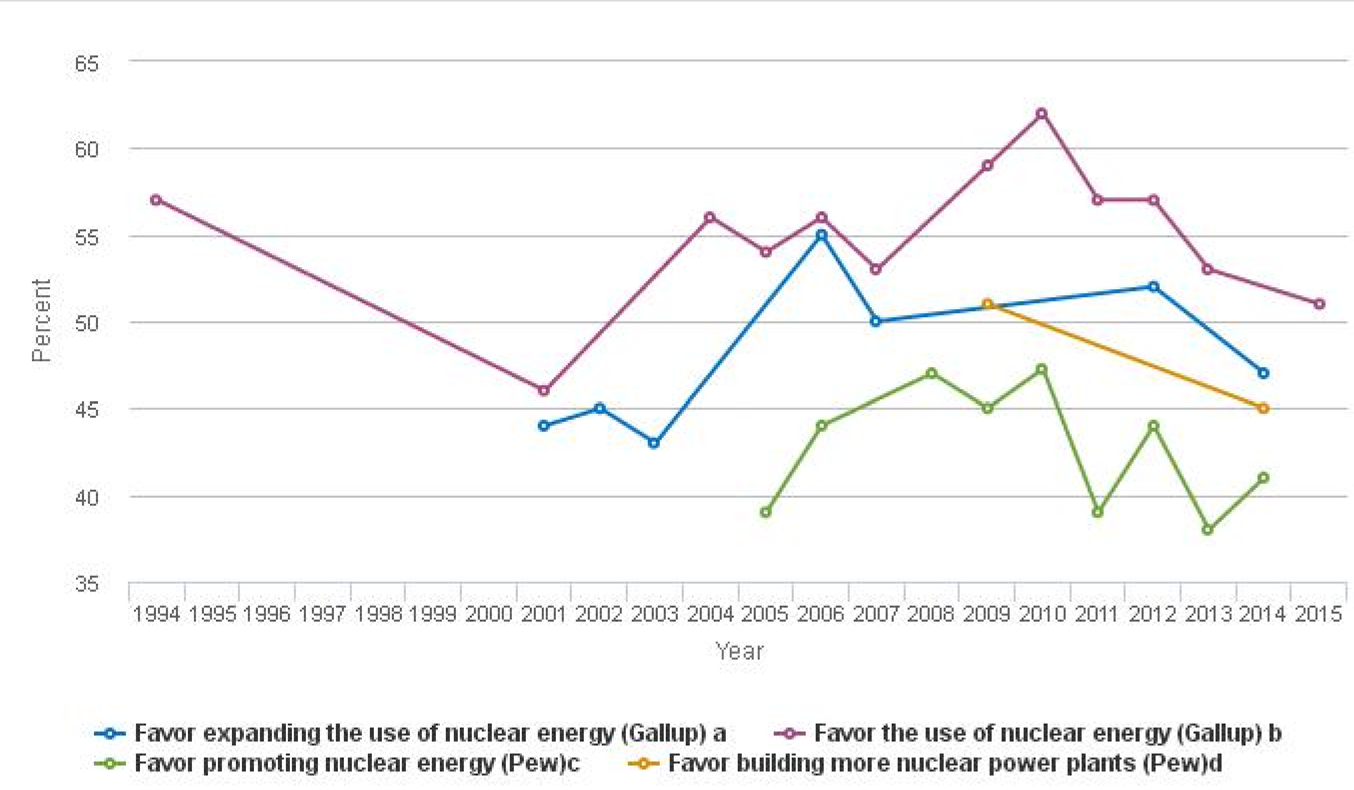
Alternative energy and conservation also do well when comparing questions that ask about specific energy options. For example, 81% of Americans favored "better fuel efficiency standards for cars, trucks, and SUVs" in 2014 (Pew Research Center 2014a), and 81% "strongly" (36%) or "somewhat" (45%) supported the need to "fund more research" on renewables in 2015 (Leiserowitz et al. 2015). The same study found that support for "tax rebates" for "energy efficient vehicles or solar panels" was equally high (80%) and that most Americans (67%) would support requiring utilities to produce a fifth of their electricity from renewable sources even if it cost consumers more (Leiserowitz et al. 2015). Gallup (Riffkin 2015) also found that many Americans would like to put "more emphasis" on "solar power" (79%) and "wind" energy (70%).

As in recent years, about half of Americans supported the use of nuclear energy in recent data (Figure 7-23). Gallup (2015a) reports that 51% of Americans said they "strongly" or "somewhat" favored nuclear energy in 2015. Support reached a high of 62% in 2010, just before the 2011 Fukushima Daiichi nuclear accident in Japan and has declined steadily since. A survey by the Pew Research Center (2014a) shows a similar decline. This search put the level of support for "promoting nuclear energy" at 41% in 2014 (down from a high of 52% in 2010, before

Fukushima, in surveys using the same question). A later 2014 survey found that 45% of Americans "favor building more nuclear power plants to generate electricity," down from 51% in 2009 in a survey using the same question (Pew Research Center 2015b). Gallup (2015a) found that only about one-third (35%) of Americans said the government should put "more emphasis" on nuclear energy. A 2014 Pew Research Center (2015b) survey of members of the scientific community found, in comparison, that 65% of scientists favored building new nuclear power plants (down from 70% in 2009).

Figure 7-23

Views on nuclear energy: 1994–2015



[a] Responses to *I am going to read some specific environmental proposals. For each one, please say whether you generally favor or oppose it. How about [e]xpanding the use of nuclear energy?*

[b] Responses to *Overall, do you strongly favor, somewhat favor, somewhat oppose, or strongly oppose the use of nuclear energy as one of the ways to provide electricity for the U.S.?* Figure shows combined responses for "strongly favor" and "somewhat favor".

[c] Responses to *As I read some possible government policies to address America's energy supply, tell me whether you would favor or oppose each. [W]ould you favor or oppose the government promoting the increased use of nuclear power?* The 2010 data point is the average of responses to four surveys conducted that year. The 2011 data point is the average of responses to two survyes conducted that year.

[d] Responses to *Do you favor or oppose building more nuclear power plants to generate electricity?*

SOURCES: Gallup, Social Series: Environment, http://www.gallup.com/file/poll/168221/Energy_I_140402.pdf, accessed 28 May 2015; Gallup, Business: Energy, http://www.gallup.com/poll/2167/energy.aspx, accessed 28 May 2015; Pew Research Center, *December 2014 Political Survey*, http://www.people-press.org/files/2014/12/12-18-14-Energy-topline-for-release.pdf, accessed 28 May 2015; Pew Research Center, *General Public Science Survey, August 15-25, 2014, http:/ /www.pewinternet.org/files/2015/07/2015-07-01_science-and-politics_TOPLINE.pdf,* accessed 28 May 2015.

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When it comes to fossil fuels, natural gas is clearly preferred over other options. According to Gallup (2015a) research, 55% said they would like to put more emphasis on this area, whereas only 41% wanted more attention to oil and 28% wanted more attention to coal. A Pew Research Center survey (2014a) found that about 56% of Americans would like to allow more "offshore oil and gas drilling." This percentage is similar to 2013 (58%), but the number has gone up and down several times since the question was first asked in 2008, reaching a high of 68% in 2009 and a low of 44% in 2010 after the *Deepwater Horizon* spill in the Gulf of Mexico. A separate 2014 set of science-focused surveys by the Pew Research Center (2015b) similarly found that 52% of Americans say they "favor" "offshore oil and gas drilling in U.S. waters," whereas 32% of members of the scientific community say they favor obtaining fossil fuels in this way.

One related subject that has received only limited polling attention but that is often in the news is the use of hydraulic fracturing, or "fracking," to help release natural gas from otherwise inaccessible deposits. Surveys by the Pew Research Center (2015b) found that the percentage of Americans who "favor" fracking declined from 48% in early 2013 to 44% in fall 2013 and then dropped again to 39% in mid-2014. A companion survey of members of the scientific community found that only 31% favored fracking. The Yale/George Mason researchers also conducted a fall 2012 survey and found that most Americans knew nothing (39%) or only "a little" (16%) about fracking. Most respondents (59%) who had heard something thought it was likely more "bad" than good. In contrast, however, 58% of all respondents said they did not know or were undecided as to whether they supported or opposed fracking. About one-fifth, "strongly" (10%) or "somewhat" (10%) opposed the use of fracking (Clarke, Boudet, and Bugden 2013).

International Comparisons

The European Commission (2013) conducted a short Eurobarometer on air pollution in 2012 that found broad support for renewable energy. The survey asked Europeans which "energy options" ought to be prioritized over the "next 30 years" and allowed up to two answers. Most (70%), however, chose only "renewable energy sources." The second highest was "energy efficiency" (26%), followed by nuclear energy (18%). A small number of Europeans said they thought the priority should be on producing natural gas from unconventional sources (i.e., fracking) (9%) or producing more conventional fossil fuels (8%). These responses varied widely across countries. For example, 82% of Portuguese respondents mentioned renewables, but only 45% of Bulgarians did so. Similarly, 44% of Czech respondents chose nuclear energy, whereas just 4% of Austrian and Cypriot respondents mentioned this potential priority. Prioritization of unconventional natural gas exploration was highest in Poland (32%) and lowest in Italy, Finland, and Sweden (all 3%). Conventional fossil fuel was mentioned most often in Latvia (19%) and least often in Sweden (3%).

The 2014 version of *Indicators* also reported the results of a 2010 international survey of a wide range of countries that suggested that the United States was relatively favorable toward nuclear energy (NSB 2014).

Genetically Engineered Food

U.S. Patterns and Trends

GE food—also sometimes called genetically modified (GM) food or genetically modified organisms (GMOs)—remains an active issue of public debate around the world as new products continue to enter the market. Some scholars point to the emergence of an anti-GE movement as something that proponents could have limited through better communication with the public during the early research and commercialization phases (Einsiedel and Goldenberg 2006). Surveys from across many years and studies, however, suggest that many Americans question the safety of genetic engineering of food, although it is not an issue on which there is evidence of substantial public knowledge.

Although there are limited national data from recent years, recent survey results are relatively consistent with findings from previous decades. A summary of surveys from the 1980s through 2000 (Shanahan, Scheufele, and Lee 2001) typically found that between one-third and one-half of Americans saw risks from genetic engineering, whereas a similar number saw benefits. This summary also found that few people felt that they knew a lot about the subject but that there was, nevertheless, broad support for labeling GE food.

Consistent with these past findings, a 2014 survey by the Pew Research Center (2015b) found that only 37% of Americans think that GE foods are "generally safe" to eat and only 28% think that "scientists have a clear understanding" of the "health effects of genetically modified crops." Similarly, a 2013 survey by the *New York Times* reported that 75% of Americans are "concerned" about the safety of GE foods (Kopicki 2013), and an ABC News survey found that 52% of Americans thought such foods were "unsafe" (Langer 2014).

There has also been active discussion on the question of how to address clear public opinion supporting mandatory labeling of food that contains GE ingredients despite arguments that such labeling would inappropriately suggest risks to buyers (McComas, Besley, and Steinhardt 2014). It seems clear, in this regard, that when directly asked, a substantial majority (93%) of Americans say they would like GE foods labeled, according to a 2013 poll for *The New York Times* (Kopicki 2013) and a similar 2014 poll for ABC News (Langer 2014).

It is also important to consider the limitations of the available data in this area. Given low knowledge, worldview and positive views about science and scientists (Frewer et al. 2013; McComas, Besley, and Steinhardt 2014) may play a central role in shaping views about genetic engineering. In other words, when many respondents answer questions about genetic engineering, they are likely reporting their general views about science or nature rather than fully answering based on consideration of genetic engineering. This recent research does not appear to have asked respondents how much they know about genetic engineering, although past work has tended to find that such knowledge is relatively low. For example, a 2001 survey found that only 13% said they had heard "a great deal" about the subject, and 47% said they had heard some. Another 29% said they heard "not much," and 11% said they had heard "nothing at all" (Hallman et al. 2002). The Pew Research Center (2015b) also reported that only 25% of Americans "always" look at labels to see whether food they are considering buying contains GE ingredients, and another 25% say they "sometimes" look. These responses, however, are difficult to reconcile with the fact that it is rare for products to include GE-related labels. Further, about 94% of U.S. soybeans and 93% of corn grown in the United States are genetically engineered (USDA 2014), and the products of both crops are used extensively in a wide variety of common food products. Also, several attempts to use referenda (e.g., in Colorado and Oregon in 2014) to require labeling of GE products have failed to receive enough votes to pass, although residents of one Hawaii county passed a ban on GE crops (Reuters 2014), and Vermont lawmakers passed a labeling law in 2014 (Strom 2014).

The reasons for using genetic engineering may also affect whether people report favorable views. When the Pew Research Center (2015b) asked about genetic modification to "create a liquid fuel replacement for gasoline," 68% of Americans and 78% of scientists said they would "favor" such a move.

International Comparisons

A recent analysis of articles on genetic engineering attitudes from around the world concluded that respondents were more opposed to animal modification than plant modification, that Europeans saw more risks and fewer benefits than Americans or Asians, and that moral concerns are highest in the United States and Asia (Frewer et al. 2013). The 2014 version of *Indicators* also reported the results of a 2010 international survey of a wide range of countries that suggested that the United States was relatively favorable toward genetic modification compared with other countries, with only 25% saying they thought such crops should be seen as "extremely dangerous to the environment." A number of other countries, including some European countries (e.g., Belgium, Norway, Denmark), were also relatively favorable toward the technology (NSB 2014). Some of the countries in which residents were least favorable to genetic engineering included Turkey, Chile, and Russia.

Nanotechnology

Nanotechnology involves manipulating matter at very small scales to create new or improved products that can be used in a variety of ways. Government and the private sector have made relatively large investments in this area in recent years, and innovations based on this work are increasingly common (Project on Emerging Nanotechnologies 2015).

Although recent data are limited, one 2014 survey conducted by researchers at the University of Wisconsin–Madison using the GfK KnowledgePanel found that 74% of respondents did not feel personally informed about "nanotechnology" and that 59% did not think the issue was "personally" important (Science, Media and the Public Research Group 2015). Despite low interest and low perceived knowledge, when asked, 45% of respondents said they thought nanotechnology was likely "risky for society as a whole," and 45% said they thought it was likely "beneficial for society as a whole." In both cases, however, more than a quarter (27% and 25%, respectively) said they were ambivalent. When the researchers combined the risk and benefit questions, they found that about slightly more than one-third (35%) indicated that they thought the risks outweighed the benefits and that a similar proportion (36%) indicated that they thought the benefits outweighed the risks. Ultimately, only 35% said they support the use of nanotechnology (25% neither agreed nor disagreed; 41% disagreed). A similar proportion (37%) said that they supported "federal funding of nanotechnology" (21% neither agreed nor disagreed; 42% disagreed). These data are largely consistent with earlier research featured in *Indicators* (NSB 2010) that found that only small portions of Americans said they had heard much about nanotechnology and that views about the relative risks and benefits were mixed.

As with the data on GE food, it is important to recognize that people's low levels of knowledge about nanotechnology likely mean that they are largely responding to questions about the issue based on such factors as their overall trust in science or their worldview. Additional factors such as the content or wording of the questions or the context of the survey may contribute to such processes.

Synthetic Biology

U.S. Patterns and Trends

Another topic for which the public may not have yet developed strong opinions but that survey researchers are beginning to study is synthetic biology, which involves using S&E to make new organisms such as bacteria to carry out specific tasks. These organisms would have genetic material that does not occur in nature. The specific tasks might include fighting diseases, cleaning up pollution, or manufacturing medicines or fuels (Woodrow Wilson International Center for Scholars 2015). Initial survey research on behalf of the Woodrow Wilson International Center for Scholars, part of the Smithsonian Institution, found that only a small number of Americans reported hearing "a lot" about the topic (Woodrow Wilson International Center for Scholars 2013). Nevertheless, this proportion steadily grew from 2% in 2008 to 6% in 2013, whereas the percentage who said they had heard "nothing at all" fell from 67% to 45% (another 30% said they heard just a little in 2013). As with genetic engineering and nanotechnology, the public is somewhat split on whether synthetic biology is likely to produce risks or benefits. In 2013, 40% said they thought that the risks and benefits would be about equal, whereas 18% saw more benefits than risks, and 15% saw more risks than benefits. The remaining 27% said they were not sure (Woodrow Wilson International Center for Scholars 2013). This project also included an effort to provide basic information about the subject and found that, once respondents heard such information, many tended to become more negative about the technology, whereas a few became more positive.

These results are largely consistent with a 2014 survey by university researchers (Akin et al. unpublished). This study found that 75% of Americans indicated they were "not informed" about synthetic biology (i.e., they responded between 0 and 4 on an 11-point scale anchored by "not at all informed" [0] and "very informed" [11]).

As with the Wilson Center research, the 2014 survey found that about equal numbers perceived risks and benefits, although the question structure was quite different. Overall, 25% perceived relatively high risks (i.e., they chose values between 8 and 11 on an 11-point scale anchored by "not at all risky" and "very risky"), and 22% perceived relatively high benefits (i.e., they chose values between 8 and 11 on an 11-point scale anchored by "not at all beneficial" and "very beneficial").

Stem Cell Research and Human Cloning

U.S. Patterns and Trends

Stem cell and cloning research focus on understanding how to use genetic material to produce living cells, tissues, and organisms. Such research creates opportunities for enhanced understanding of life and opportunities to develop new health care treatments. The intersection of health, human life, and the destruction of human embryos, however, raises ethical issues that have spurred public debate.

Most Americans appear to support the use of stem cells for medical research. Annual Gallup (Jones and Saad 2014) data showed that, in 2014, 65% of Americans saw using stem cells from human embryos in medical research as "morally acceptable." The percentage of those who saw such research as morally acceptable is up 5 points from 2013, although it is similar to the previous high of 64% found in 2007. In 2014, about 27% said it was "morally wrong." More generally, the percentage of Americans seeing the use of human embryos as morally acceptable climbed from 52% in 2002, when Gallup started polling on the issue, to the 65% high in 2014. The percentage of Americans viewing stem cell research as morally acceptable has ranged between 57% and 65% since 2007.

A minority of Americans support the cloning of humans and animals (Jones and Saad 2014). About 13% of Americans supported cloning of humans in 2014. This is identical to the level of support in 2013 and is the highest it has been since Gallup began asking about the subject in 2001. At that point, support stood at 7%.

International Comparisons

The last time a large sample of Europeans was asked about cloning was in 2010 when a Eurobarometer survey found that 63% of respondents across 27 European countries supported the use of stem cells from human embryos either with no special laws (12%) or "as long as this is regulated by strict laws" (51%). The use of adult stem cells, in contrast, was supported by 69% of Europeans, including 15% who saw no need for special laws and 54% who would approve if use was regulated by "strict laws." The survey did not address human cloning, but it included several questions about animal cloning, and the results suggested widespread disapproval of the technology. About 17% said that they saw it as "safe for future generations," and 70% of Europeans disagreed that "animal cloning in food production should be encouraged" (European Commission 2010b).

Animal Research

U.S. Patterns and Trends

The medical research community conducts experimental tests on animals for many purposes, including testing the effectiveness of drugs and procedures that may eventually be used to improve human health and advance scientific understanding of biological processes.

Most Americans support at least some kinds of animal research, but this support has fallen in recent years. According to Gallup (Jones and Saad 2014), about 57% of Americans said they saw "medical testing on animals" as "morally acceptable" in 2014, similar to previous years but down from 65% in 2001 when Gallup first began asking the question in 2001 (Riffkin 2014). A different question by the Pew Research Center (2015b) found that, in 2014, 47% of Americans said they "favor" "the use of animals in scientific research," down from 52% in 2009.

International Comparisons

The most recent similar data from Europe are from a 2010 survey showing that, on average, Europeans oppose animal testing, but these views vary widely. Respondents were asked whether "scientists should be allowed to experiment on animals like dogs and monkeys if this can help sort out human health problems." About 44% of Europeans said they "totally" or "tend to" agree that such experiments should be allowed, whereas 37% said they "totally" or "tend to" disagree (European Commission 2010a).

Science, Technology, Engineering, and Mathematics Education

Formal education plays a central role in how people think about S&T and other factors such as involvement in informal education (e.g., museums) and media use. As noted previously, few Americans saw American STEM education as world class in 2014. Just 7% of Americans said they viewed U.S. K–12 STEM education as among the "best in the world," and just 22% said they thought it was "above average." About 39% saw it as "average," and 29% saw it as "below average." A companion survey of members of the scientific community was even more pessimistic, with just 1% seeing U.S. STEM education as among the "best in the world," and 15% seeing it as "above average." Most scientists said they thought U.S. K–12 STEM education was either "average" (38%) or "below average" (46%). In contrast, almost all of these same members of the scientific community said they thought "doctoral training in science and technology" was either the "best in the world" (46%) or "above average" (41%) (Pew Research Center 2015b).

Conclusion

Overall, the survey results presented above suggest that—for good or ill—attitudes and knowledge about S&T are relatively stable in the United States. As in previous years, Americans express relatively high interest in various S&T issues, with the one change being that they continue to shift their focus toward getting that information online. The results also show that many Americans know basic facts about science, although many still get the questions asked wrong. If change in basic science knowledge is occurring, it is occurring slowly. For attitudes, a substantial majority of Americans continue to see substantially more benefits than harms from science, have relatively high levels of confidence in the scientific community, and would like to see science supported. Views about specific scientific issues, including environmental, energy, and emerging technologies, are more varied. Although there are debates about issues such as climate change and GE food, many of the key trend lines discussed are either stable or gradually moving in favor of more positive views about science. International comparisons continue to show that Americans are often more interested in and positive about S&T than residents of many other countries. However, there are many countries around the world where S&T is also highly regarded, and residents of other countries often express more concern about the environment. From a historic standpoint, Americans' concern about the environment is no longer at historic lows, but concern is also not as high as it was in previous decades.

In reviewing this chapter, it is important to recall that the purpose of the types of indicators described here is to allow a fact-based discussion about what Americans think and know about topics related to science, technology, and engineering. The emphasis on between-group comparisons, over-time comparisons, and between-country comparisons is not to rank groups or countries but to provide the type of context that allows a discussion about where the United States may have had success and where there might be potential for improvement. For example, the finding that many Americans have, over time, lost confidence in the medical community, as well as groups such as those involved in education or journalism, suggests that longstanding confidence in the scientific community should not be taken as a given. Similarly, the fact that Americans appear to visit more S&T museums and centers than residents of many other countries might suggest an area of strength on which we might build. As an *Indicators* chapter, the current report, however, highlights the nature of and trends in public views without assessing why changes may have occurred. This leaves to others the challenge of determining the causes of the patterns and trends described.[i] Some of this literature is cited here, but the work of better understanding public attitudes and knowledge about science is ongoing.

Further, in reading the chapter, it is important to consider the overall mosaic that can be assembled from all of these indicators and to avoid putting too much emphasis on any specific statistic. As survey data, the indicators discussed are subject to random variation; as such, it is important to analyze long-term trends and multiple related questions before drawing strong conclusions. Another ongoing limitation of the available indicators is that many of the international comparison data come from Europe, with only limited recent data from the Asia-Pacific region, where there is a high level of S&T activity. Data from Africa and South America are even scarcer. Similarly, the questions asked vary by country in small and large ways. As such, international comparisons should be made with caution, and thoughtful consideration should be given to what we may know and what we do not know.

Despite such concerns, one pattern in the surveys reviewed continues to stand out. Year after year, Americans who have had more exposure to S&T—including those who are college educated and have completed college courses in science and mathematics—tend to understand more about S&T, see S&T in a more positive light, and engage with S&T more often. Although it is not clear whether this association is causal, the pattern underscores the potential role of formal STEM education in shaping how people think about S&T. It is also important, however, to recognize that Americans interact with science beyond formal education systems through channels such as museums, a range of media (television, websites), and daily interactions with others in their personal or professional lives. Data on these types of exposure pathways are not generally as available as data related to formal education.

Ultimately, those who would seek to change knowledge and attitudes about S&T appear to have an increasing range of formal and informal channels through which to reach Americans. Attracting young people to S&T professions and cultivating positive attitudes about the value of S&T will be important for the United States to remain a world leader in S&T. Efforts to engage with the public on such matters are occurring through a range of online tools and in the community (e.g., schools, museums, restaurants), workplaces, and homes. The challenge for S&T advocates is to ensure that current efforts to engage Americans of all ages on S&T topics are sufficient and having the desired effects.

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[i] The GSS on which recent versions of this chapter are based is publicly available for online analysis or download at http://www3.norc.org/GSS+Website/.

Glossary

Biotechnology: The use of living things to make products.

Climate change: Any distinct change in measures of climate lasting for a long period of time. Climate change means major changes in temperature, rainfall, snow, or wind patterns lasting for decades or longer. Climate change may result from natural factors or human activities. Global warming is often the focus of climate change discussion.

Cloning: Reproductive cloning involves using technology to generate genetically identical individuals with the same nuclear DNA as another individual. Therapeutic cloning involves medical research to develop new treatments for diseases.

European Commission: The governance body for the European Union (EU) that is responsible for the Eurobarometer series of surveys. As of September 2015, the EU comprised 28 member nations: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom. Unless otherwise noted data on the EU include all of these 28 members. In this regard, Eurobarometer data from earlier years often does not include recently added members.

Genetically engineered (GE) food: A food product containing some quantity of any GE organism as an ingredient. Also sometimes called genetically modified (GM) food, genetically modified organisms (GMOs), or agricultural biotechnology.

Global warming: An average increase in temperatures near the Earth's surface and in the lowest layer of the atmosphere. Increases in temperatures in the Earth's atmosphere can contribute to changes in global climate patterns. Global warming can be considered part of climate change along with changes in precipitation, sea level, and so forth.

Nanotechnology: Manipulating matter at unprecedentedly small scales to create new or improved products that can be used in a wide variety of ways.

Organisation for Economic Co-operation and Development (OECD): Intergovernmental organization made up of most highly developed economies aimed at promoting policies to improve economic and social well-being.

Synthetic biology: Involves a combination of science and engineering to make or modify living organisms to carry out specific functions. The focus is on creating new genetic code that does not exist in nature.

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Introduction

Science and Engineering Indicators (SEI) contains data compiled from a variety of sources. This appendix explains the methodological and statistical criteria used to assess possible data sources for inclusion in SEI and to develop statements about the data. It also provides basic information about how statistical procedures and reasoning are applied.

This appendix has four main sections, a glossary, and information on viewing the data sources for this report. The first section describes the considerations that are part of the selection process for information to be included in SEI. The second discusses the different sources of information (e.g., sample surveys, censuses, and administrative records) used in the report and provides details about each type. The third discusses factors that can affect accuracy at all stages of the survey process. The fourth discusses the statistical testing used to determine whether differences between sample survey-based estimates are *statistically significant*, i.e., greater than could be expected by chance. The glossary covers statistical terms commonly used or referred to in the text. The appendix concludes by providing information on how to access the report's data sources, which can be viewed by chapter and by data provider.

Selection of Data Sources

Information is available from many sources and it can vary in substantial ways. Several criteria guide the selection of data for SEI:

Representativeness. Data should represent the entire national or international populations of interest and should reflect the heterogeneity of those populations. Data should be also available for the subdomains of interest covered in SEI (e.g., the population of scientists and engineers or the topic of R&D spending by universities).

Relevance. Data should include indicators central to the functioning of the science and technology enterprise.

Timeliness. Data that are not part of a time series should be timely (i.e., they should be the most recent data available that meet the selection criteria).

Statistical and Methodological Quality. Survey methods used to collect data should provide sufficient assurance that survey estimates are robust and statements based on statistical analysis of the **data are valid and reliable.** Data included in SEI must be of high quality. Data quality has several characteristics. Some key dimensions of quality include the following.

> **Validity.** Data have *validity* if they accurately measure the phenomenon they are supposed to represent.
>
> **Reliability.** Data have *reliability* if similar results would be produced if the same measurement or procedure were performed multiple times on the same population.
>
> **Accuracy.** Data are *accurate* if estimates from the data do not widely deviate from the true population value.

Data that are collected by U.S. government agencies and are products of the federal statistical system meet the rigorous statistical and methodological criteria described above. Unless otherwise indicated, these data are representative of the nation as a whole and of the demographic, organizational, or geographic subgroups that constitute it.

For data collected by governments in other countries and by nongovernment sources, including private survey firms and academic researchers, methodological information is examined to assess conformity with the criteria U.S. federal agencies typically use. Government statistical agencies in the developed world cooperate extensively both in developing data-quality standards and in improving international comparability for key data, and these agencies ensure that the methodological information about the data generated by this international statistical system is relatively complete.

Often, methodological information about data from nongovernmental sources and from governmental agencies outside the international statistical system is less well documented. These data must meet basic scientific standards for representative sampling of survey respondents and adequate and unbiased coverage of the population under study. The resulting measurements must be sufficiently relevant and meaningful to warrant publication despite methodological uncertainties that remain after the documentation has been scrutinized.

Many data sources that contain pertinent information about a segment of the S&E enterprise are not cited in SEI because their coverage of the United States is partial in terms of geography, incomplete in terms of segments of the population, or otherwise not representative. For example, data may be available for only a limited number of

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states, or studies may be based on populations not representative of the United States as a whole. Similarly, data for other countries should cover and be representative of the entire country. In some cases, data that have limited coverage or are otherwise insufficiently representative are referenced in sidebars.

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Types of Data Sources

Much of the data cited in SEI comes from surveys. Surveys strive to measure characteristics of target populations. To generalize survey results correctly to the population of interest, a survey's *target population* must be rigorously defined and the criteria determining membership in the population must be applied consistently in determining which units to include in the survey. After a survey's target population has been defined, the next step is to establish a list of all members of that target population (i.e., a *sampling frame*). Members of the population must be selected from this list using accepted statistical methods so that it will be possible to generalize from the sample to the population as a whole. Surveys sometimes sample from lists that to varying extents omit members of the target population, because complete lists are typically unavailable.

Some surveys are censuses (also known as *universe surveys*), in which the survey attempts to obtain data for all population units. The decennial census, in which the target population is all U.S. residents, is the most familiar census survey. SEI uses data from the Survey of Earned Doctorates, an annual census of individuals who earn research doctorates from accredited U.S. institutions, for information about the numbers and characteristics of new U.S. doctorate holders.

Other surveys are *sample surveys*, in which data are obtained for only a portion of the population units. Samples can be drawn using either probability or non-probability based sampling procedures. A sample is a *probability sample* if each unit in the sampling frame has a known, nonzero probability of being selected for the sample. Probability samples are preferred because their use allows the computation of measures of precision and the subsequent statistical evaluation of inferences about the survey population. An example of a sample survey is the National Survey of College Graduates (NSCG). The NSCG gathers data on the nation's college graduates, with particular focus on those educated or employed in an S&E field. In *nonprobability sampling*, the sample is drawn with an unknown probability of selection. Polls that elicit responses from self-selected individuals, such as opt-in Internet surveys or phone-in polls are examples of nonprobability sample surveys. Except for some Asian surveys referenced in chapter 7, sample surveys included in SEI use probability sampling.

Surveys may be conducted of individuals or of organizations, such as businesses, universities, or government agencies. Surveys of individuals are referred to as *demographic surveys*. Surveys of organizations are often referred to as *establishment surveys.* An example of an establishment survey used in SEI is the Higher Education Research and Development Survey.

Surveys may be longitudinal or cross-sectional. In a *longitudinal survey*, the same sample members are surveyed repeatedly over time. The primary purpose of longitudinal surveys is to investigate changes over time. The Survey of Doctorate Recipients is a longitudinal sample survey of individuals who received research doctorates from U.S. institutions. SEI uses results from this survey to analyze the careers of doctorate holders.

Cross-sectional surveys provide a "snapshot" at a given point of time. When conducted periodically, cross-sectional surveys produce repeated snapshots of a population, also enabling analysis of how the population changes over time. However, because the same individuals or organizations are not included in each survey cycle, cross-sectional surveys cannot, in general, track changes for specific individuals or organizations. National and international assessments of student achievement in K–12 education, such as those discussed in chapter 1, are examples of repeated cross-sectional surveys. Most of the surveys cited in SEI are conducted periodically, although the frequency with which they are conducted varies.

Surveys can be self- or interviewer-administered, and they can be conducted using a variety of modes (e.g., postal mail, telephone, Web, e-mail, or in person). Many surveys are conducted using more than one mode. The NSCG is

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an example of a multimode survey. It is conducted primarily via the Web; potential participants who do not respond to the questionnaire are contacted via telephone.

Some of the data in SEI come from *administrative records* (data collected for the purpose of administering various programs). Examples of data drawn directly from administrative records in SEI include patent data from the records of government patent offices; bibliometric data on publications in S&E journals, compiled from information collected and published by the journals themselves; and data on foreign S&E workers temporarily in the United States, drawn from the administrative records of immigration agencies.

Many of the establishment surveys that SEI uses depend heavily, although indirectly, on administrative records. Universities and corporations that respond to surveys about their R&D activities often use administrative records developed for internal management or income tax reporting purposes to respond to these surveys.

Data Accuracy

Accurate information is a primary goal of censuses and sample surveys. Accuracy can be defined as the extent to which results deviate from the true values of the characteristics in the target population. Statisticians use the term "error" to refer to this deviation. Good survey design seeks to minimize survey error.

Statisticians usually classify the factors affecting the accuracy of survey data into two categories: nonsampling and sampling errors. *Nonsampling error* applies to administrative records and surveys, including censuses, whereas *sampling error* applies only to sample surveys.

Nonsampling Error

Nonsampling error refers to error related to the design, data collection, and processing procedures. Nonsampling error may occur at each stage of the survey process and is often difficult to measure. The sources of nonsampling error in surveys have analogues for administrative records: the purposes for and the processes through which the records are created affect how well the records capture the concepts of interests of relevant populations (e.g., patents, journal articles, immigrant scientists and engineers). A brief description of five sources of nonsampling error follows. For convenience the descriptions refer to samples, but they apply to censuses and administrative records.

Specification Error. Survey questions often do not perfectly measure the concept for which they are intended as indicators. For example, the number of patents does not perfectly quantify the amount of invention.

Coverage Error. The sampling frame, the listing of the target population members used for selecting survey respondents, may be inaccurate or incomplete. If the frame has omissions, duplications or other flaws, the survey is less representative because coverage of the target population is inaccurate. Frame errors often require extensive effort to correct.

Nonresponse Error. Nonresponse error can occur if not all members of the sample respond to the survey. *Response rates* indicate the proportion of sample members that respond to the survey. Response rate is not always an indication of nonresponse error.

Nonresponse can cause *nonresponse bias*, which occurs when the people or establishments that respond to a question, or to the survey as a whole, differ in systematic ways from those who do not respond. For example, in surveys of national populations, complete or partial nonresponse is often more likely among lower-income or less-educated respondents. Evidence of nonresponse bias is an important factor in decisions about whether survey data should be included in SEI.

Managers of high-quality surveys, such as those in the U.S. federal statistical system, do research on nonresponse patterns to assess whether and how nonresponse might bias survey estimates. SEI notes instances where reported data may be subject to substantial nonresponse bias.

Measurement Error. There are many sources of measurement error, but respondents, interviewers, mode of administration, and survey questionnaires are the most common. Knowingly or unintentionally, respondents may provide incorrect information. Interviewers may influence respondents' answers or record their answers incorrectly. The questionnaire can be a source of error if there are ambiguous, poorly worded, or confusing questions, instructions, or terms or if the questionnaire layout is confusing.

In addition, the records or systems of information that a respondent may refer to, the mode of data collection, and the setting for the survey administration may contribute to measurement error. Perceptions about whether data will be treated as confidential may affect the accuracy of survey responses to sensitive questions, such as those about business profits or personal incomes.

Processing Error. Processing errors include errors in recording, checking, coding, and preparing survey data to make them ready for analysis.

Sampling Error

Sampling error is the most commonly reported measure of a survey's precision. Unlike nonsampling error, sampling error can be quantitatively estimated in most scientific sample surveys.

Sampling error is the uncertainty in an estimate that results because not all units in the population are measured. Chance is involved in selecting the members of a sample. If the same, random procedures were used repeatedly to select samples from the population, numerous samples would be selected, each containing different members of the population with different characteristics. Each sample would produce different population estimates. When there is great variation among the samples drawn from a given population, the sampling error is high and there is a large chance that the survey estimate is far from the true population value. In a census, because the entire population is surveyed, there is no sampling error, but nonsampling errors may still exist.

Sampling error is reduced when samples are large, and most of the surveys used in SEI have large samples. Typically, sampling error is a function of the sample design and size, the variability of the measure of interest, and the methods used to produce estimates from the sample data.

Sampling error associated with an estimate is often measured by the coefficient of variation or margin of error, both of which are measures of the amount of uncertainty in the estimate.

Statistical Testing of Sample Survey Data

Statistical tests can be used to determine whether differences observed in sample survey data are “real” differences in the population. Differences that are termed *statistically significant are likely to occur in the target population.* When SEI reports statements about differences on the basis of sample surveys, the differences are statistically significant at least at the 10% level. This means that, if there were no true difference in the population, the chance of drawing a sample with the observed or greater difference would be no more than 10%.

A statistically significant difference is not necessarily large, important, or significant in the usual sense of the word. It is simply a difference that is unlikely to be caused by chance variation in sampling. With the large samples common in SEI data, extremely small differences can be found to be statistically significant. Conversely, quite large differences may not be statistically significant if the sample or population sizes of the groups being compared are small. Occasionally, apparently large differences are noted in the text as not being statistically significant to alert the reader that these differences may have occurred by chance.

Numerous differences are apparent in every table in SEI that reports sample data. The tables permit comparisons between different groups in the survey population and in the same population in different years. It would be impractical to test and indicate the statistical significance of all possible comparisons in tables involving sample data.

As explained in “About Science and Engineering Indicators” at the beginning of this volume, SEI presents indicators. It does not model the dynamics of the S&E enterprise, although analysts could construct models using the data in SEI. Accordingly, SEI does not make use of statistical procedures suitable for causal modeling and does not compute effect sizes for models that might be constructed using these data.

Glossary

Most glossary definitions are drawn from U.S. Office of Management and Budget, Office of Statistical Policy (2006), "Standards and Guidelines for Statistical Surveys" and U.S. Bureau of the Census (2006), "Organization of Metadata, Census Bureau Standard Definitions for Surveys and Census Metadata." In some cases, glossary definitions are somewhat more technical and precise than those in the text, where fine distinctions are omitted to improve readability.

Accuracy: Accuracy is the difference between the estimate and the true parameter value.

Administrative records: Microdata records collected for the purpose of carrying out various programs (e.g., tax collection).

Bias: Systematic deviation of the survey estimated value from the true population value. Bias refers to systematic errors that can occur with any survey under a specific design.

Census: A data collection that seeks to obtain data directly from all eligible units in the entire target population. It can be considered a sample with a 100% sampling rate. A census may use data from administrative records for some units, rather than direct data collection.

Coverage: Extent to which all elements on a frame list are members of the population and to which every element in a population appears on the frame list once and only once.

Coverage error: Discrepancy between statistics calculated on the frame population and the same statistics calculated on the target population. *Undercoverage* errors occur when target population units are missed during frame construction, and *overcoverage* errors occur when units are duplicated, enumerated incorrectly, or are not part of the target population.

Cross-sectional sample survey: Based on a representative sample of respondents drawn from a population at a particular point in time.

Estimate: A numerical value for a population parameter derived from information collected from a survey or other sources.

Estimation error: Difference between a survey estimate and the true value of the parameter in the target population.

Frame: A mapping of the universe elements (i.e., sampling units) onto a finite list (e.g., the population of schools on the day of the survey).

Item nonresponse: Occurs when a respondent fails to respond to one or more relevant items on a survey.

Longitudinal sample survey: Follows the experiences and outcomes over time of a representative sample of respondents (i.e., a cohort).

Measurement error: Difference between observed values of a variable recorded under similar conditions and some fixed true value (e.g., errors in reporting, reading, calculating, or recording a numerical value).

Nonresponse bias: Occurs when the observed value deviates from the population parameter due to systematic differences between respondents and nonrespondents. Nonresponse bias may occur as a result of not obtaining 100% response from the selected units.

Appendix: Methodology

Nonresponse error: Overall error observed in estimates caused by differences between respondents and nonrespondents. It consists of a variance component and nonresponse bias.

Nonsampling error: Includes specification errors and measurement errors due to interviewers, respondents, instruments, and mode; nonresponse error; coverage error; and processing error.

Parameter: An unknown, quantitative measure (e.g., total revenue, mean revenue, total yield or number of unemployed people) for the entire population or for a specified domain of interest.

Population: The set of persons or organizations to be studied, which may not be of finite size.

Precision of survey results: How closely results from a sample can reproduce the results that would be obtained from a complete count (i.e., census) conducted using the same techniques. The difference between a sample result and the result from a complete census taken under the same conditions is an indication of the precision of the sample result.

Probabilistic methods: Any of a variety of methods for survey sampling that gives a known, nonzero probability of selection to each member of a target population. The advantage of probabilistic sampling methods is that sampling error can be calculated. Such methods include random sampling, systematic sampling, and stratified sampling. They do not include convenience sampling, judgment sampling, quota sampling, and snowball sampling.

Reliability: Degree to which a measurement technique would yield the same result each time it is applied. A measurement can be both reliable and inaccurate.

Response bias: Deviation of the survey estimate from the true population value due to measurement error from the data collection. Potential sources of response bias include the respondent, the instrument, the mode of data collection, and the interviewer.

Response rates: Measure the proportion of the sample frame represented by the responding units in each study.

Sample design: Refers to the combined target population, frame, sample size, and the sample selection methods.

Sample survey: A data collection that obtains data from a sample of the frame population.

Sampling error: Error that occurs because all members of the frame population are not measured. It is associated with the variation in samples drawn from the same frame population. The sampling error equals the square root of the variance.

Standard error: Standard deviation of the sampling distribution of a statistic. Although the standard error is used to estimate sampling error, it includes some nonsampling error.

Statistical significance: Attained when a statistical procedure applied to a set of observations yields a *p* value that exceeds the level of probability at which it is agreed that the null hypothesis will be rejected.

Target population: Any group of potential sample units or individuals, businesses, or other entities of interest.

Unit nonresponse: Occurs when a respondent fails to respond to all required response items (i.e., fails to complete or return a data collection instrument).

Universe survey: Involves the collection of data covering all known units in a population (i.e., a census).

Validity: Degree to which an estimate is likely to be true and free of bias (systematic errors).

View Data Sources

The complete list of data sources used in this volume can be found in the Data Sources section (http://www.nsf.gov/statistics/2016/nsb20161/#/data/source). Data sources can be viewed by chapter and data provider.

SEI 2016 Errata

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SEI 2016 Errata

Science and Engineering Indicators 2016 Errata

The following issues were discovered and corrected after publication of *Science and Engineering Indicators 2016*. To report an error, please send an email to ncsesweb@nsf.gov.

This page was last updated on April 3, 2018.

Chapter 1

Figure 1-11 PDF and PNG files updated to correct a composition error on the x-axis labels. (01/29/16)

Chapter 5

A reference was omitted from the Trends in Citation of S&E Publications section, after the statement "Each of these nations had a top 1% share of world citations, relative to their share of S&E publications, which was above that of the United States in 2012." The reference is below. (03/17/16)

> Leydesdorff L, Wagner C, and Bornmann L. 2014. The European Union, China, and the United States in the top-1% and top-10% layers of most-frequently cited publications: Competition and collaborations. *Journal of Informetrics*. 8(3): 606-617.

Chapter 6

A loading error resulted in displaying the same values for Appendix Tables 6-2 and 6-4. Appendix Table 6-4 has been corrected. (08/03/16)

In the paragraphs on SBIR investment within the Venture Capital and Small Business Innovation Research Investment section, the text inadvertently referred to dollar amounts in "millions" rather than "billions" throughout. The text has been corrected to "billions." Related Figure 6-36 was unaffected. (03/30/16)

Appendix Tables 6-2 and 6-4 through 6-18 have been corrected. The data points for Israel and Jordan were errantly switched in the original publication. (03/01/16)

Chapter 7

In Appendix Table 7-8, the column head representing the question "How long does it take for the Earth to go around the Sun: one day, one month, or one year?" erroneously indicated the answer is "one day." The correct answer is "one year." The column head has been fixed. The data in the column are unaffected and displayed the percent who correctly answered "one year." (04/03/18)

Figure 7-11 omitted data for selected non-Organisation for Economic Co-operation and Development countries /economies. All available file formats of the figure have been updated. (08/03/16)

State Indicators (formerly Chapter 8)

Indicator 8-47 Table View has been updated to correctly apply the constant dollar adjustment. (01/29/16)

Indicator 8-51 Map View updated to show correct quartile placement of states with "*" values. (01/29/16)

State Indicators PDF file updated to correct category labels in the Overview section. (01/29/16)

SEI 2016 Errata

Display settings in the Chart View corrected so charted data points for all values match the corresponding values under Table View. (01/29/16)

Display settings in the Chart View "detail" views updated to correctly show the constant dollar deflator for ratio indicators, where applicable. (01/29/16)

Settings in the Table View interactive trend charts updated to show correct x-axis labels and display consistently across various web browsers. (01/29/16)