Overview

List of Tables

List of Figures

The United States in a Changing World

Research and development in the United States has materially contributed to innovation and economic growth. The strong U.S. economic performance during the 1990s has given impetus to the trend toward a knowledge-based economy: that is, one in which research, its commercial exploitation, and other intellectual work play a growing role in driving economic growth.

That strong U. S. performance has become the benchmark against which governments around the world measure their countries' science and technology (S&T) activities and their progress toward a more knowledge-based economy. Seeking to emulate elements of the U.S. model of knowledge-driven economic growth, they are striving to expand knowledge-intensive sectors of their economies and are taking steps to develop the highly educated technical workforces they need to do so. The European Union (EU) has set a goal of becoming "the most competitive and dynamic knowledge-based economy in the world by 2010."[1]

U.S. investment and performance in R&D and S&T remain strong and progress toward a more knowledge-based economy continues. This progress takes place in an environment of increasing globalization of S&T-related activities as advances in communication and transportation, the cross-fertilization of ideas, increasingly open markets, and responses to significant cost differentials among competing countries spur innovation.

The United States has long benefited from the participation of large numbers of foreign-born scientists and engineers in the S&E workforce. Data from the 2000 U.S. Census show that in S&E occupations approximately 17 percent of bachelor's degree holders, 29 percent of master's degree holders, and 38 percent of doctorate holders are foreign born. These individuals contribute talent, scientific ingenuity, and technical sophistication to the U.S. S&T enterprise and help open up avenues for international scientific cooperation.

The outlook for U.S. S&E is affected by uncertainties in three major areas: the effects of policy adjustments arising from the September 11, 2001, attacks, the current weak worldwide economy, and developments affecting the U.S. S&E workforce.

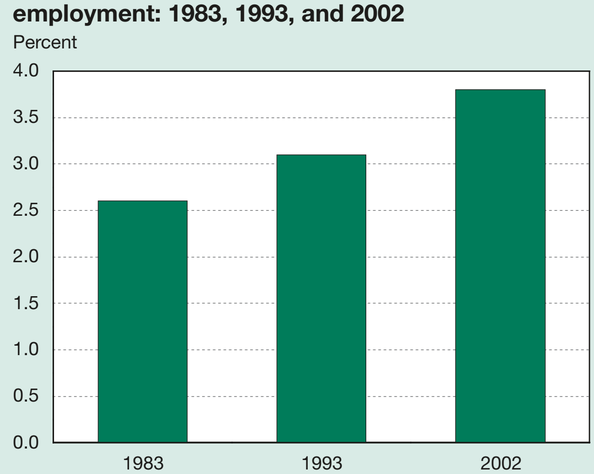
The first source of uncertainty is the recasting of the relationship between S&T and U.S. national security. The attacks of September 2001 have given increased urgency and a new focus to the changing strategic role of S&T in the post-Cold War era. The role of foreign students, scientists, and engineers in the U.S. S&E system; the appropriate balance between security and openness in scientific communication; the direction of certain Federal R&D initiatives; and the contributions that R&D can make in the domestic security arena are all issues of concern. The eventual resolution of these issues and the related effects on the U.S. S&T system remain unclear, particularly because only a few of the relevant data series available at this writing cover the 2002–03 period.

A second source of uncertainty is the duration, depth, and eventual effects of the current worldwide economic weakness. In particular, the effect this weakness will have on the structure and activities of high-technology firms around the world is unclear. As is the case with the aftermath of September 11, only fragmentary trend data are available that cover the 2002–03 period, and 1-year deviations from these trends are difficult to interpret with confidence.

A third source of uncertainty is the effect of the continuing globalization of labor markets on the U.S. knowledge-based economy. Employment in the U.S. S&E workforce has been growing significantly faster than overall employment for several decades (figure O-1), made possible in part by the U.S. ability to attract foreign-born S&E workers. The U.S. S&E workforce is entering a period of rising retirements, particularly among (but not limited to) doctorate holders. If present degree trends, retirement behavior, and international migration patterns persist, S&E workforce growth will slow considerably, potentially affecting the relative technological position of the U.S. economy.

The international S&E labor force is growing and becoming increasingly mobile. Governments are implementing policies designed to lure more of their citizens into S&E; keep their researchers at home or, in the case of the EU, in EU countries; and attract highly trained S&E personnel from abroad. Private firms are responding to competitive pressures and market opportunities by opening high-technology operations in foreign locations, developing strategic international alliances, and consummating cross-national spinoffs and mergers. A consequence of these trends is the further spread of technological know-how and the development of significant scientific and technical capacity in new locations across the globe.

Figure O-1
S&E occupation share of total civilian employment: 1983, 1993, and 2002



SOURCES: U.S. Bureau of the Census, Public Use Microdata Sample (PUMS), 1980 and 1990; and U.S. Bureau of the Census, Current Population Survey, 2000.

Science & Engineering Indicators – 2004

[1]European Union, Lisbon, 2000.

As with the uncertain implications of security concerns and the weak economic environment, the dynamics of skilled labor migration in the context of changing government and industry policies also are hard to predict. Conclusions about their impact on the U.S. S&T position may require the accumulation of several years' worth of data to distinguish between temporary deviations from major trends and changes in the trends themselves.

The remainder of this overview sets out the main U.S. S&E trends in the context of national and international developments that affect the knowledge-based economy in the United States. It begins by looking at trends in R&D investment, discusses trends related to R&D outputs and performance, and considers S&E labor force indicators. The overview then examines two sectors of strategic importance to the development and use of knowledge: the academic sector, including Ph.D. employment, and the high-technology sector. It closes with a summary consideration of U.S. S&T competitiveness in an uncertain environment.

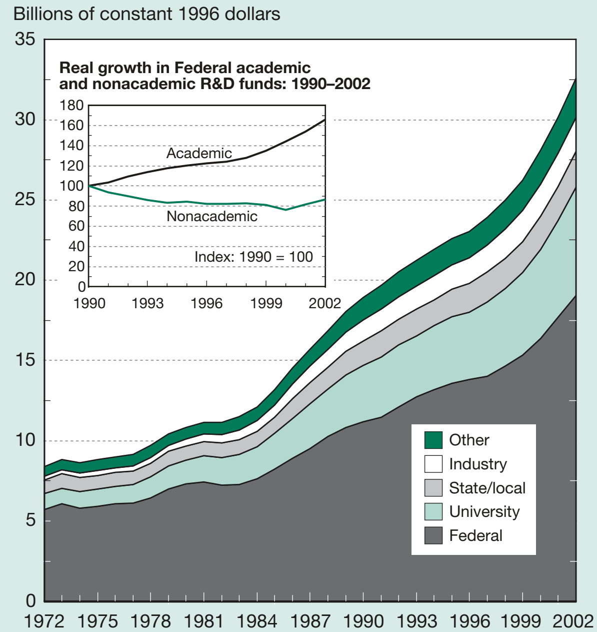
R&D Investment

U.S. strength in S&T reflects many decades of government support for the conduct of R&D, the development and maintenance of the necessary infrastructure, and the education and training of scientists and engineers. Federal R&D funds have been especially important to the academic sector, which is the source of much of the nation's basic research. Federal funds constituted close to 60 percent of academic R&D expenditures in the past decade. Since 1990, inflation-adjusted Federal dollars for academic R&D have grown continuously, increasing by about 66 percent through 2002. Real support to all other sectors declined during the decade, rebounding from its 2000 low but still contracting by about 14 percent over the period (figure O-2).

The strong U.S. R&D investment also reflects industry's commitment to R&D as an engine of competitive strength and profit growth. Company-funded R&D, which first surpassed federally funded R&D in 1980, reached a record $180 billion in 2000. Although it has slowed down sharply, it remained near this level in the face of 2 years of economic weakness. In 2002, U.S.-based firms spent an estimated $177 billion of their own funds on R&D, providing two-thirds of the national total of $276 billion (figure O-3).

This continued strength in industry spending for R&D—combined with an upswing in Federal Government support that mainly reflects increases in health-related R&D—has allowed the United States to maintain its longtime preeminence in the world's R&D activities. In 2001, the last year with internationally comparable data, U.S. R&D accounted for 44 percent of the combined R&D spending of the 30 member countries of the Organisation for Economic Cooperation and Development (OECD). The United States spent nearly three times as much on R&D as Japan, the nation with the second-highest total R&D expenditure. The U.S. total is half again as much as all EU countries combined

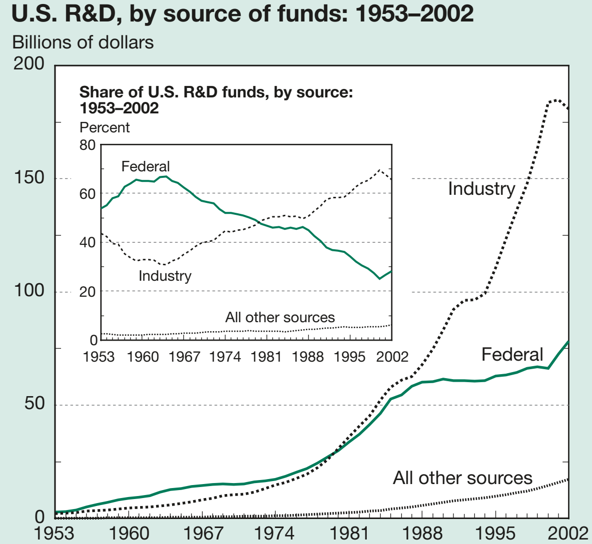
Figure O-2
Academic R&D expenditures, by source of funds: 1972–2002



SOURCES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), *National Patterns of R&D Resources;* annual series; and NSF/SRS, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 4-4.

Science & Engineering Indicators – 2004

Figure O-3
U.S. R&D, by source of funds: 1953–2002



NOTE: Other sources include nonprofit, academic, and non-Federal government.

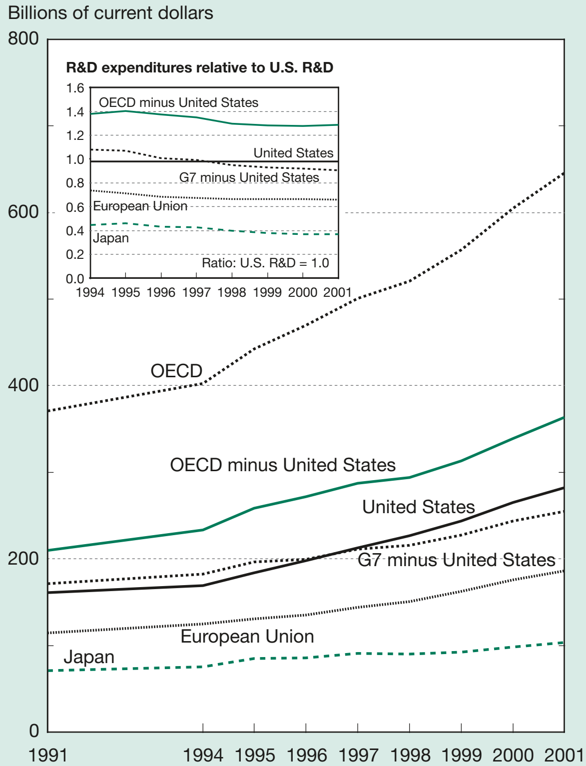
SOURCES: National Science Foundation, Division of Science Resources Statistics, *National Patterns of R&D Resources;* annual series. See appendix table 4-5.

Science & Engineering Indicators – 2004

and more than the combined total of the other G-7 countries [Japan, the United Kingdom (U.K.), Canada, France, Germany, and Italy]. Relative to U.S. R&D expenditures, the EU and all of these countries except Canada lost ground over the period (figure O-4).

A significant development in industrial R&D performance in the United States (and to a lesser extent elsewhere) is the growth of R&D carried out in service-sector industries. Computer software firms and companies performing R&D on a contract basis primarily led this growth. U.S. service-sector R&D volume surged during the late 1980s and early 1990s and again after 1997.[2] In contrast to the United States, manufacturing industries—chiefly electronics, chemicals, motor vehicles, and electrical machinery—carry out almost all R&D in Japan. The EU shows a trend toward an increasing share of R&D by service-sector industries, but it remains well below 15 percent of the total (figure O-5).

Figure O-4
Gross domestic R&D expenditure, by selected country/region: Selected years, 1991–2001



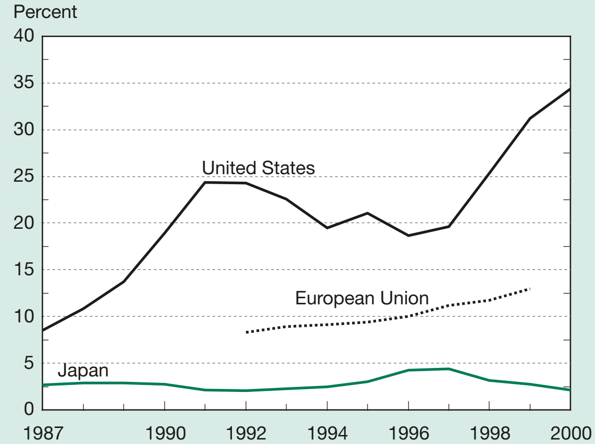
G7 Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.
OECD Organisation for Economic Co-operation and Development

NOTES: OECD purchasing power parity units are based on U.S. dollars. All data for 1992 and 1993 are extrapolated.

SOURCE: OECD, *Main Science and Technology Indicators,* 2003 (1) (Paris, 2003).

Science & Engineering Indicators – 2004

Figure O-5
Service-sector R&D share of industrial R&D in United States, European Union, and Japan: 1987–2000



SOURCE: Organisation for Economic Co-operation and Development, EAS, ANBERD database, July 2002. See appendix tables 6-7 to 6-9.

Science & Engineering Indicators – 2004

The R&D environment has changed in response to developing global markets; closer links between R&D and the creation of new products, services, and markets; and the opportunities offered by advances in information and communication technologies. Industry has responded by outsourcing R&D both nationally and internationally, opening overseas operations, forming strategic technology alliances with U.S. and international partners, and engaging in both divestiture and acquisition of strategic technology units. U.S.-based companies have a prominent role in international alliances: the bulk of these strategic technology alliances have a U.S.-based firm as the ultimate parent company (figure O-6). The United States has also fostered the development of university-industry links and has stimulated the commercialization of "public" (mostly academic) research.

R&D Performance, Outputs, and Capabilities

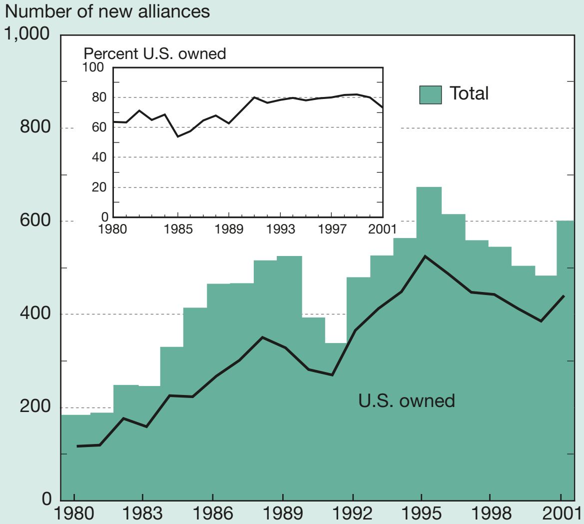
The strength of the R&D performance of U.S.-based companies has attracted the attention of firms elsewhere. U.S. affiliates of foreign firms are increasing funds to conduct R&D in this country. In the late 1980s, U.S. companies provided $7.9 billion to their overseas affiliates for R&D, whereas foreign companies provided $6.7 billion to their U.S.-based affiliates. However, in the 1990s, these R&D investment trends reversed.[3] By 2000, R&D expenditures by foreign-owned firms in the United States had reached almost $26 billion, whereas overseas R&D spending of U.S. firms remained below $20 billion (figure O-7).

In S&E research output (as measured by publication in the world's key journals), the number of U.S. articles

[2]The apparent acceleration in growth after 1997 may in part reflect changes in industry classification.

[3]Part of this development reflects mergers and acquisitions.

Figure O-6
Total and U.S.-owned international technology alliances: 1980–2001



NOTE: Country assignment based on ultimate parent company of alliance members.

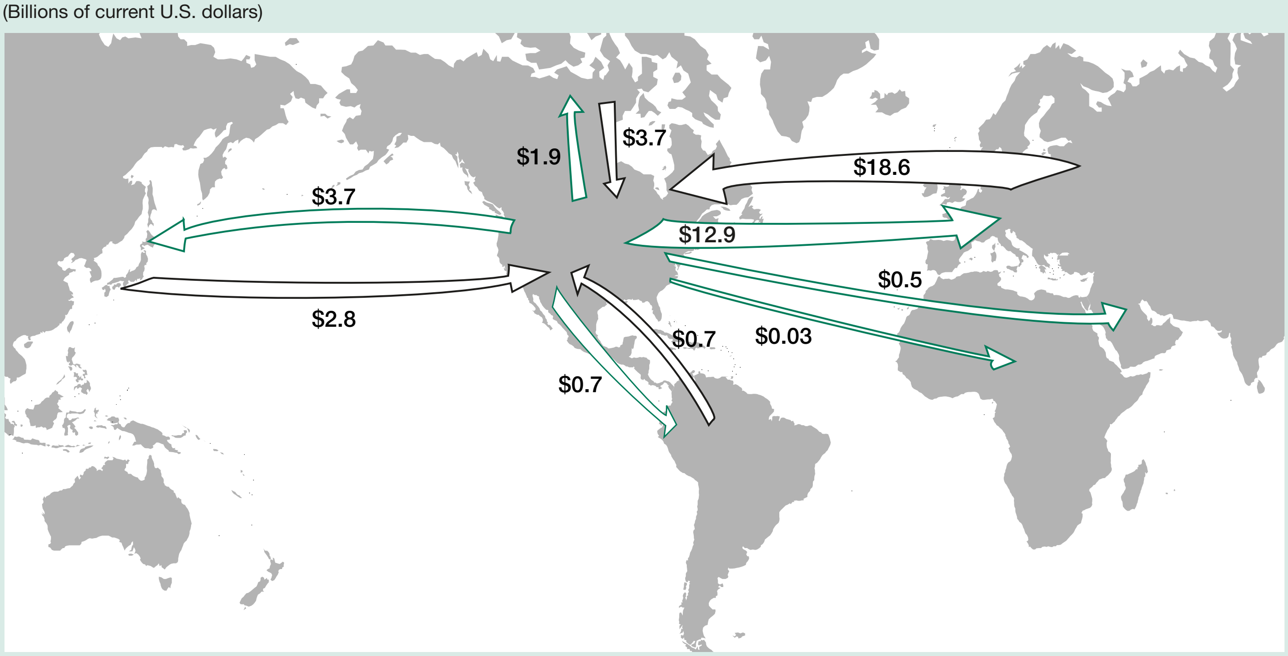
SOURCE: Maastricht Economic Research Institute on Innovation and Technology, Co-operative Agreements and Technology Indicators database, special tabulations. See appendix table 4-42.

Science & Engineering Indicators – 2004

stopped increasing after the early 1990s. The U.S. share of world output has declined, indicative of the development of cutting-edge research capabilities elsewhere (figure O-8). Yet, U.S. researchers continue to make important contributions to the world's S&T knowledge as evidenced by the high volume of citations of their work by other researchers: articles by U.S. authors are cited abroad more frequently than might be expected based on their worldwide share of all articles. In many other countries' S&T publications, references to U.S. articles are more numerous than are references to the domestic literature (figure O-9).

International scientific collaboration continues to expand as more and more countries take part, and U.S.-based researchers are active participants. Domestic and international collaborations are expanding in response to the complexities of new scientific fields, the growing scale and scope of scientific initiatives, new capabilities provided by advances in information and communications technologies, professional ties established during study or work abroad, and explicit government policies and incentives.[4] In recent years, about 45 percent of the world's internationally coauthored articles had at least one U.S.-based researcher among their authors. Among coauthored articles published in the United States in 2001, nearly one-fourth had at least one foreign coauthor, up from 10 percent in the late 1980s (figure O-10).

Figure O-7
Foreign-owned R&D in United States and U.S.-owned R&D overseas, by investing/host region: 2000
(Billions of current U.S. dollars)

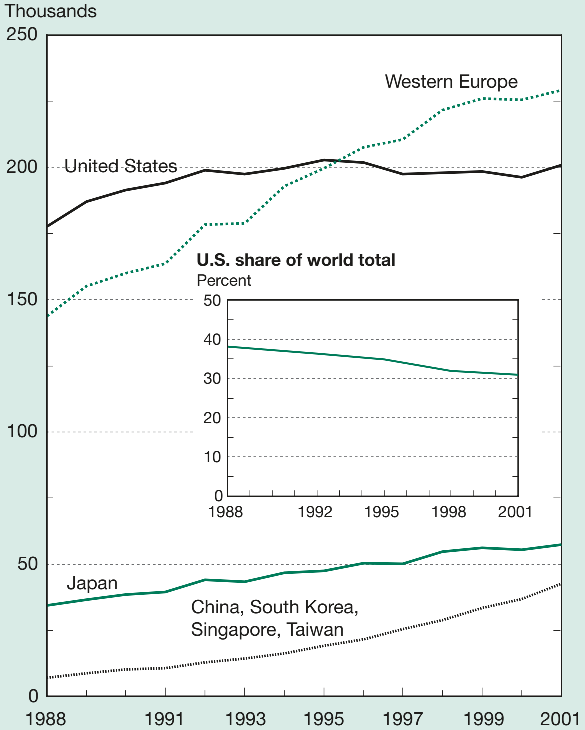


SOURCES: U.S. Bureau of Economic Analysis, *Foreign Direct Investment in the United States,* annual series; and U.S. Bureau of Economic Analysis, *U.S. Direct Investment Abroad,* annual series. See appendix tables 4-49 and 4-51.

Science & Engineering Indicators – 2004

[4]The European Union's Sixth Framework Programme targets the creation of a European Research Area, in part through development of regional transnational centers of excellence and emphasis on transnational collaboration.

Figure O-8
S&E articles, by selected country/region and U.S. share of world total: 1988–2001



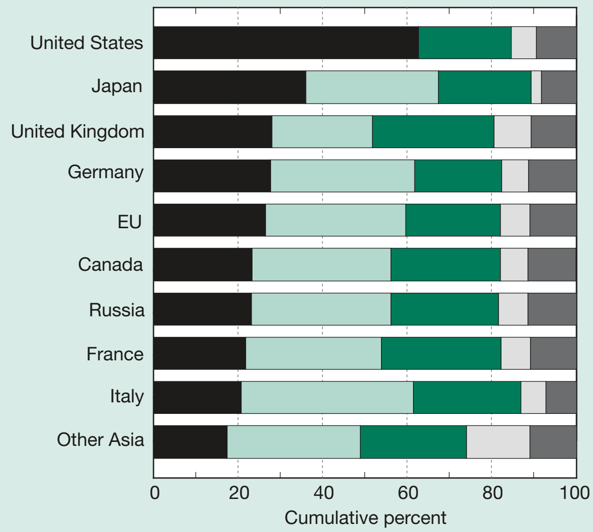
SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-35.

Science & Engineering Indicators – 2004

The volume of patents issued for inventions provides a broad measure of technological change, and the number of U.S. patents has surged, increasing from about 80,000 in 1988 to 166,000 in 2001. The large and dynamic U.S. market is attractive to foreign inventors, who have received between 44 and 48 percent of all U.S. patents since the late 1980s. The volume and nature of these foreign-owned patents provide insight into the relative technological competitiveness of other countries and regions in the U.S. market. Japan, with the largest share of foreign-owned U.S. patents, has seen that share decline since the early 1990s. The EU's share fell from the late 1980s to the early 1990s, then stabilized at about 35 percent. The share of selected Asian economies (China, South Korea, Singapore, Taiwan, and Malaysia) rose steeply, from less than 2 to 12 percent, which is indicative of their rapid technological progress (figure O-11).

U.S. inventors also are well represented in the patent portfolios of other nations. In most other countries, nonresident inventors account for a larger share of patents than they do in the United States. Among Western industrial countries, the foreign-owned share ranges from 60 percent in Germany to 90 percent in Canada; however, it is only 10 percent in Japan. In most countries, the United States received more

Figure O-9
International S&E articles cited, by country/region: 2001



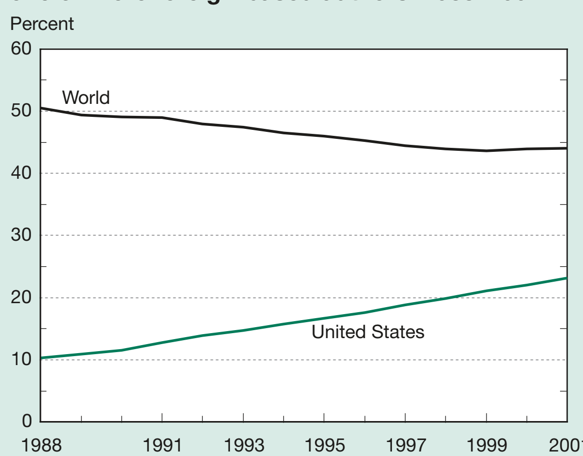
EU European Union

NOTE: For EU members, EU articles cited refer to those of other EU countries. Other Asia excludes Japan. Asian articles cited by Japan and other Asian countries exclude domestically cited articles.

SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science & Engineering Indicators – 2004

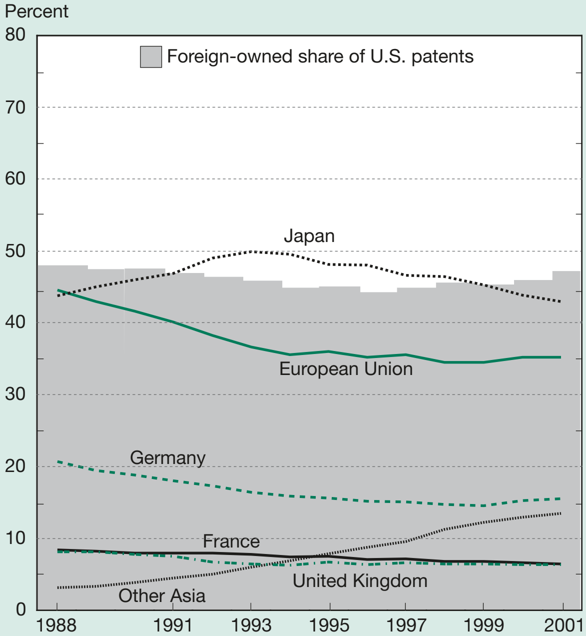
Figure O-10
World's internationally coauthored articles with one or more U.S. authors and U.S. articles with one or more foreign-based authors: 1988–2001



SOURCES: Institute for Scientific Information, Science Citation Index and Social Sciences Citation Index; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science & Engineering Indicators – 2004

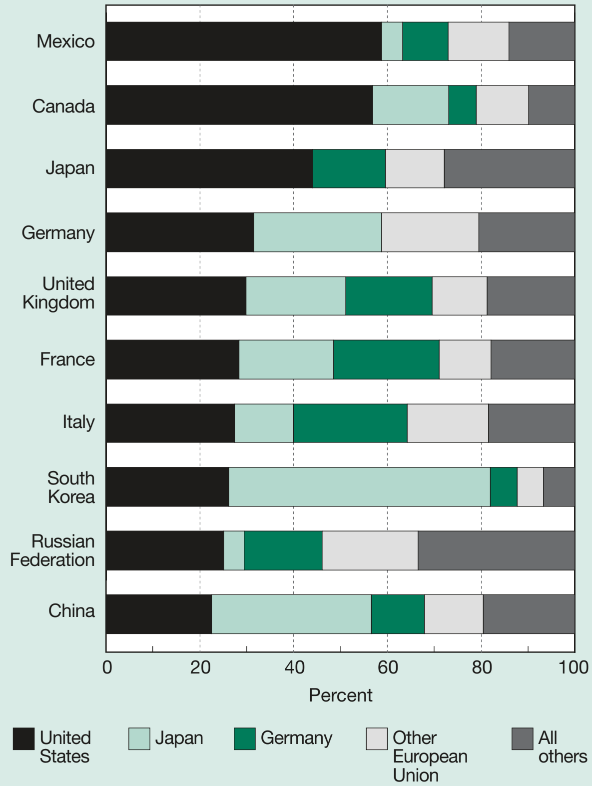
Figure O-11
Foreign-owned U.S. patents, by selected country/region: 1988–2001



SOURCE: U.S. Patent and Trademark Office, special tabulations. See appendix table 6-10.

Science & Engineering Indicators – 2004

Figure O-12
Foreign-owned patents, by selected country: 2000



SOURCE: World International Property Organization, Industrial Property Statistics (Geneva, Switzerland, 2003). See appendix table 6-14.

Science & Engineering Indicators – 2004

foreign patents than any other nation, followed by Japan and Germany. In China and South Korea, Japanese inventors led those from other countries (figure O-12).

Many countries are trying to stimulate university-industry links as a means of improving their innovation performance. Patents based on research results have become a valued output of academic R&D. In the United States, the number of patents awarded to academic institutions has risen to more than 3,000 annually (figure O-13). This is more than 5 percent of all U.S. inventor patents, compared with a share of about 1 percent 2 decades ago. During that period, the incidence of citations to S&E literature in all U.S. patents has risen to an average of about two citations per patent (figure O-13). The time lag between article publication and citation in patents has grown quite short, and the cited articles often appear in basic science journals, indicating an increasing tie between basic science and practical application.

S&E Workforce Trends

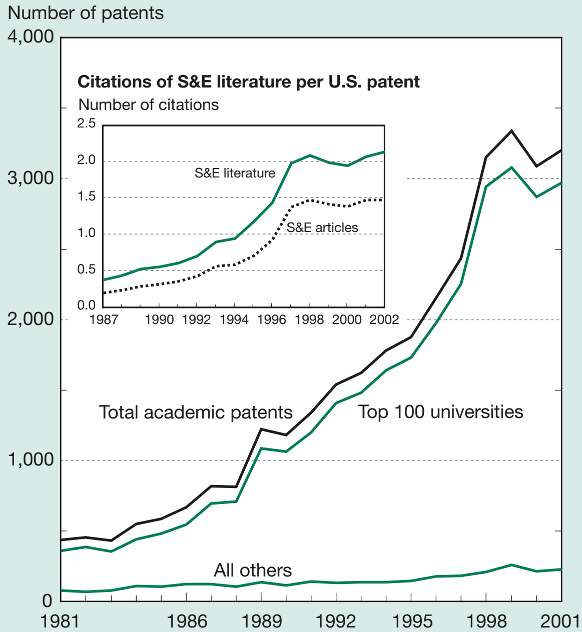
Many industrial countries have slow-growing or stagnating populations with rising average ages, and their young citizens are not inclined to enter S&E careers. Outflows of highly educated personnel to other countries, especially to the United States, are a growing focus of policy attention. Advanced developing nations are expanding their higher education systems and the high-technology sectors of their economies in an effort to develop internationally competitive centers of excellence. In the past, these countries have been a main source of internationally mobile scientific and technical talent, but recently some of them have developed programs designed to retain their highly trained personnel and to even attract people from abroad. Because their more developed counterparts also face this issue, these trends have set up the potential for growing competition in the recruitment of foreign talent and for continuing international mobility of firms to low-cost countries with well-trained workforces. In the United States, the issue of expanding the domestic S&E degree production is receiving increased attention.

Status of U.S. S&E Workforce

At the end of the past decade, about one-third of the 10.5 million people with bachelor's or higher degrees in S&E were employed in S&E occupations, holding job titles such as engineer; mathematician; and physical, life, computer, or social scientist.[5] Others worked in jobs not classified as

[5]The most recent available detailed data on the total S&E workforce are for 1999, but the broad patterns and trends discussed here are unlikely to be materially changed by more recent information, with one major exception. Data based on the 2000 Census show much higher rates of foreign-born scientists and engineers than earlier estimates derived from a sample based on the 1990 Census.

Figure O-13
Patents granted to U.S. universities and colleges: 1981–2001

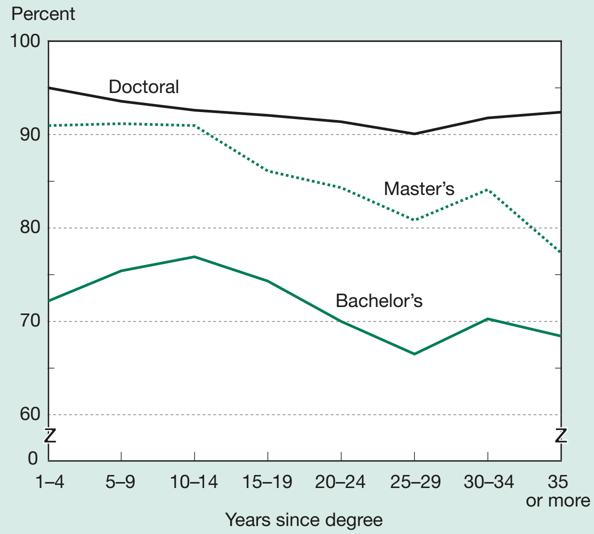


NOTES: Citations to S&E articles are references to S&E articles in journals indexed and tracked by the Institute for Scientific Information's (ISI) Science Citation Index. Citations to S&E literature are references to S&E articles within and outside of ISI's coverage and non-article material such as reports, technical notes, conference proceedings, etc. Citation counts are based on a 12-year window with a 3-year lag. For example, citations for 2000 are references made in U.S. patents issued in 2000 to articles published in 1986-97. 2002 patent data are preliminary and subject to change. Average patent citations refer to all U.S.-issued patents.

SOURCES: U.S. Patent and Trademark Office, Institute for Scientific Information; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-54.

Science & Engineering Indicators – 2004

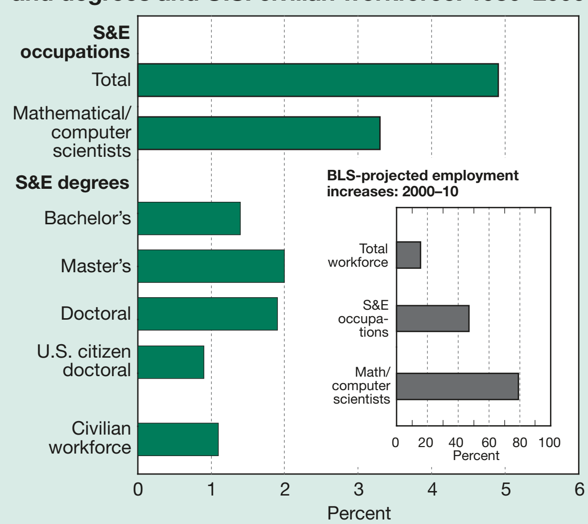
Figure O-14
S&E highest degree holders employed in jobs closely or somewhat related to highest degree, by years since degree: 1997



SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), 1999.

Science & Engineering Indicators – 2004

Figure O-15
Average annual growth rate of S&E occupations and degrees and U.S. civilian workforce: 1980–2000



BLS Bureau of Labor Statistics

SOURCES: U.S. Department of Labor, BLS, and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov.

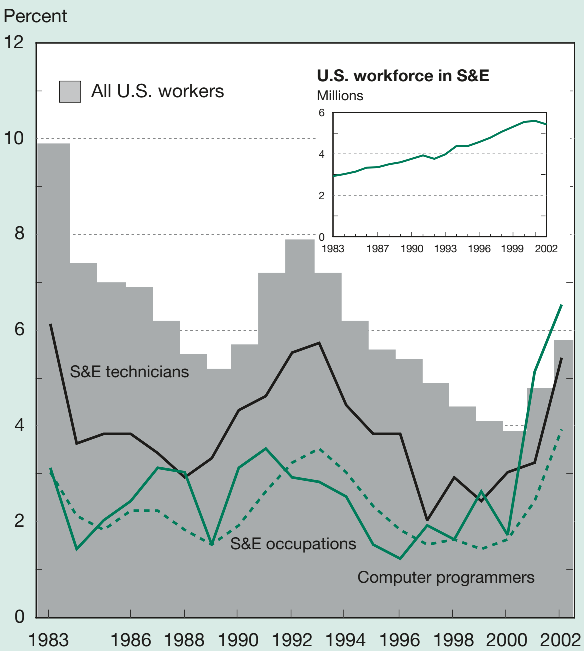
Science & Engineering Indicators – 2004

S&E, such as managerial, marketing and sales, planning, and quality control positions. In both types of jobs, their role is critical to the functioning of a knowledge-based economy. They produce new knowledge; transform it into innovative products, processes, and services; move these innovations into the marketplace; and develop entirely new markets. Even individuals who are not working in an S&E occupation in the later stages of their careers generally regard the nature of their S&E degree as related to their job (figure O-14).

The long-term growth of the S&E labor force has been considerably stronger than that of the civilian labor force as a whole, indicating a trend toward growing technical sophistication (figures O-1 and O-15). Since 1980, the number of S&E positions has risen at more than four times the rate of growth for all jobs, reflecting the transformation of the U.S. economy. Even if the creation of mathematician and computer scientist jobs is omitted, growth in the remaining S&E occupations still outpaced the growth of the civilian labor force as a whole. The growth rate of U.S. S&E degree production has exceeded the growth rate of the civilian labor force but lagged behind the growth rate of S&E occupations, which is indicative of the key role of foreign scientists and engineers in the U.S. S&E labor force. In fact, the number of S&E doctorates earned by U.S. native-born and naturalized citizens has grown more slowly than the growth rate of the overall civilian labor force.

The U.S. Bureau of Labor Statistics (BLS) projects differential growth that favors S&E occupations over the decade ranging from 2000 to 2010. Much of the projected difference is attributable to expected strong growth in mathematics/computer-related occupations. Even without the addition of these jobs, the growth rate of S&E jobs remains higher than the rate for the labor force as a whole, but not by an order of magnitude. Because the BLS projection has not been updated to reflect current difficulties in the information technology (IT) sector, those growth estimates are likely to change. An indication of the difficulties that the IT sector—and S&E employment in general—faces can be gleaned from employment and unemployment trends reflected in the BLS Current Population Survey.[6] BLS figures show that employment in S&E occupations rose strongly throughout the 1990s until 2001 (when it reached a record 5.6 million), and then declined to 5.4 million in 2002. Unemployment rates for S&E occupations, which traditionally have been lower than the national average for the civilian labor force as a whole, rose strongly in 2002. Breaking precedent, the unemployment rate for computer programmers exceeded the national average in 2002, and the rate for S&E technicians approached the average (figure O-16). Whether this signals a temporary or long-term slowdown in the IT sector is unclear.

Figure O-16
Unemployment rate, by selected occupations: 1983–2002



SOURCES: U.S. Department of Labor, Bureau of Labor Statistics, Current Population Survey; and National Bureau of Economic Research, Merged Outgoing Rotation Groups, special tabulations.

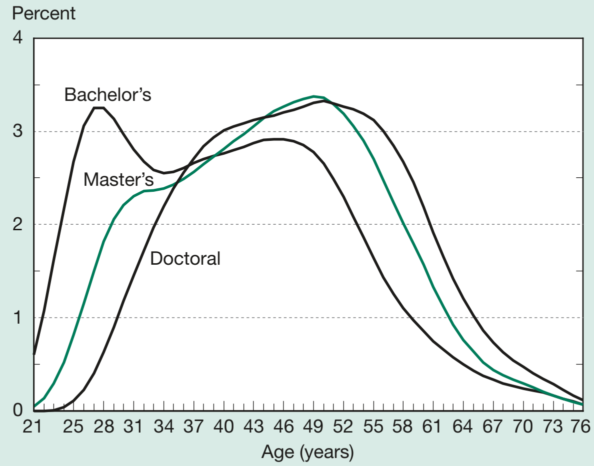
Science & Engineering Indicators – 2004

[6]This survey uses different definitions of S&E occupations than discussed previously.

Retirements and Demographic Shifts

Unless current retirement rates change dramatically, the S&E workforce in the United States will experience rapid growth in total retirements over the next 2 decades. More than half of those with S&E degrees are age 40 or older, and the 40–44 age group is nearly four times as large as the 60–64 age group. Without changes in degree production, retirement behavior, or immigration, these figures imply that the U.S. S&E workforce will continue to grow, but at a slower rate than before, and that its average age will increase over the next 2 decades (figure O-17). These trends have placed attention on the needed replenishment of the U.S. S&E workforce, with a focus on domestic degree production.

Figure O-17
Age distribution of individuals with S&E degrees in U.S. workforce: 1999

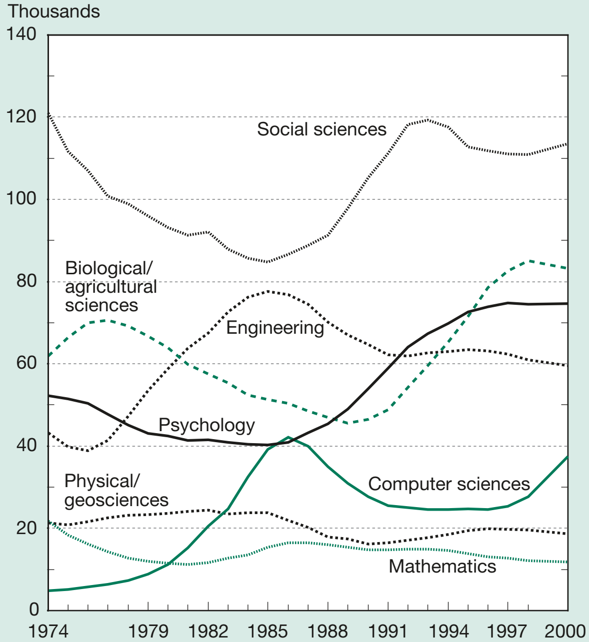


SOURCE: National Science Foundation, Division of Science Resources Statistics, Scientists and Engineers Statistical Data System (SESTAT), special tabulations.

Science & Engineering Indicators – 2004

In recent decades, universities and colleges in the United States have educated a growing share of the college-age population. In 1980, there were 22 bachelor's degrees awarded per 100 24-year-olds (taken here as a proxy of the college-age population); by 2000 that number had risen to 34. During that period, the S&E share of all baccalaureate degrees fluctuated between 30 and 34 percent. The share of natural science and engineering (NS&E) degrees was more volatile, rising from 16 to 21 per 100 by the mid-1980s, and then declining to the current 17 per 100. Over the past decade, the number of bachelor's degrees in all fields rose by 18 percent, and the numbers for S&E and NS&E degrees increased by 21 and 24 percent, respectively. Increases in S&E degrees reflect strong growth in biological sciences, computer sciences, and psychology. However, since 1990, bachelor's degrees in engineering have declined by 8 percent and degrees in mathematics have dropped by about 20 percent (figure O-18).

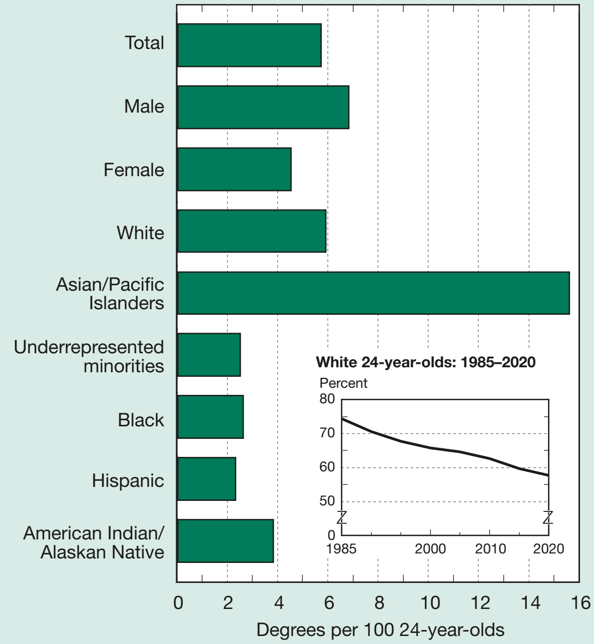
Figure O-18
Bachelor's degrees earned in selected S&E fields: 1974–2000



SOURCE: National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov.

Science & Engineering Indicators – 2004

Figure O-19
Ratio of NS&E bachelor's degrees to 24-year-old population: 2000



NS&E natural sciences and engineering

SOURCES: U.S. Bureau of the Census, Population Division; U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-4 and table 2-8.

Science & Engineering Indicators – 2004

Demographic changes in the United States complicate the task of increasing the number of S&E degrees relative to the relevant age cohort. The proportion of non-Hispanic whites among 24-year-olds has been on a steady multidecade decline, falling from 74 percent in 1985 to a projected 58 percent by 2020. This shift largely reflects strong growth of population groups, especially Hispanics, that traditionally have been underrepresented in S&E. Students from these population groups earn associate's degrees more often than they earn bachelor's degrees. In recent years, their overall attainment rate for bachelor's degrees has been about half that of whites, and in NS&E, it has been less than half that of whites (figure O-19). Complicating the picture, S&E attainment rates by white non-Hispanic men have been on a long-term downturn that has been approximately counterbalanced by the rising participation of women.

Even as larger proportions of U.S. citizens avail themselves of higher education, the nation has lost the advantage it held for several decades as the country offering by far the most widespread access to higher education. Starting in the late 1970s and accelerating in the 1990s, other countries built up their postsecondary education systems, and a number of them now provide a first-level college degree to at least one-third of their college-age cohort. There is evidence that many countries are trying to increase production of degrees in NS&E. They appear to be succeeding in that goal well beyond what the United States has been able to achieve over the past 25 years (figure O-20).

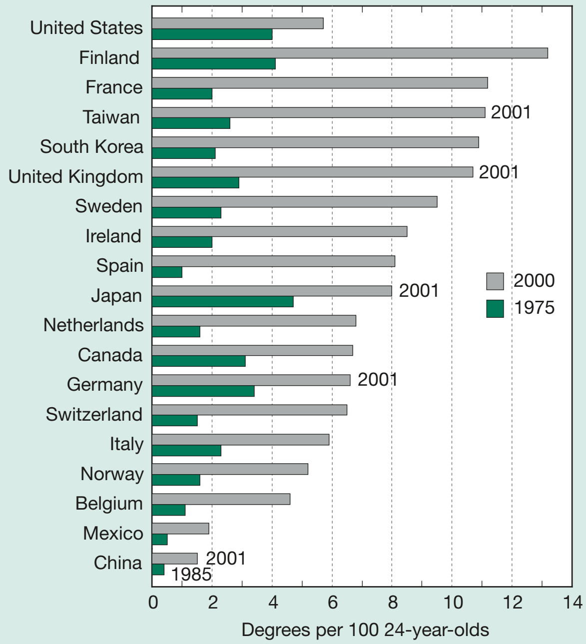
Degree Trends

Over the past 2 decades, three prominent trends in S&E degrees emerged. Among both U.S. citizens and noncitizens, women earned larger numbers of degrees, whereas the number of degrees earned by men rose more slowly or stagnated. Among U.S. citizens, underrepresented minorities increased their share of degrees, chiefly during the 1990s. More foreigners earned U.S. S&E degrees, especially advanced degrees, increasing both their total number and their share.

In 2000, women earned between 40 and 60 percent of bachelor's degrees in mathematics; physical, earth, ocean, and atmospheric sciences; and agricultural and biosciences. They also earned more than 75 percent of psychology degrees. Their share of engineering degrees increased from 2 percent in the mid-1970s to 20 percent, but their computer science share remained below one-third. The proportion of bachelor's degrees earned by white students declined from 87 percent in 1977 to 68 percent in 2000. During the 1990s, the number of degrees earned by white students decreased in all S&E fields except computer sciences, biological and agricultural sciences, and psychology.

The number of new S&E doctoral degrees rose strongly during the 1980s, and that trend continued through 1998; it then declined from its high of 28,800 to 27,100 in 2001.

Figure O-20
Ratio of first university NS&E degrees to 24-year-old population, by selected country/economy: 1975 and 2000 or most recent year

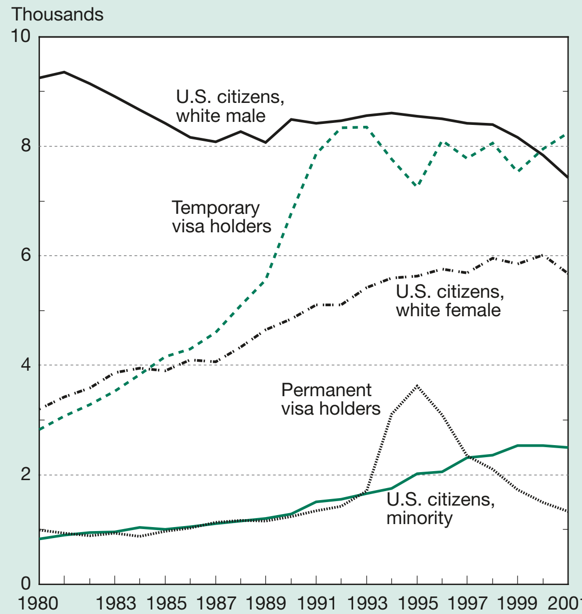


NS&E Natural sciences and engineering

SOURCES: U.S. Bureau of the Census, Population Division; national statistical agencies; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database system, http://caspar.nsf.gov. See appendix table 2-33.

Science & Engineering Indicators – 2004

Figure O-21
S&E doctorates earned by U.S. citizens and noncitizens: 1980–2001



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations.

Science & Engineering Indicators – 2004

Among U.S. citizens, the number of white non-Hispanic men earning Ph.D.s dropped from about 9,400 in the early 1980s to 7,500 by 2001, whereas degrees earned by white non-Hispanic women almost doubled and degrees earned by minority groups approximately tripled. Growth in S&E doctorates earned by temporary visa holders was strong during the 1980s, and that number has fluctuated at around 8,000 since the early 1990s. Their share of U.S. S&E doctorates rose from 17 to 33 percent over the period, with even higher percentages in mathematics, computer sciences, and engineering. The number of degrees earned by permanent visa holders spiked during the 1990s (reflecting the conversion to permanent visa status of Chinese students) but has since declined to previous levels (figure O-21). Overall S&E master's degree trends mirror those for doctorates, with the foreign-student component earning in excess of 25 percent of degrees earned, more than double the rate in the late 1970s.

The United States attracts many scientists and engineers who come here to work, and U.S. colleges and universities have trained many scientists and engineers from other countries. From 1985 to 2001, U.S. colleges and universities awarded about 150,000 S&E doctorates, 350,000 S&E master's degrees, and 270,000 S&E bachelor's degrees to temporary visa students. Many of these younger scientists and engineers stay on after completing their education, particularly if they receive doctoral degrees, and they continue to contribute to U.S. strength in R&D. Others go home or leave for other destinations, but often maintain ties with U.S. colleagues that contribute to collaborations across national boundaries (figure O-22).

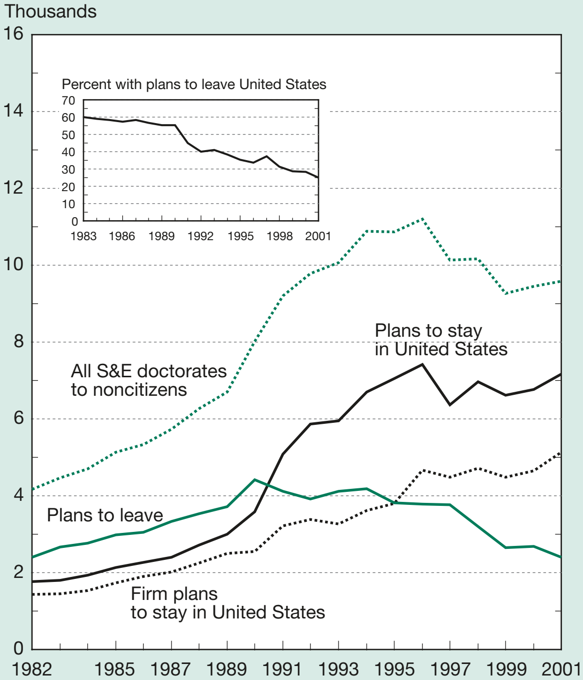
U.S. Reliance on Foreign Talent

The United States has benefited for decades from a steady inflow of foreign scientists and engineers and continues to place greater reliance than other countries on foreign-born talent. This reliance has grown in both absolute numbers and relative share of foreign-born individuals in the workforce, especially during the 1990s. Census-based estimates of the proportion of foreign-born scientists and engineers working in the United States in S&E occupations[7] in 1990 and in 2000 show steep increases at every degree level (figure O-23). These increases reflect both the immigration patterns of the 1990s and the inflow of foreign specialists under various work visa categories.[8] The most recent figures, which are based on more complete data, exceed earlier minimum estimates developed without data on the entry of foreign-degreed nationals into U.S. S&E occupations from 1990 to 2000. These earlier (1999) estimates from the National Science Foundation's Scientists and Engineers Statistical Data System indicated 11 percent of bachelor's degree holders

[7]People in occupations classified as S&E jobs. For technical reasons, postsecondary teachers are omitted.

[8]These figures exclude foreign-born, U.S.-educated scientists and engineers hired by U.S. firms into positions at their overseas affiliates.

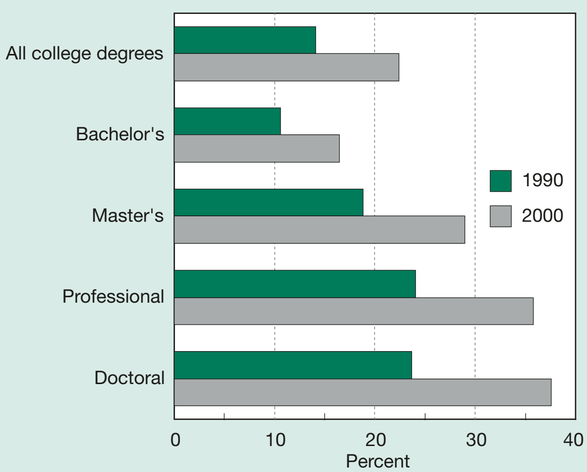
Figure O-22
Foreign student plans after receipt of U.S. S&E doctorate: 1982–2001



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations.

Science & Engineering Indicators – 2004

Figure O-23
Foreign-born scientists and engineers in U.S. S&E occupations, by degree level: 1990 and 2000



NOTE: Data exclude postsecondary teachers because field of instruction was not included in occupation coding for the 2000 Census.

SOURCE: U.S. Bureau of the Census, Public Use Microdata Sample (PUMS), 1990 and 2000 (5-percent sample).

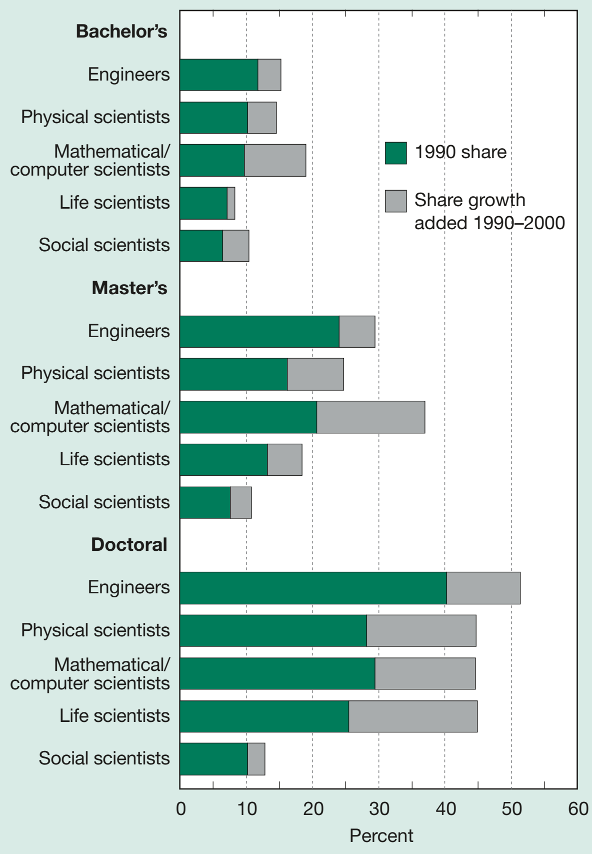
Science & Engineering Indicators – 2004

in S&E occupations were foreign born, compared with 17 percent according to the 2000 Census data; 19 percent of master's degree holders, compared with 29 percent; and 29 percent of doctorate holders, compared with 38 percent.

The share of foreign-born individuals varies according to their occupation and degree level. In 2000, approximately half of all doctorate holders among engineers; physical, life, and computer scientists; and mathematicians were foreign born. Among computer scientists and mathematicians, more than one-third of master's degree holders and approximately one-fifth of bachelor's degree holders were foreign born (figure O-24).

Graduate education in the United States has long been attractive to foreign students, and, over the years, their representation among all S&E graduate students has approached 30 percent. Foreign students with temporary visas represent half of all graduate enrollment in engineering, mathematics, and computer sciences, and one-third of enrollment in the physical, earth, ocean, and atmospheric sciences combined

Figure O-24
Foreign-born scientists and engineers in U.S. S&E occupations, by degree level and field: 1990 and 2000

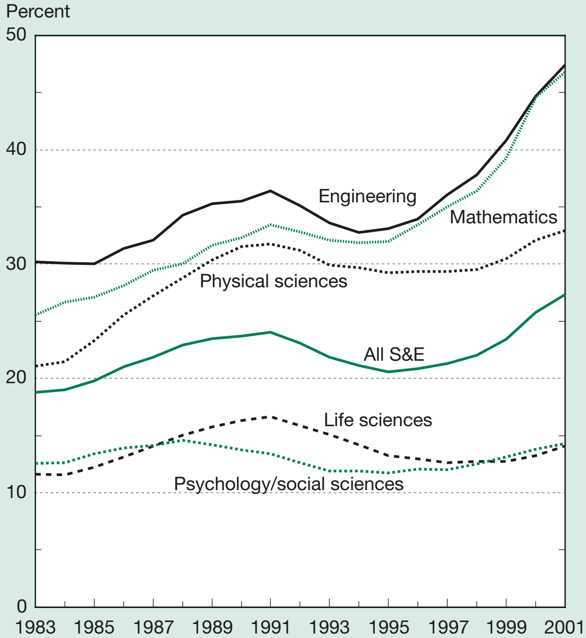


NOTE: Data exclude postsecondary teachers because field of instruction was not included in occupation coding for the 2000 Census.

SOURCE: U.S. Bureau of the Census, Public Use Microdata Sample (PUMS), 1990 and 2000 (5-percent sample).

Science & Engineering Indicators – 2004

Figure O-25
S&E graduate students with temporary visas, by field: 1983–2001



NOTE: S&E includes health sciences.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Postdoctorates and Graduate Students in Science and Engineering, special tabulations.

Science & Engineering Indicators – 2004

(figure O-25). The share of foreign students is much lower among undergraduates, as they earn approximately 4 percent of S&E bachelor's degrees; this rate has generally been steady. However, foreign students do earn approximately 8 percent of engineering and computer science bachelor's degrees.

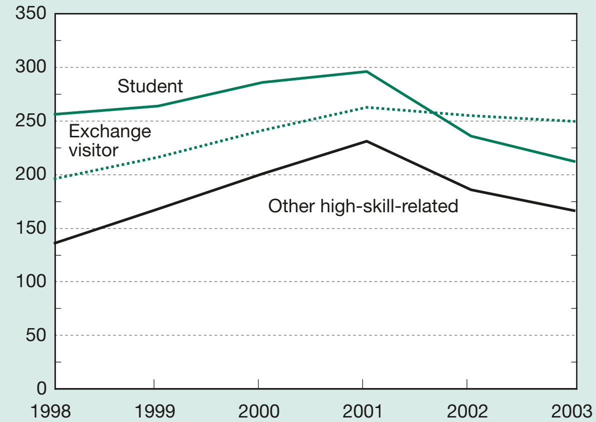
The terrorist attacks of September 2001 have added a security dimension to ongoing discussions about the future of the U.S. S&E workforce, which focus on how and with whom to fill new positions and existing jobs vacated by retirement, especially in government or security-related areas. Available data indicate an initial reaction to the new security environment: the number of high-skill-related visas issued to students, exchange visitors, and others in 2002 was significantly lower than the number issued in 2001, and it continued to decline in 2003[9] (figure O-26). These data reflect both a drop in applications for all visa classes, except exchange visitors, and higher U.S. Department of State visa refusal rates (table O-1).

Academic Employment

U.S. universities and colleges play a unique role in the U.S. R&D system. They conduct about half of the nation's basic research and, in so doing, train successive generations of scientists and engineers for R&D and other types of positions in all sectors of the economy. Like other sectors, academia is facing rising retirement rates among its largely doctorate-level scientists and engineers. More than 30 percent of its faculty are 55 years of age or older, and the total of individuals below age 45 has fallen to 36 percent (figure O-27). However, barring changes in degree production, retirement behavior, or foreign participation, there appear to be sufficient numbers of new doctorate holders to replace retiring incumbents and allow for some growth.

[9]Data are for October 1 through September 14 of each year.

Figure O-26
Student, exchange visitor, and other high-skill-related temporary visas issued: FY 1998–2003



NOTES: Student visa is F-1, exchange visitor visa is J-1, and other visa categories include L-1, H-1B, H-3, O-1, O-2, and TN. See appendix table 3-24 for visa category definitions.

SOURCE: U.S. Department of State, Immigrant Visa Control and Reporting Division, 1998–2002.

Science & Engineering Indicators – 2004

Table O-1
Visa applications and refusals by major high-skilled categories: FY 2001–2003

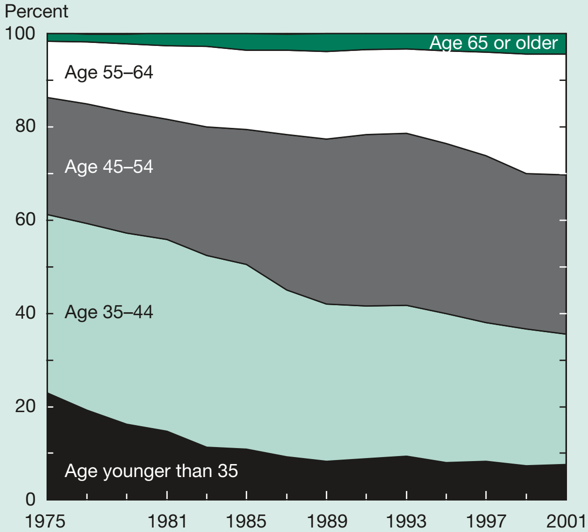
Visa action	2001	2002	2003
		Thousands	
Applications			
Student (F-1)	400.0	346.4	325.8
Exchange visitor (J-1)	279.5	278.6	295.6
Other high-skill related	248.4	203.6	200.2
		Percent	
Refusals			
Student (F-1)	27.6	33.3	35.2
Exchange visitor (J-1)	7.8	10.5	15.9
Other high-skill related	9.6	11.9	17.8

NOTES: Data for each fiscal year is through September 14 and excludes last 2 weeks of reporting. Other high-skill-related visas include L-1, H-1b, H-3, O-1, O-2, and TN visas.

SOURCE: U.S. Department of State, Immigrant Visa Control and Reporting Division, administrative data.

Science & Engineering Indicators – 2004

Figure O-27
Age distribution of academic S&E doctorate holders employed in faculty positions: 1975–2001

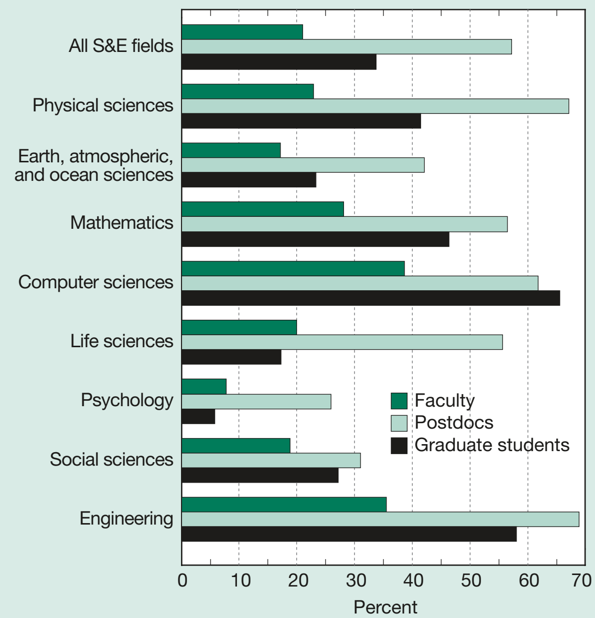


NOTE: Faculty are employed full time as full, associate, and assistant professors and instructors.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-21.

Science & Engineering Indicators – 2004

Figure O-28
Foreign-born share of S&E doctoral faculty, postdocs, and graduate students, by major degree field: 2001



NOTE: Because data include only U.S. doctorate holders, the foreign-born share is understated.

SOURCES: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), Survey of Doctorate Recipients, special tabulations; and NSF/SRS, Survey of Postdoctorates and Graduate Students in Science and Engineering.

Science & Engineering Indicators – 2004

Employment of foreign-born S&E doctorate holders in academia shows a similar, but attenuated, pattern to that of industry. A minimum estimate is that about 25–30 percent of S&E doctorate holders employed in academia are foreign born; the rate is lower among faculty and higher among postdocs. Among faculty members, computer sciences, engineering, and mathematics have the highest shares of foreign-born individuals, ranging from 28 to 38 percent. Among postdocs, who play an important role in academic research, these figures are significantly higher, reaching almost 70 percent for engineering and 55–65 percent for most fields (figure O-28).

Postdoc positions have long played an important part in the early careers of physical and life scientists, and they have become more prominent in other fields as well. These positions are intended to provide further specialized training beyond the doctorate level, and the number of these positions has more than doubled since the mid-1970s, rising from about 22,000 to 47,000.[10] Almost all of them are in academia, but other sectors, chiefly industry, account for 10–14 percent. At present, most individuals in postdoc positions name reasons for accepting these positions that are consistent with the objective of obtaining further specialized training. For example, in 2001, only 12 percent stated that "other employment [was] not available," a sharp drop from the 32 percent giving that response in 1999.

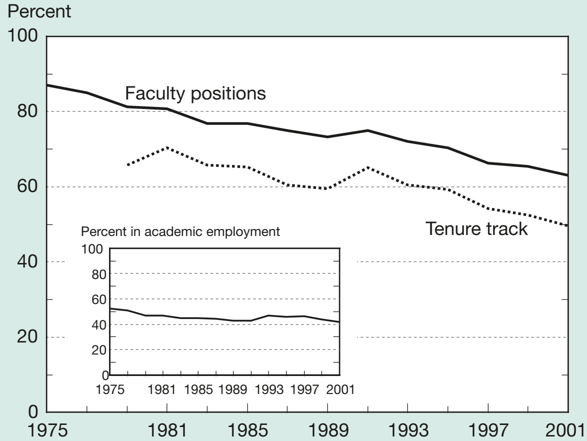
An academic postdoc position is not necessarily a stepping stone to an academic faculty position. Of individuals in postdoc positions in April 1999, 37 percent were still in a postdoc position 2 years later, 12 percent had obtained tenure-track faculty positions, 20 percent held other types of positions at educational institutions, and 31 percent had found nonacademic employment.

The perception that most S&E doctorate holders work in academia has been outdated for many years. Since the early 1980s, more than half of all S&E doctorate holders have worked in industry, government, nonprofit institutions, or elsewhere. That trend is most readily apparent for young Ph.D.s in full-time positions.[11] Over the past 3 decades, growing numbers of these S&E Ph.D.s have found employment outside academia as academia's share has declined from 52 to 42 percent. Among individuals with academic appointments, growing numbers are hired for nonfaculty and postdoc positions. By 2001, only 63 percent held faculty positions, and only half were in tenure-track jobs (figure O-29).

[10]This number includes postdocs with non-U.S. doctorates.

[11]Young Ph.D.s are defined here as having earned their doctorate 4–7 years earlier.

Figure O-29
Faculty and tenure-track status of young academic S&E doctorate holders: 1975–2001



NOTE: Data are for individuals whose doctorates were earned 4–7 years earlier.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations.

Science & Engineering Indicators – 2004

Health of U.S. High Technology

Indicators of the competitiveness of a nation's high-technology sectors provide a good measure of the performance of its S&T system. A nation's competitiveness may be judged by its ability to produce goods and services that find demand both in the global marketplace and at home while maintaining or improving its citizens' standard of living. For high-wage nations like the United States, high-technology industries and the S&E base on which they rest are the means of remaining competitive in today's global market.[12] These industries create new markets; produce a large share of innovations in goods, services, and processes; have high value-added production and above-average compensation levels; and compete in international markets. The results of their activities diffuse throughout the economy, leading to increased productivity and business expansion.

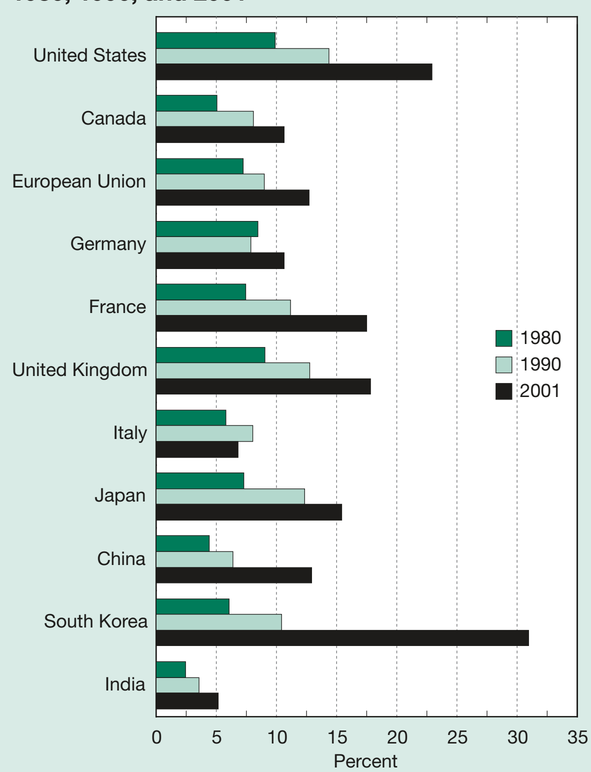
U.S. Performance in Knowledge-Intensive Industries

The U.S. economy continues to be the world's largest, ranking high on all measures of high-technology competitiveness. The global market for high-technology products has been growing faster than the market for other manufactured goods, increasing by a real growth rate that averages nearly 6.5 percent, compared with 2.4 percent for other manufactured goods. High-technology industries are driving economic growth around the world: their share of global manufacturing output rose from approximately 8 to 16 percent over the past 2 decades (figure O-30).

Many other nations have advanced their technological capacity and are challenging U.S. prominence in a variety of technology areas. The U.S. share of the global high-technology market, measured as the percentage of global industry shipments, declined from a high of 33 percent in the early 1980s to below 30 percent in 1991; in recent years, it has held steady in the 32–33 percent range. The EU market share has gradually declined over the past 2 decades, largely reflecting losses by Germany, the United Kingdom, and Italy; only France gained share over the period. Declines by the EU and Japan contrast with the strong rise of China and South Korea (figure O-31).

The United States continues to hold the largest world market shares in four of the five high-technology industry sectors, with U.S. companies generally losing ground to competitors during the 1980s and gaining it back during the 1990s. The only exception is in pharmaceuticals, where the EU has held the lead position for the past 2 decades at 30–34 percent (figure O-32). In aerospace, the United States has accounted for about half of all shipments since the late 1990s but has lost some ground to the EU (30 percent in 2001). China showed strong growth in that sector, increasing

Figure O-30
High-technology industry share of total manufacturing output, by selected country/region: 1980, 1990, and 2001



SOURCE: Global Insight, Inc., World Industry Service database, 2003.

Science & Engineering Indicators – 2004

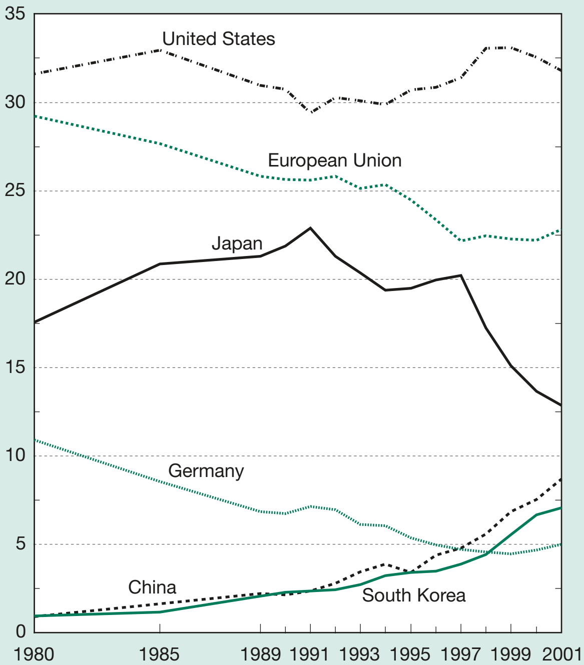
[12]Following the OECD definition, high-technology industries are defined by their R&D intensity and include aerospace, pharmaceuticals, computers and office machinery, communications equipment, and scientific instruments.

from less than 1 percent to nearly 7 percent in 2001, whereas Brazil's share dropped sharply, falling to 3 percent from 15 percent 2 decades earlier. China registered strong gains in the communications equipment and computers and office machinery industries; South Korea also showed consistent growth in the latter area.

Exports reflect the success of an economy's products in international markets. U.S. high-technology exports declined from 23 to 19 percent of the world's total during the 1990s, but the United States continued to produce a positive trade balance in high-technology goods. (The United States ranked second behind the EU, which also lost export market share, as did Japan.) In contrast, the remainder of the Asian region has rapidly gained market share over the past 2 decades; the combined high-technology exports of China, South Korea, Malaysia, Singapore, and Taiwan rose from 8 percent in the early 1980s to nearly 28 percent in 1999. The flattening of these countries' market share in 2000 and 2001 reflects downturns in exports of communications equipment and computers and office machinery (figure O-33).

The decades-long growth in the importance of the U.S. service-sector industries to the nation's economy has largely been driven by communications, financial, business (including computer software development), education, and health services. These knowledge-intensive industries incorporate science, engineering, and technology in either their services or the delivery of their services. The first three industries

Figure O-31
Global high-technology market share, by selected country/region: 1980–2001

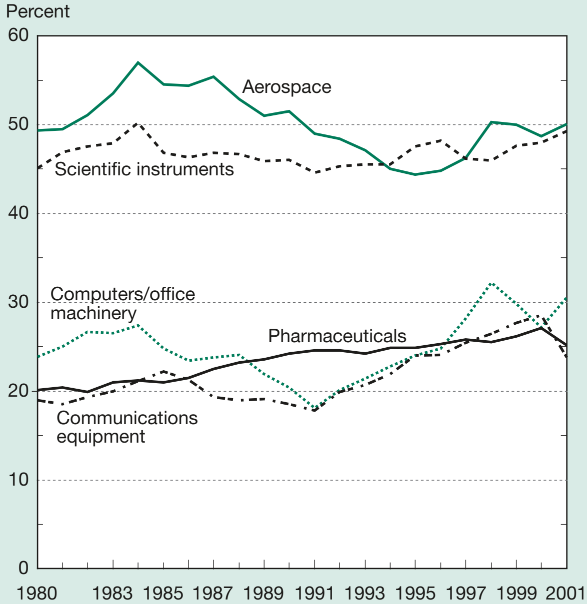


NOTE: Data for 1981–84 and 1986–88 are extrapolated.

SOURCE: Global Insight, Inc., World Industry Service database, 2003.

Science & Engineering Indicators – 2004

Figure O-32
U.S. global high-technology market share, by industry: 1980–2001

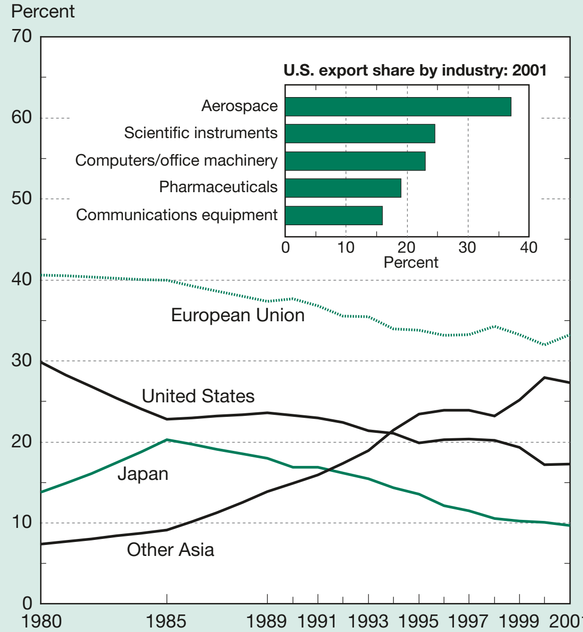


NOTE: Share of total world shipments by industry.

SOURCE: Global Insight, Inc., World Industry Service database, 2003.

Science & Engineering Indicators – 2004

Figure O-33
Global high-technology export share, by selected country/region: 1980–2001



NOTES: Other Asia includes China, South Korea, Malaysia, Singapore, and Taiwan. Data for 1981–84 and 1986–88 are extrapolated.

SOURCE: Global Insight, Inc., World Industry Service database, 2003.

Science & Engineering Indicators – 2004

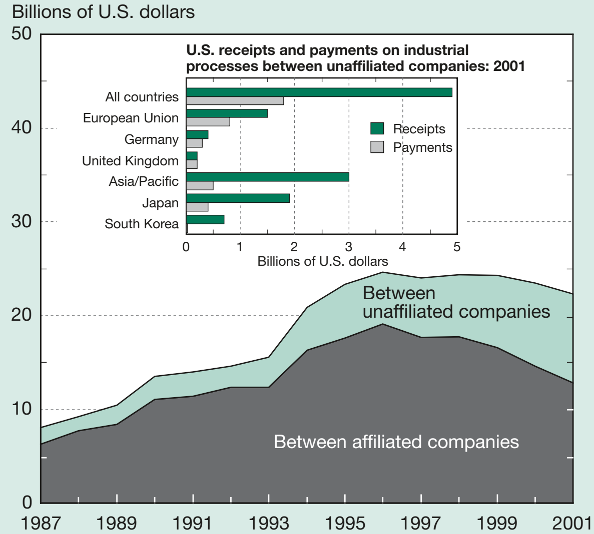
have global markets; health services and education tend to be more local, often largely provided by governments, and reflect population size differences, thus making international share comparisons less meaningful. Combined global sales of all five service industries rose in inflation-adjusted terms from $5.4 trillion in 1980 to $8 trillion in 1990, and then to $12.3 trillion in 2001 (figure O-34).

The United States has been the leading provider of high-technology services, accounting for about one-third of the world total throughout the past 2 decades. It held the largest market share in financial services (40 percent), followed by the EU and Japan (26 and 10 percent, respectively). It also led in communications services (38 percent compared with the EU's 24 and Japan's 11 percent). The EU held the largest market share in business services at 37 percent, followed by the United States and Japan (34 and 15 percent, respectively).

Firms increasingly license or franchise proprietary technologies, trademarks, and entertainment products across national boundaries, generating royalties and licensing fees from these transactions. The United States has traditionally shown a large and growing trade surplus in these intellectual-property transactions, which include cross-border payments between affiliated and unaffiliated companies. However, since the mid-1990s, this surplus has been declining. Examining only payments for use of intellectual property between unaffiliated companies more accurately reflects the value of technical know-how being traded. Here again the United States is a net exporter, with overall receipts about three times as large as U.S. payments to companies abroad (figure O-35).

Around the world, the availability of venture capital financing in the United States is viewed as key to the nation's rate of new firm creation and overall economic vitality. U.S. venture capital disbursements rose gradually from the early 1980s until 1994, reaching a level of just over $4 billion. These disbursements then rose more rapidly, reaching $22 billion by 1998 and soaring beyond $100 billion in 2000 at the height of the dot.com boom. Disbursals in 2001–02 dropped back to 1998–99 levels, which are still high by historical standards (figure O-36). During the 1990s, most funds

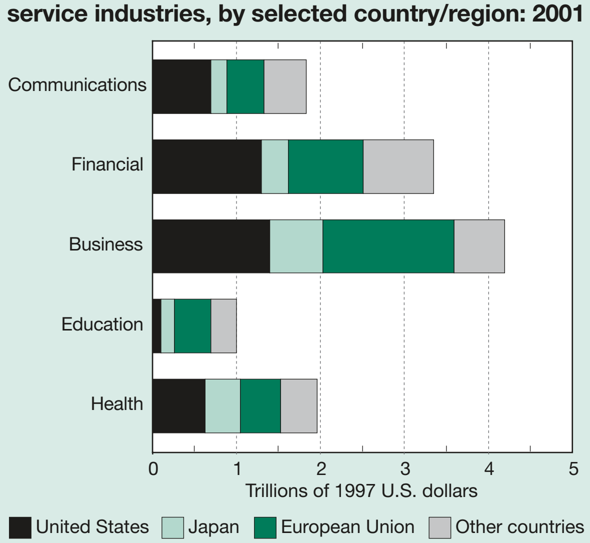
Figure O-35
U.S. trade balance in royalties and fees: 1987–2001



SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, Survey of Current Business.

Science & Engineering Indicators – 2004

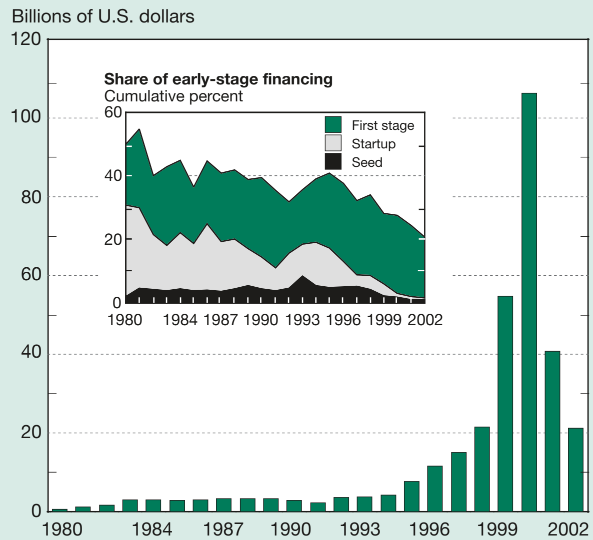
Figure O-34
Global revenue generated by knowledge-intensive service industries, by selected country/region: 2001



SOURCE: Global Insight, Inc., World Industry Service database, 2003.

Science & Engineering Indicators – 2004

Figure O-36
U.S. venture capital disbursements: 1980–2002



NOTE: Seed funds are for proof of concept, startup funds for product development/early marketing, and first-stage funds for capital replenishment.

SOURCE: Thomson Venture Economics, special tabulations.

Science & Engineering Indicators – 2004

were directed to companies engaged in computer hardware and software production and related services and to medical and health care firms. Internet-specific companies became the leading recipients in 1999–2000, receiving more than 40 percent of the total, and they continued to receive more than 20 percent of the total in 2001–02. In the United States, the availability of early-stage financing remains a concern because of a shrinking share of total disbursed funds. Funds for proof-of-concept work and early product development and initial marketing have fallen to a historic low of 1.5 percent.[13]

Conclusion

Many decades of investment in R&D have helped to lay the basis for an S&E system that generates about one-third of the world's research articles, a multitude of technological innovations, and numerous high-technology industries that exploit innovations to their profit and to the nation's economic benefit. The United States has maintained its scientific and technological edge in the world even as new centers of scientific and technical know-how and innovation have emerged. It attracts many of the world's best scientists and engineers, remains the world's leading producer of high-technology products, and benefits from the rapid growth of knowledge-intensive service industries. Its policies and practices are studied around the world as models that might be applied by other countries in their efforts to boost their competitive standing in a world that is moving toward more knowledge-intensive industries.

Although the United States remains the world's S&T leader, a collection of trends in indicators of U.S. S&T competitiveness paints a more differentiated picture. In R&D performance, the United States is slowly widening the gap with other leading nations and regions such as the EU, non-U.S. G-7 countries, and non-U.S. OECD nations. However, some non-OECD economies, including China, the Russian Federation, and Taiwan, are slowly raising their spending relative to that of OECD members. In S&E research output, as measured by publications in the world's key journals, the U.S. share continues to decline, indicative of the development of cutting-edge research capabilities elsewhere. The overall U.S. world market share in high-technology products is steady, but the nation's aerospace industry is losing market share. Although the U.S. balance in intellectual products trade remains positive, it is showing signs of a gradual decline.

A range of indicators traces a trend that shows growing competitive strength in the Asian region outside of Japan, chiefly in China, South Korea, Malaysia, Singapore, and Taiwan. Scientists based in those countries produce a growing share of the S&T articles appearing in the world's leading journals, and development of regional scientific collaboration (centered on China) is apparent. These Asian economies have an expanding world market share of high-technology production. In exports of high-technology products, they are gaining market share on all major industrial nations including the United States. They are increasing their production of S&E degrees with a special focus on NS&E, thus providing a growing stream of new technical talent for their economies. They have in place, or are instituting, policies and incentives to retain their highly trained personnel, attract expatriates, or otherwise benefit from their nationals working abroad, chiefly in the United States.

As nations have turned to the task of developing a broader base of knowledge-intensive industries, they face the necessity of rethinking their workforce needs. Many are further expanding their education systems, placing emphasis on S&T training. Japan and the mature industrial nations of Europe, which have aging and declining or stagnating populations, are seeking an inflow of scientists and engineers from abroad as well as the return of their own researchers from other countries. All of these nations face declining interest in S&E among their young people, and all emphasize the importance of attracting more women to S&E careers. Increasingly, these nations seek to attract foreign students: there is growing interest in what makes the United States attractive to people from around the world as a place to study and work.

The United States faces somewhat different issues connected with the development of the S&T workforce. Like the other industrialized nations, the United States faces a period of growing retirements among its S&E workforce. Unlike them, it has a growing population whose average age is projected to decline rather than increase. Its college-age population will increasingly be made up of minority group members, such as Hispanics, blacks, and American Indian/Alaskan Natives, whose current participation rates in S&E are half or less those of white non-Hispanic students. As lower proportions of white non-Hispanic men obtain S&E degrees, the importance of women and minorities pursuing degrees in these fields rises.

Over the past 2 decades, the U.S. S&E workforce has grown at more than four times the rate of total employment, in part because of the U.S. ability to integrate large numbers of foreign-born scientists and engineers into its workforce. Nevertheless, barring changes in current retirement, degree production, and immigration trends, the growth of the S&E workforce will slow down, leading to a rising average age.

Information about some key indicators is missing. This scenario does not include the potential effects on foreign scientists' longer term willingness to work or study in the United States caused by the nation's reaction to the attacks of September 2001. It does not reflect restrictions the U.S. government might place on foreign scientists' access to the United States. Most important, it does not include indicators on U.S.- and foreign-based firms' inclination to locate operations overseas in pursuit of new markets, well-trained talent, and lower costs.

[13]Early-stage financing includes seed funds for proof-of-concept, startup funds for product development and initial marketing, and first-stage funds for capital replenishment to initiate commercial manufacturing and sales.