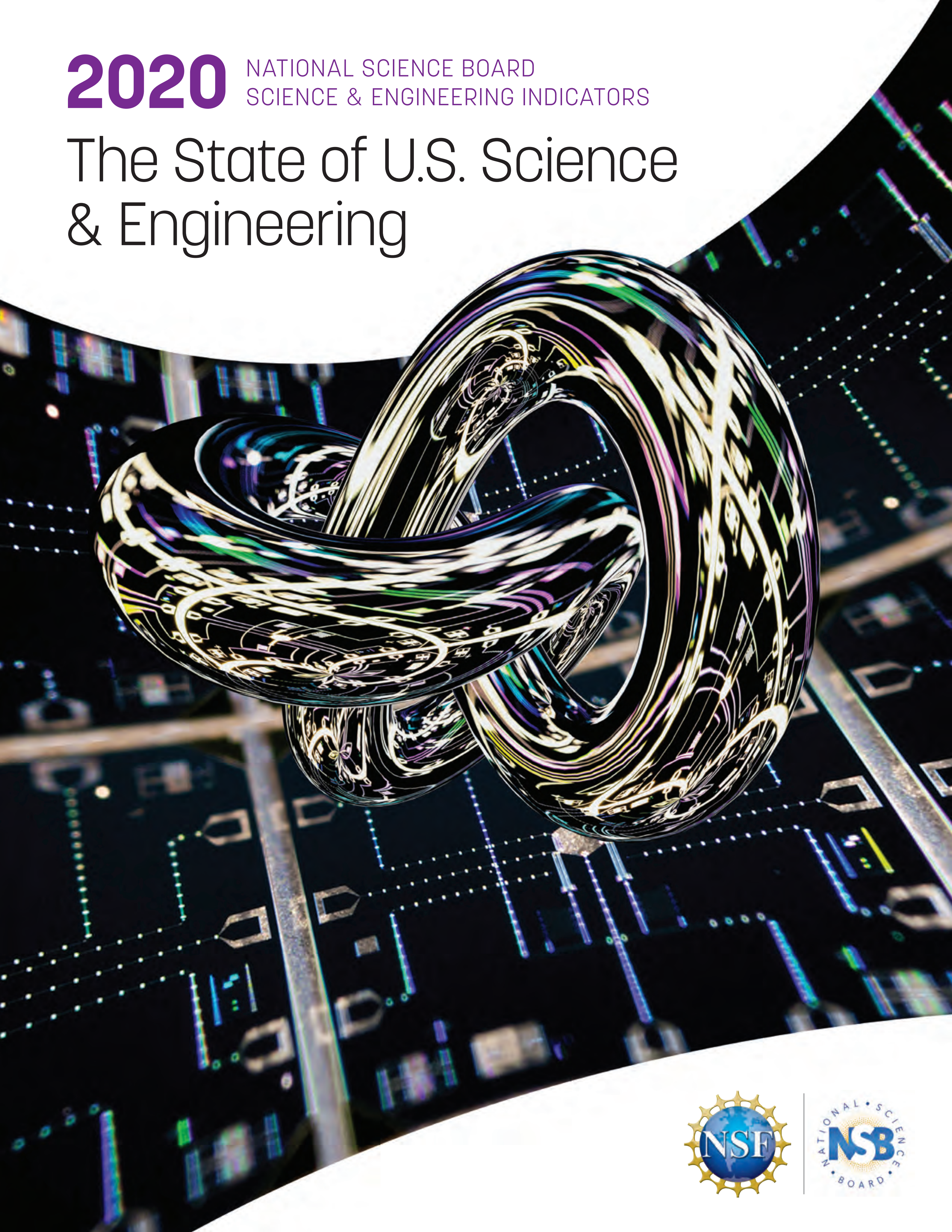
2020 NATIONAL SCIENCE BOARD SCIENCE & ENGINEERING INDICATORS

The State of U.S. Science & Engineering



National Science Board

2020 NATIONAL SCIENCE BOARD
SCIENCE & ENGINEERING INDICATORS

The State of U.S. Science & Engineering

January 2020
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Preface

The National Science Board (Board) is required under the National Science Foundation (NSF) Act, 42 U.S.C. § 1863 (j)(1) to prepare and transmit the biennial *Science and Engineering Indicators (Indicators)* report to the President and Congress every even-numbered year. The report is prepared by the National Center for Science and Engineering Statistics (NCSES) within NSF under the guidance of the Board. It is subject to extensive review by Board members, outside experts, interested federal agencies, and NCSES internal reviewers for accuracy, coverage, and balance.

Indicators provides information on the state of the U.S. science and engineering (S&E) enterprise over time and within a global context. *Indicators* is a factual and policy-neutral source of high-quality U.S. and international data; it does not offer policy options or make policy recommendations.

The indicators presented in the report are quantitative representations relevant to the scope, quality, and vitality of the S&E enterprise.

With the 2020 edition, *Indicators* is being redesigned to be maximally useful and accessible to a wide audience while maintaining the high quality of previous editions. It is being transformed from a single, voluminous report into a series of streamlined reports. *Indicators 2020* will consist of nine thematic reports produced and published beginning in the fall of 2019. In addition, *The State of U.S. Science and Engineering*, which highlights the key findings from the *Indicators 2020* thematic reports, will be delivered to the President and Congress on 15 January 2020 in fulfillment of the congressional mandate.

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Executive Summary

The State of U.S. Science and Engineering shows that the U.S. S&E enterprise continues to advance along several dimensions. The United States continues to perform the largest share of global research and development (R&D), generate the largest share of R&D-intensive industry output globally, award the largest number of S&E doctoral degrees, and account for significant shares of S&E research articles and citations worldwide. However, other nations, particularly China, are rapidly developing their science and technology (S&T) capacity. The changing global landscape affects the position of the United States relative to the other major global players. For example, the United States has seen its relative share of global S&T activity remain unchanged or shrink, even as its absolute activity levels have continued to rise.

Although total U.S. R&D investment has grown, funding and performance patterns have changed. Since 2000, the rise in U.S. R&D was driven mainly by the business sector, which continues to perform and fund most of the overall R&D in the United States, as well as most of the applied research and experimental development. During this period, the share of U.S. R&D funded by the federal government has declined. This decline is notable as federally funded R&D is an important source of support, particularly for the higher education sector and for the nation's basic research enterprise.

The U.S. S&E workforce continues to grow overall. The number of women and underrepresented minorities (URMs)—blacks, Hispanics, and American Indians or Alaska Natives—has grown. However, these groups remain underrepresented in the S&E workforce relative to their overall presence in the workforce and the population.

Science, technology, engineering, and mathematics (STEM) competencies in elementary, secondary, and post-secondary schooling are an important component of the pathway to an S&E-capable workforce. U.S. eighth graders continue to rank in the middle of advanced economies in international mathematics and science assessments. Similarly, U.S. national assessments of mathematics show little to no growth in scores over the past decade. At the same time, for higher education, the United States remains the destination for the largest number of internationally mobile students. Foreign-born noncitizens make up a considerable proportion of S&E doctorate recipients, including half or more of the doctorate recipients in engineering, mathematics and computer sciences, and economics. Many of these students stay in the United States after graduation. As such, foreign-born individuals account for a sizeable share of U.S. S&E employment, particularly among workers with graduate degrees.

Although *The State of U.S. Science and Engineering* does not forecast future outcomes, the data clearly show the evolution of the United States in the global S&E enterprise. Increasingly, the United States is seen globally as an important leader rather than the uncontested leader. Whether and how long the current global trends continue is an important question that will be affected by the overall S&E environment, along with the economic, social, and political forces that shape the S&E environment in the United States and around the world.

Introduction

Contributions from and innovation in S&T over many decades have resulted in dramatic improvements to American lives, including enhanced living standards and life expectancy, better access to information and connectivity across the globe, and increased access to and affordability of consumer goods (Baumol 1989; Cutler and McClellan 2001; Gordon 2012; Alston, Beddow, and Pardey 2009). Even though the transformative nature of S&T is not free of risks (e.g., privacy concerns, cyber security threats), most Americans believe that the federal government has a role in funding scientific research and that the benefits of S&T justify its expense (NSB 2018). Although the United States has long been a global leader in the advancement, development, and production of S&T, other countries are increasing their S&T investments and activities. In addition, the U.S. S&E enterprise faces competition from other national priorities for limited resources. Growth of S&T capabilities in other nations has outpaced that of the United States along several dimensions, enabling some countries to converge with, or even to be poised to overtake, the United States in developing specific areas of S&E expertise. This has resulted in a regional shift in S&T performance and capabilities from the United States, Western Europe, and Japan to other parts of the world, notably to China and other Southeast Asian economies.

The analysis in this report is based on data from *Science and Engineering Indicators 2020 (Indicators 2020)*, which has been redesigned to ensure that the content is maximally useful and accessible to a wide audience. *Indicators 2020* consists of nine thematic reports that provide a high-level overview of the U.S. S&E enterprise, which includes elementary and secondary science and mathematics education, S&E higher education, S&E workforce, S&E publications, R&D investment, academic R&D, R&D-intensive industries, innovation, and public perceptions of S&T. These thematic reports along with the detailed underlying data are available online at https://ncses.nsf.gov/indicators/. This report, *The State of U.S. Science and Engineering*, highlights the key findings and indicators from the *Indicators 2020* thematic reports. Detailed analysis of these key indicators, as well as numerous important topics, are addressed in the individual thematic reports and are summarized in the executive summary of each report.

This report is organized in six topical sections. The report begins with the topic of education, including performance of K–12 students and S&E degrees awarded in the United States, along with relevant international comparisons. The second section describes the demographic composition of the U.S. S&E workforce and employment trends, including trends in the skilled technical workforce. The next two sections focus on R&D, including the U.S. position within a global context and the structure of U.S. R&D performance and funding. The fifth section examines trends in global S&T capabilities, including S&E research publications and R&D-intensive industry output. The sixth section focuses on innovation-related indicators, as well as U.S. public attitudes toward S&T. The report ends with concluding remarks, as well as references and resources, such as a glossary of terms and acronyms, detailed notes for figures, and information on the other reports, including *Indicators 2020* thematic reports that provide the underlying analysis for each section.

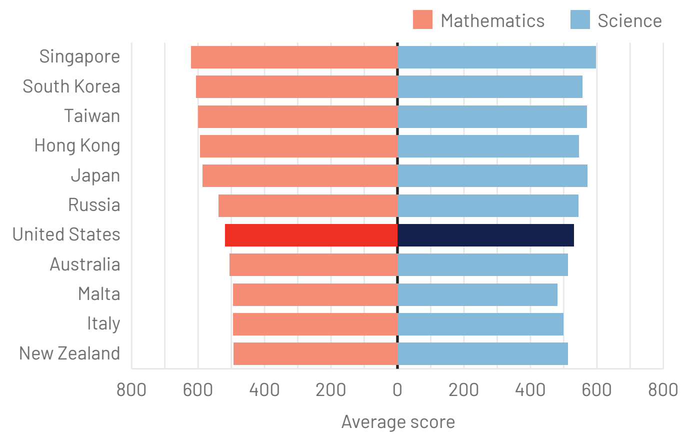
U.S. and Global Education

U.S. eighth graders rank in the middle of advanced economies in international mathematics and science assessments, and U.S. national assessments of mathematics show little to no growth in scores over the past decade. The United States awards the most S&E doctoral degrees of any single country and receives the largest number of internationally mobile students.

K–12 Mathematics and Science

Internationally, U.S. eighth graders ranked in the middle of the advanced economies that participated in science and mathematics assessments (Figure 1). Singapore was the highest scoring country. While U.S. students' mathematics scores have improved since 1990 on national assessments, improvements have slowed in the past decade (Figure 2). Science literacy scores and technology and engineering literacy scores improved 4 points and 2 points (out of a maximum score of 300), respectively, during the period for which comparable data are available.

Figure 1. Average TIMSS mathematics and science scores of students in grade 8 among selected high-income countries and economies: 2015

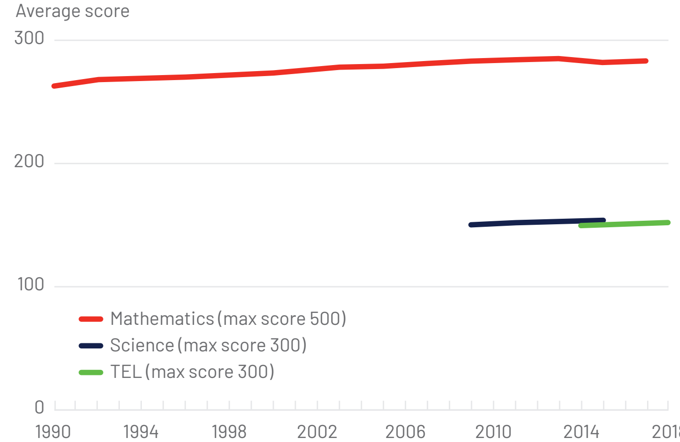


NOTES: TIMSS is Trends in International Mathematics and Science Study. Nineteen developed economies participated in grade 8 TIMSS. Of these, Canada, England, Ireland, Israel, Lithuania, Norway, Slovenia, and Sweden had average mathematics or science scores that were not statistically different from that of the United States and therefore are not shown. Russia, an upper-middle income economy, is included for comparison purposes. See p. 22.

SOURCE: NCSES, special tabulations (2018) of the 2015 TIMSS.

Indicators 2020: K–12 Education

Figure 2. Average scores of U.S. students in grade 8 on the NAEP mathematics, science, and TEL assessments: 1990–2018



NOTES: NAEP is National Assessment of Educational Progress; TEL is technology and engineering literacy. Assessments are not scheduled for all years. See p. 22.

SOURCES: NCSES, special tabulations (2018) of the 1990–2018 NAEP mathematics, TEL, and science assessments, NCES, ED.

Indicators 2020: K–12 Education

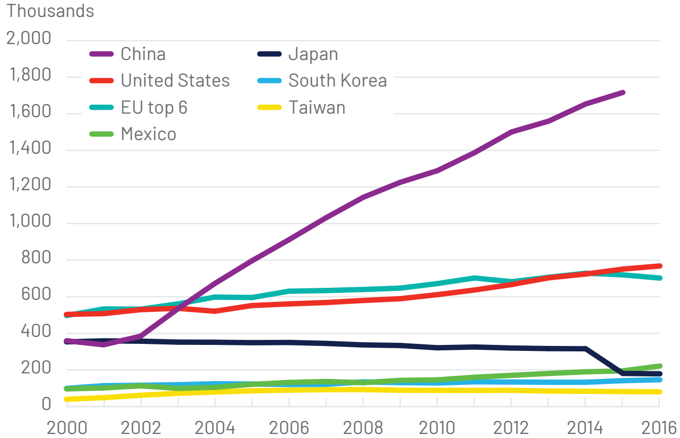
Degree Awards

Community colleges play a key role in preparing Americans to enter the workforce with associate's degrees or certificates or to transition to four-year educational institutions. In 2017, the United States awarded 93,000 associate's degrees in S&E fields and another 133,000 in S&E technologies. Among U.S. students who earned S&E bachelor's degrees between 2010 and 2017, about half (47%) had done some coursework at a community college and nearly a fifth (18%) earned associate's degrees.

According to the most recent estimates, the United States awarded nearly 800,000 S&E first university degrees in 2016, broadly equivalent to a bachelor's degree. The 28 European Union (EU) countries together produced nearly 1 million of these degrees, with the top 6 EU countries accounting for about 70% of the EU total (see Glossary for EU member countries). China produced 1.7 million S&E first university degrees. The number of such degrees in China has doubled over the past 10 years, while other large, degree-producing countries have seen modest increases (Figure 3). Much of China's increase has been in engineering, which accounted for nearly 70% of China's S&E first university degrees.

The United States awarded about 40,000 S&E doctorates in 2016 (Figure 4). The combined EU countries awarded about 77,000. Starting from a low base, China has seen a rapid increase over time and in 2015 awarded about 34,000 S&E doctoral degrees, predominantly in the natural sciences and engineering. China surpassed the United States in 2007 as

Figure 3. First university degrees in S&E, by selected region, country, or economy: 2000–16

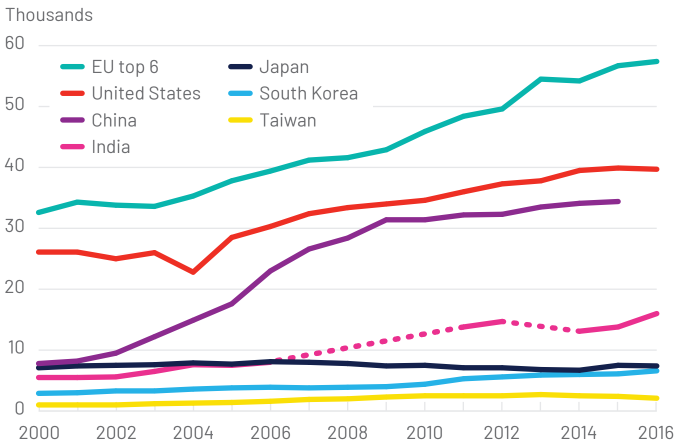


NOTES: EU top 6 is France, Germany, Italy, Poland, Spain, and the United Kingdom. Data are not available for all regions, countries, or economies for all years. See p. 22.

SOURCES: Educational statistics of OECD, Eurostat, MEXT (Japan), NBS (China), and MOE (Taiwan).

Indicators 2020: Higher Education

Figure 4. Doctoral degrees in S&E, by selected region, country, or economy: 2000–16

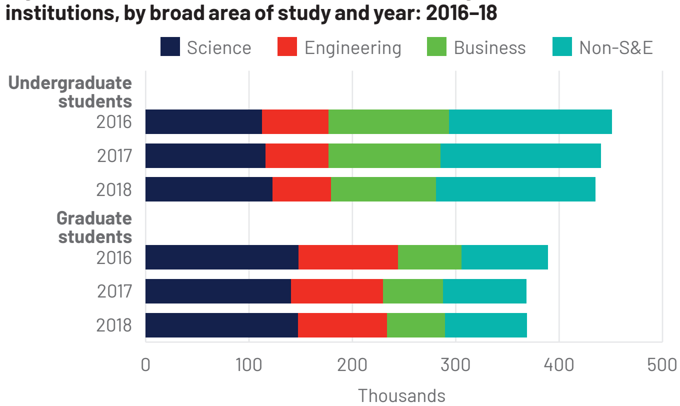


NOTES: EU top 6 is France, Germany, Italy, Sweden, Spain, and the United Kingdom. Data are not available for all regions, countries, or economies for all years. See p. 22.

SOURCES: Educational statistics of OECD, Eurostat, MEXT (Japan), NBS (China), and MOE (Taiwan).

Indicators 2020: Higher Education

Figure 5. International students enrolled in U.S. higher education institutions, by broad area of study and year: 2016–18



NOTES: Undergraduate level includes associate's and bachelor's degrees. Graduate level includes master's and doctoral degrees. See p. 22.

SOURCE: DHS, ICE, special tabulations (2018), SEVIS database.

Indicators 2020: Higher Education

the world's largest producer of doctoral degrees in natural sciences and engineering (excluding social and behavioral sciences) and has remained in the lead ever since. In 2015, China awarded 32,000 doctorates in these fields and the United States awarded 30,000.

Internationally Mobile Students and Stay Rates

Understanding the relationship between degrees conferred in a country and the capabilities of its workforce is complicated as rising numbers of students receive higher education outside their home countries. In the United States, a substantial proportion of S&E doctoral degrees are conferred to international students with temporary visas. In 2017, temporary visa holders earned one-third (34%) of S&E doctoral degrees, a relatively stable proportion over time. They account for half or more of the doctoral degrees awarded in engineering, mathematics and computer sciences, and economics. Three Asian countries—China, India, and South Korea—are the largest source countries and accounted for just over half (54%) of all international recipients of U.S. S&E research doctoral degrees since 2000. By comparison, students on temporary visas earn a smaller share (6% in 2017) of S&E bachelor's degrees. However, the number of these students has more than doubled over the past 10 years.

A majority of the S&E doctorate recipients with temporary visas—ranging between 64% and 71% between 2003 and 2017—stayed in the United States five years after obtaining their degree. Those from China and India, however, saw a decline in their respective "stay rates" from 93% and 90%, respectively, in 2003 to 84% and 85%, respectively, in 2013; the rates remained stable from 2013 through 2017. The stay rate increased for those from South Korea (from 36% in 2003 to 57% in 2017). Stay rates also vary by field of doctoral degree. Among S&E doctorate recipients, social sciences (52%) has a lower stay rate than the average across all fields (71% in 2017).

The United States is the destination for the largest number of internationally mobile students worldwide (19% in 2016). Other popular destinations include the United Kingdom, Australia, France, Germany, and Russia. However, enrollment of international students at U.S. institutions has declined since 2016. Underlying this overall decline is a mixed picture that varies by degree level and field of study (Figure 5), as well as by country of origin. Between 2016 and 2018, the number of international students studying science rose at the undergraduate level and declined slightly at the graduate level; the number of those studying engineering declined at both levels. Among the two largest source countries, the number of Chinese S&E graduate students at U.S. institutions increased during this period, whereas the number of those from India declined.

U.S. S&E Workforce

Workers employing S&E and technological expertise in their occupations experience better labor market outcomes than those in many other types of jobs. Women and certain racial and ethnic groups—blacks, Hispanics, and American Indians or Alaska Natives—are underrepresented in S&E. However, their total numbers in S&E occupations have increased. Foreign-born individuals account for a considerable share of S&E employment, particularly among workers with graduate degrees. Both the number and proportion of foreign-born S&E workers have risen over time.

Workforce Growth and Employment Sector

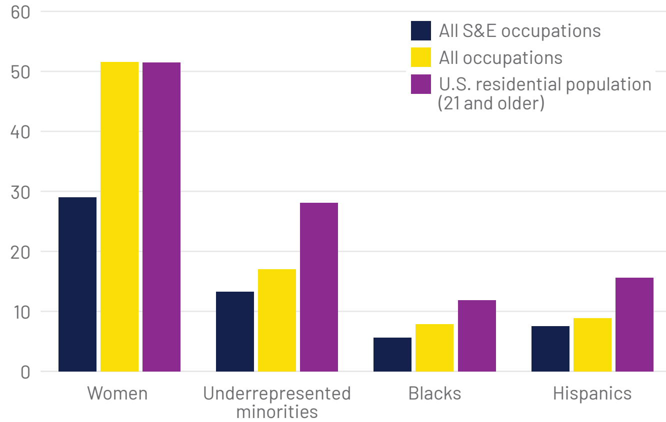
S&E employment in the United States—made up of occupations like software developers, computer system analysts, chemists, mathematicians, economists, psychologists, and engineers—has grown more rapidly than the workforce overall and now represents 5% (about 7 million) of all U.S. jobs. In 2017, the median annual salary in S&E occupations (across workers at all education levels) was $85,390, which is more than double the median for all U.S. workers ($37,690). Individuals in S&E occupations work for a variety of employers, including businesses (72%), educational institutions (16%), and government (12%). Many others with S&E training are employed in and apply their S&E knowledge and skills in occupations not formally classified as S&E jobs.

Women and Underrepresented Minorities

Women account for about half (52%) of the college-educated workforce (Figure 6), and between 2003 and 2017, the number of women in S&E jobs rose from nearly 1.3 million to nearly 2.0 million. Despite this increase, women in 2017 accounted for 29% of S&E employment, compared with 26% in 2003. The number of women grew in all broad S&E occupations (Figure 7). In addition, their presence varies across occupational categories. In 2017, women accounted for nearly half or more of the workforce in the life sciences and in psychology and social sciences. In comparison, women accounted for 27% of computer and mathematical scientists, 16% of engineers, and 29% of physical scientists.

Similarly, in 2017, there were 901,000 S&E workers from URM groups, up from 432,000 in 2003. The proportion of individuals from URM groups in S&E jobs, although up from 9% in 2003 to 13% in 2017, remains below their share of the college-educated workforce (17%) (Figure 6). URMs also vary in their presence across S&E, accounting for 10% to 22% of the workforce in each broad S&E occupational category

Figure 6. Women, underrepresented minorities, blacks, and Hispanics in S&E and all occupations: 2017

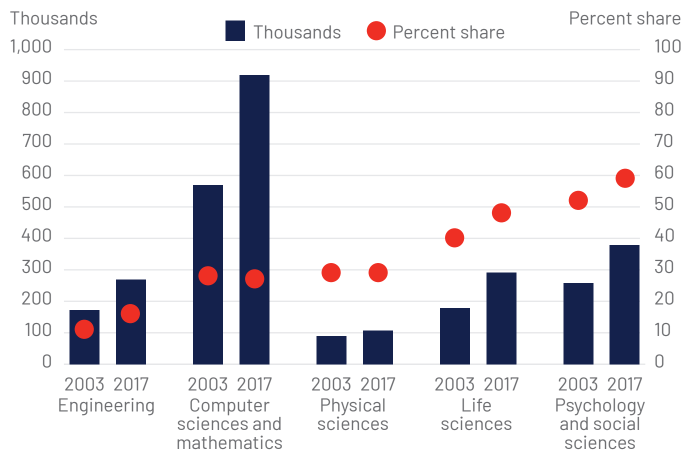


NOTES: Underrepresented minorities includes individuals who are black, Hispanic, or American Indian or Alaska Native. The S&E and all occupations data are for those with a bachelor's degree and above. The U.S. residential population data are for those at all education levels.

SOURCES: NCSES, 2017 NSCG; Census Bureau, 2017 ACS.

Indicators 2020: Labor Force

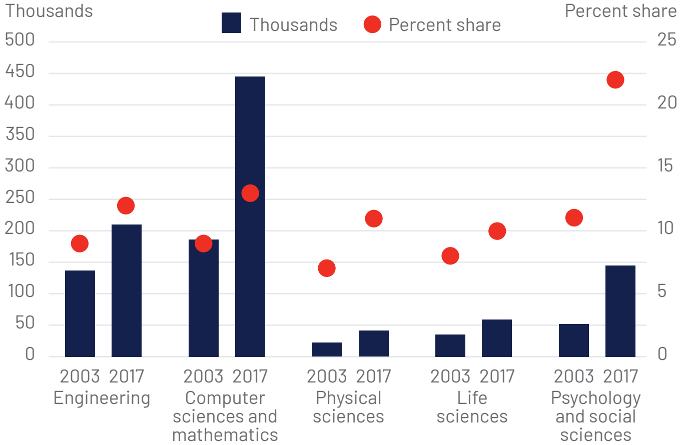
Figure 7. Women in S&E occupations, by broad occupational category: 2003 and 2017



SOURCES: NCSES, 2003 SESTAT and 2017 NSCG.

Indicators 2020: Labor Force

Figure 8. Underrepresented minorities in S&E occupations, by broad occupational category: 2003 and 2017

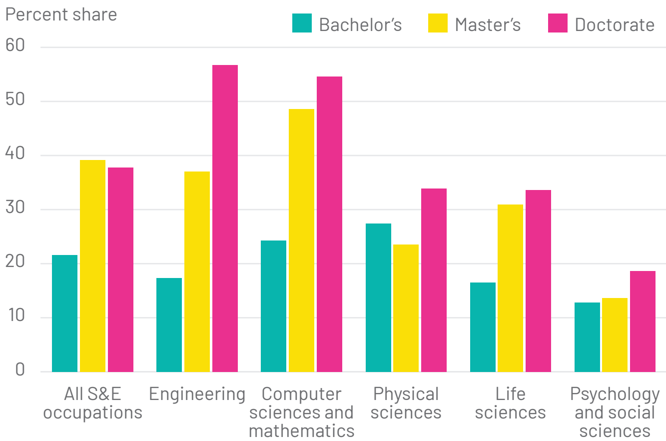


NOTE: Underrepresented minorities includes individuals who are black, Hispanic, or American Indian or Alaska Native.

SOURCES: NCSES, 2003 SESTAT and 2017 NSCG.

Indicators 2020: Labor Force

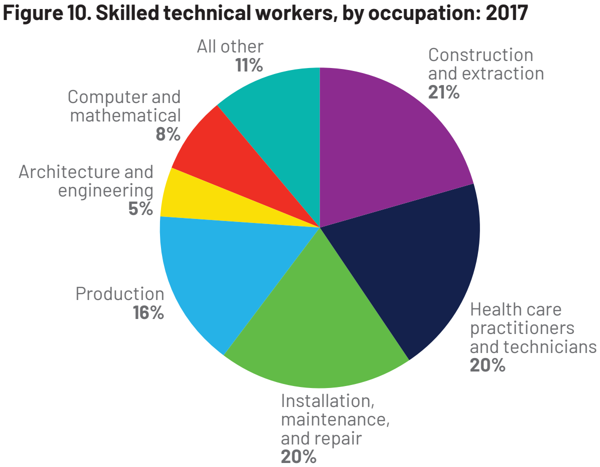
Figure 9. Foreign-born individuals in S&E occupations in the United States, by level of degree and occupation: 2017



SOURCE: NCSES, 2017 NCSG.

Indicators 2020: Labor Force

Figure 10. Skilled technical workers, by occupation: 2017



NOTE: Employment counts are of employed individuals with an educational attainment of less than a bachelor's degree.

SOURCE: Census Bureau, 2017 ACS.

Indicators 2020: Labor Force

(Figure 8). Representation varies further across minority groups and within occupations. The share of Hispanics among psychologists (15%), political scientists (33%), postsecondary teachers in computer science (13%), and industrial engineers (17%) is large relative to the Hispanic share of S&E occupations overall (7%). The share of black individuals among computer systems analysts (13%), computer support specialists (14%), and network and computer systems administrators (14%) is large relative to the share of black individuals in S&E occupations overall (6%).

Foreign-Born Scientists and Engineers

Foreign-born workers—ranging from long-term U.S. residents with strong roots in the United States to more recent immigrants—account for 30% of workers in S&E occupations. The number and proportion of the S&E workforce that are foreign born has grown. In many of the broad S&E occupational categories, the higher the degree level, the greater the proportion of the workforce who are foreign born. More than one-half of doctorate holders in engineering and in computer science and mathematics occupations are foreign born (Figure 9). In comparison, about 18% of the overall population and 17% of the college graduate population in the United States are foreign born.

Skilled Technical Workforce

According to the most recent estimates, the U.S. workforce includes about 17 million skilled technical workers, that is, those who are employed in occupations that require S&E expertise and technical knowledge and whose educational attainment is some high school or a high school diploma, some college or an associate's degree, or equivalent training. These workers are concentrated in four broad occupational categories: construction and extraction (21%), health care (20%), installation, maintenance, and repair (20%), and production (16%) (Figure 10).

Skilled technical occupations provide better career opportunities than other occupations. In 2017, skilled technical workers had a higher median salary ($45,000) and a lower unemployment rate (3%) than did workers with less than a bachelor's degree in all other occupations ($29,000 and 5%). The skilled technical workforce is made up primarily of men—only 28% are women. Although the racial and ethnic distribution is largely similar to the overall workforce, Asians account for a smaller share of this workforce (4% versus 6% of the overall workforce), as do foreign-born individuals (16% versus 18%).

Global R&D

The United States spent more on R&D than did any other country in 2017. However, its global share since 2000 fell as R&D spending rose in many Asian countries, especially China. In R&D intensity (ratio of R&D to gross domestic product [GDP]), the United States ranked 10th in 2017. The R&D-intensity level has risen modestly in the United States since 2000, while China and South Korea have seen rapid increases.

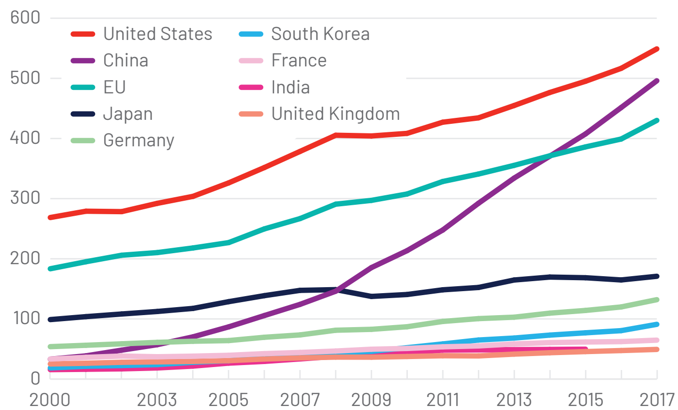
Where

Total global R&D expenditures have risen substantially, expanding threefold between 2000 ($722 billion) and 2017 ($2.2 trillion). Global R&D activity remains concentrated in the United States, EU, and the combination of East-Southeast and South Asia regions (see Glossary for member countries of each region).

Among individual countries, the United States was the largest R&D performer in 2017, followed by China, whose R&D spending now exceeds that of the EU (Figure 11). Together, the United States (25%) and China (23%) accounted for nearly half of the estimated global R&D total in 2017. Japan (8%) and Germany (6%) are next, followed by South Korea (4%). France, India, the United Kingdom, Russia, Brazil, Taiwan, Italy, Canada, Spain, Turkey, and Australia account for about 1%–3% each of the global total. Many other countries also conduct R&D, with annual expenditures well below these top countries and economies.

Figure 11. Gross domestic expenditures on R&D, by selected region, country, or economy: 2000–17

Billions of PPP dollars



NOTES: PPP is purchasing power parity. Data are for the top eight R&D-performing countries and the EU. Data are not available for all countries for all years. The EU includes France, Germany, and the United Kingdom. See p. 22.

SOURCES: NCSES, National Patterns of R&D Resources; OECD, MSTI 2019/1; UNESCO, UIS R&D.

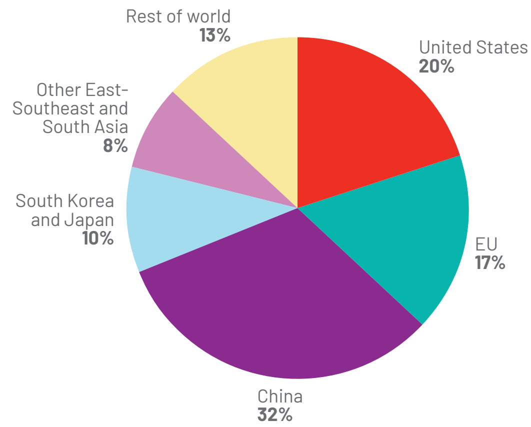
Indicators 2020: R&D

Growth

A notable trend over the past decade has been the growth in R&D spending in the regions of East-Southeast and South Asia, compared to the other major R&D-performing areas. Asian countries, most notably China, have heavily contributed to the overall increase in worldwide R&D expenditures, with China accounting for almost one-third (32%) of the total global growth between 2000 and 2017 (Figure 12). The United States (20%) and the EU (17%) together accounted for over one-third (37%) of the global growth.

Across countries, regions, and economies, the differential growth rates have led to shifting global R&D shares. Despite average annual growth in R&D spending of 4.3% in the United States and 5.1% in the EU between 2000 and 2017 (Figure 13), global R&D shares declined for the United States (37% to 25%) and for the EU (25% to 20%) (Figure 14). At the same time, the economies of East-Southeast and South Asia—including

Figure 12. Contributions to growth of worldwide R&D expenditures, by selected region, country, or economy: 2000–17

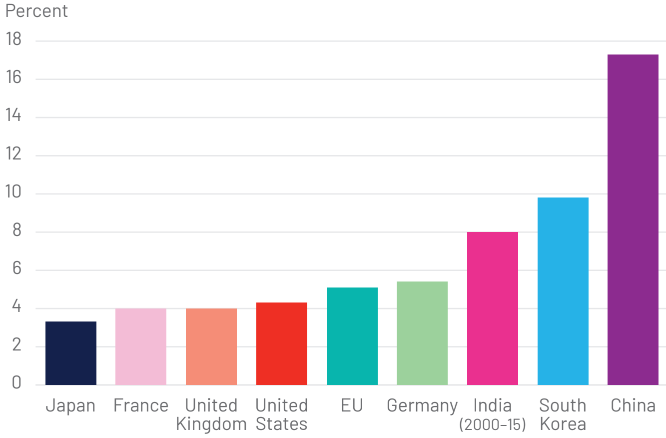


NOTE: Other East-Southeast and South Asia include Cambodia, India, Indonesia, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Taiwan, Thailand, and Vietnam.

SOURCES: NCSES, National Patterns of R&D Resources; OECD, MSTI 2019/1; UNESCO, UIS R&D.

Indicators 2020: R&D

Figure 13. Average annual growth rate of domestic R&D expenditures, by selected region, country, or economy: 2000–17

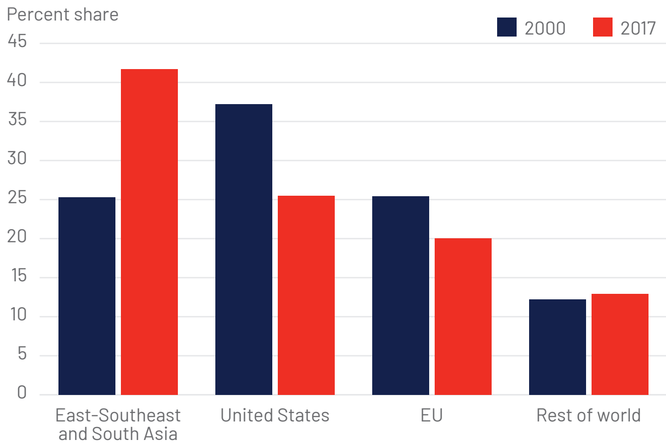


NOTE: The EU includes France, Germany, and the United Kingdom.

SOURCES: NCSES, National Patterns of R&D Resources; OECD, MSTI 2019/1; UNESCO, UIS R&D.

Indicators 2020: R&D

Figure 14. Shares of worldwide R&D expenditures, by selected region, country, or economy: 2000 and 2017

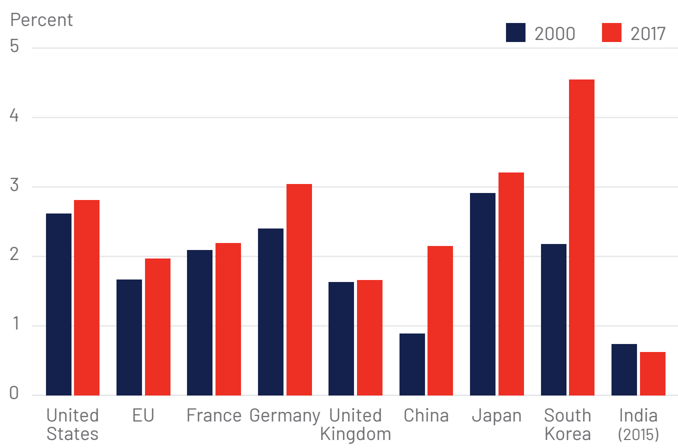


NOTE: East-Southeast and South Asia include Cambodia, China, India, Indonesia, Japan, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand, and Vietnam.

SOURCES: OECD, MSTI 2019/1; UNESCO, UIS R&D.

Indicators 2020: R&D

Figure 15. R&D intensity, by selected region, country, or economy: 2000 and 2017



NOTES: Data are for the top eight R&D-performing countries and the EU. The EU includes France, Germany, and the United Kingdom. See p. 22.

SOURCES: NCSES, National Patterns of R&D Resources; OECD, MSTI 2019/1; UNESCO, UIS R&D.

Indicators 2020: R&D

China, Japan, Malaysia, Singapore, South Korea, Taiwan, and India—increased their combined global share from 25% to 42%, so this region now exceeds the respective U.S. and EU R&D shares and leads in global R&D expenditures.

Intensity

Although the United States invests more in R&D than does any other individual country, several other, smaller economies have a greater "R&D intensity"—that is, a higher ratio of R&D expenditures to GDP (Figure 15). South Korea has the highest ratio at 4.6%. Over the past decade, U.S. R&D intensity has fluctuated within a relatively narrow range and remained generally high relative to historic levels, although the global U.S. rank in this indicator fell from 8th in 2009 to 10th in 2017. Since 2000, the R&D-to-GDP ratio rose sharply for both South Korea and China, although those countries started with a low base, whereas R&D intensity rose gradually in the EU.

Many governments have limited direct control over achieving a targeted R&D-to-GDP ratio since, for the most part, the business sector is the predominant source of R&D funding among the top R&D-performing countries. In 2017, the business sector accounted for approximately three-quarters of R&D funding in the leading Asian countries: Japan (78%), China (76%), and South Korea (76%). The business share of total R&D was lower but still significant in the United States (62%) as well as in leading European countries, with Germany at 66%, France at 56%, and the United Kingdom at 52%. These shares provide consistent cross-country comparisons of R&D; the methodology differs from that of the U.S. R&D data that follow in the next section.

Countries also vary in their relative focus on basic research, applied research, and experimental development (see Glossary for definitions). According to the most recent estimates, the United States spends 17% and China spends 6% of its annual R&D funds on basic research. In comparison, this proportion was 21% for France. However, this amounted to $13 billion of basic research performance in France, smaller than the amounts spent in the United States ($91 billion) and China ($27 billion). China spends 84% of its R&D funds on experimental development, compared to 63% in the United States.

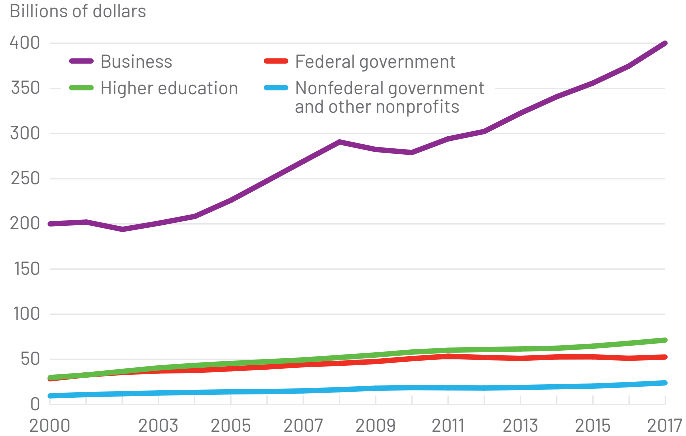
U.S. R&D Performance and Funding

Businesses perform and fund most of the overall R&D in the United States as well as most of the applied research and experimental development. Higher education is the second-largest performer of R&D and performs the largest share of basic research; the federal government is the second-largest funder of R&D and funds the largest share of basic research. While federal R&D funding of basic research has increased since 2000, the proportion of R&D funded by the federal government has declined. Eight federal departments and agencies together account for most of the federal R&D spending.

Performance and Funding Trends

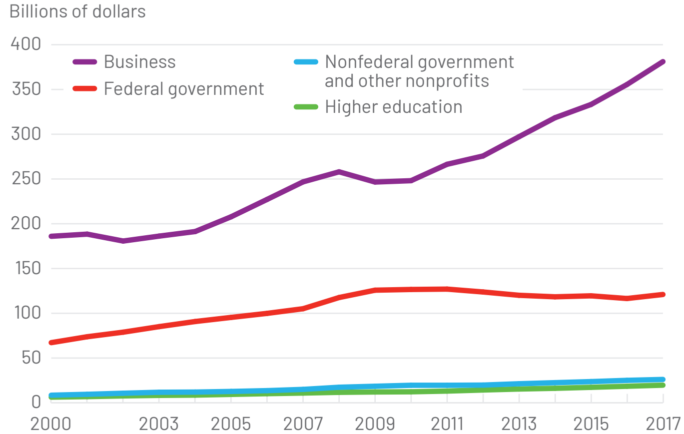
The business sector performed most (73%) of the $548 billion of U.S. R&D total in 2017. The next largest performers were higher education (universities and colleges; 13%) and the federal government (10%) (Figure 16). Many organizations performing R&D receive outside funding; they may also be significant funders of R&D themselves. Mirroring its predominant role in R&D performance, the business sector is also the leading source of R&D funding (70%) in the United States. However, nearly all (98%) of the business sector's R&D funding supported R&D performance by businesses, either the same business that funded the R&D or another business. The federal government, the second-largest source of R&D funding (22%) (Figure 17), supports all R&D-performing sectors. Federal support, however, varies by sector. In 2017, federal funding supported half (51%) of all academic R&D performance. Federal funds also supported R&D performance by businesses (6%), nonprofits (35%), and federally funded research and development centers (FFRDCs) (98%).

Figure 16. U.S. R&D expenditures, by performing sector: 2000–17



SOURCE: NCSES, National Patterns of R&D Resources.
Indicators 2020: R&D and Academic R&D

Figure 17. U.S. R&D expenditures, by source of funds: 2000–17

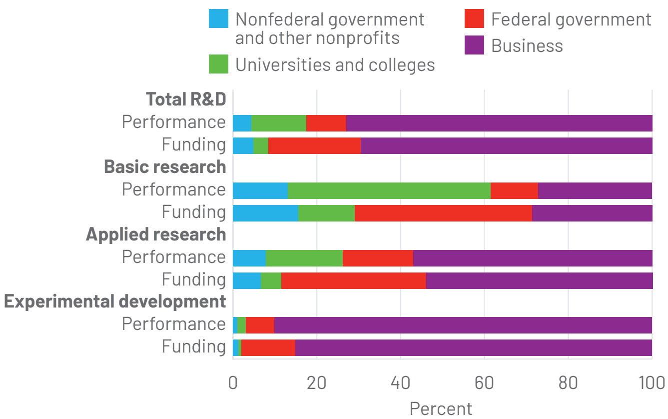


SOURCE: NCSES, National Patterns of R&D Resources.
Indicators 2020: R&D and Academic R&D

Type of R&D

About 17% of the U.S. R&D performance is for basic research, while the remainder, more than 80%, is for applied research and experimental development. Organizations bring different perspectives and approaches to R&D. The business sector, with its focus on new and improved goods, services, and processes, dominates both experimental development (90% of performance and 85% of funding) and applied research (57% of performance and 54% of funding). In comparison, nearly half (48%) of U.S. basic research is performed by higher education institutions, while 42% of funding for all basic research is provided by the federal government (Figure 18). The role of higher education is not surprising given the integration of advanced graduate education and R&D performance. However, businesses are now funding more basic research. Between 2000 and 2017, the share of basic research funded by the business sector increased from 19% to 29%.

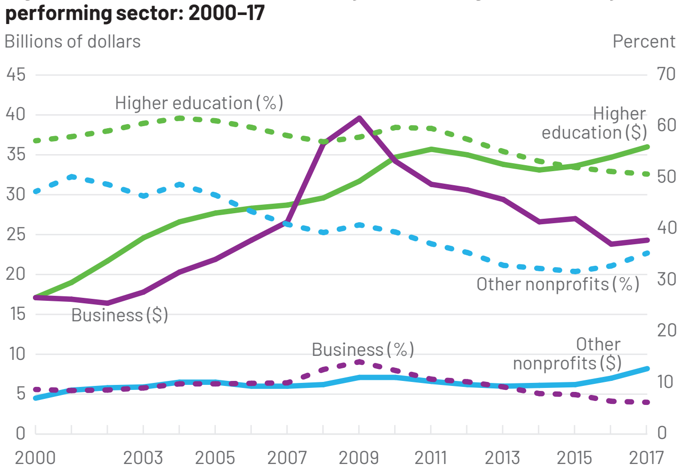
Figure 18. U.S. R&D performance and funding, by type of R&D and sector: 2017



SOURCE: NCSES, National Patterns of R&D Resources.

Indicators 2020: R&D and Academic R&D

Figure 19. R&D performance funded by the federal government, by performing sector: 2000–17

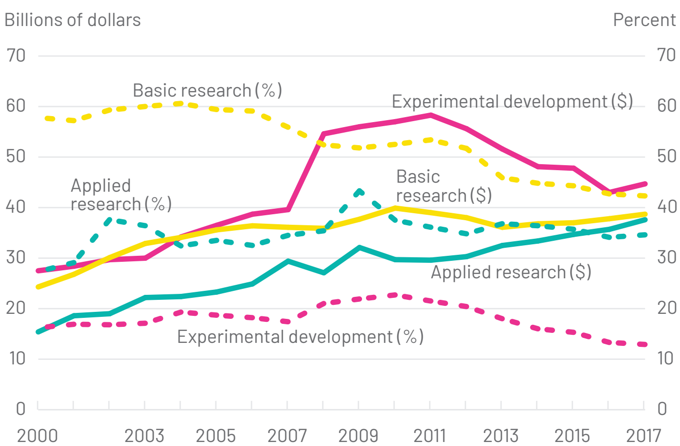


NOTE: Percentages represent federal funding divided by total performance for each sector.

SOURCE: NCSES, National Patterns of R&D Resources.

Indicators 2020: R&D and Academic R&D

Figure 20. R&D performance funded by the federal government, by type of R&D: 2000–17



NOTE: Percentages represent federal funding divided by total performance for each type.

SOURCE: NCSES, National Patterns of R&D Resources.

Indicators 2020: R&D and Academic R&D

Federal R&D

Since 2000, the expansion in U.S. R&D has been driven primarily by the business sector, notwithstanding the temporary boost provided by the federal government in the wake of the 2008 financial crisis. Although the levels of federal R&D funding rose across performing sectors between 2000 and 2017, the share of total U.S. R&D funded by the federal government declined from 25% to 22%. This decline was observed across performing sectors including higher education institutions, other nonprofit institutions, and businesses (Figure 19). Among higher education institutions, where the federal government is a major source of R&D support, the share of federally funded R&D performance declined from 57% in 2000 to 51% in 2017.

By type of R&D, the shares of federal government funding for basic research and experimental development declined since 2000 despite rising levels of funding (Figure 20). The federal government is a major funder of basic research, and between 2000 and 2017, the share of basic research funded by the federal government declined from 58% to 42%. Federally funded applied research was an exception during this period, as both the level and share rose.

Eight federal departments and agencies together account for most of the federal R&D spending. Defense has long been a federal R&D budget priority, accounting for 44% of federal R&D support in 2017. This R&D support comes mainly from the Department of Defense but also from several other defense-related agencies. Over half (56%) of the federal R&D budget is devoted to nondefense. Health and environment account for slightly more than one-half (56%) of federal nondefense R&D budget. The other federal agencies with large R&D portfolios—the Department of Health and Human Services, Department of Energy, National Science Foundation, Department of Agriculture, Department of Commerce, and Department of Transportation—focus primarily in the areas of basic and applied research. The National Aeronautics and Space Administration distributes its budget more evenly across the different types of R&D, with about half going to basic and applied research and half to experimental development.

Global Science and Technology Capabilities

The 28 nations that make up the EU collectively have the highest output of S&E publications globally. China's S&E publication output ranks next, followed by the United States. The citation impact of China's publications is rising rapidly, although it is currently lower than that of the United States and the EU. With respect to industrial output between 2003 and 2018, the U.S. share of worldwide value-added output declined for R&D-intensive industries even though the U.S. level of output rose.

Research Publications

R&D produces new knowledge. The EU, China, United States, India, Japan, and South Korea together produce more than 70% of the worldwide refereed S&E publications (Figure 21). As with the worldwide trends for degrees awarded and R&D spending, the output of peer-reviewed S&E publications in recent years has grown more rapidly in middle-income countries, especially China, than in high-income countries, including the United States (see Glossary for definitions). China's S&E publication output has risen nearly tenfold since 2000, and as a result, China's output in terms of absolute quantity now exceeds that of the United States.

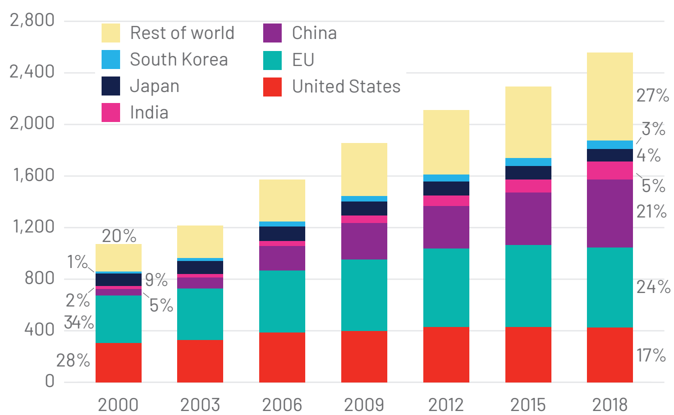
As measured by publication output, the subject-matter emphasis of scientific research varies across countries and regions. Among the largest producers in 2018, the United States and the EU each produced more biomedical and health sciences articles than did China. However, China surpassed the United States and the EU individually in the production of engineering articles and now produces more than twice as many engineering articles as the United States.

Publications receiving more citations generally have more impact on a particular scientific discipline. The relative impact of an economy's S&E research can be compared through the representation of its articles among the world's top 1% of cited articles, normalized to account for the size of each country's pool of S&E publications. This normalized value is referred to as an index and is similar to a standardized score. For example, if a country's global share of top articles is the same as its global share of all publication output, the index is 1.0. The U.S. index was 1.9 in 2016, meaning that its share of the top 1% of cited articles was about twice the size of its share of total S&E articles (Figure 22). Between 2000 and 2016, the EU index of highly cited articles grew from 1.0 to 1.3 while China's index more than doubled, from 0.4 to 1.1, indicating rising impact from both areas.

International Research Collaboration

U.S. research capacity, as well as that of other nations, is enhanced through connection with researchers around the world. The proportion of worldwide articles produced

Figure 21. S&E articles by selected region, country, or economy: Selected years, 2000–18

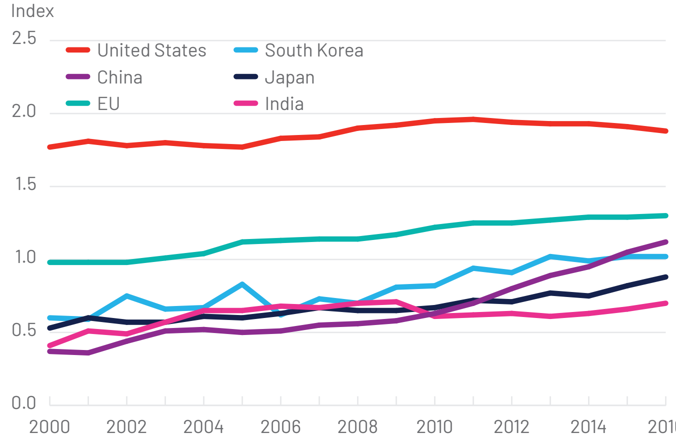


NOTES: Articles are fractionally counted and classified by publication year and assigned to a region, country, or economy by author's institutional address(es). Percentages shown represent share of global S&E articles. See p. 22.

SOURCE: NCSES, special tabulations (2019) of Elsevier's Scopus database.

Indicators 2020: Publication Output

Figure 22. Top 1% cited article index, by selected region, country, or economy: 2000–16

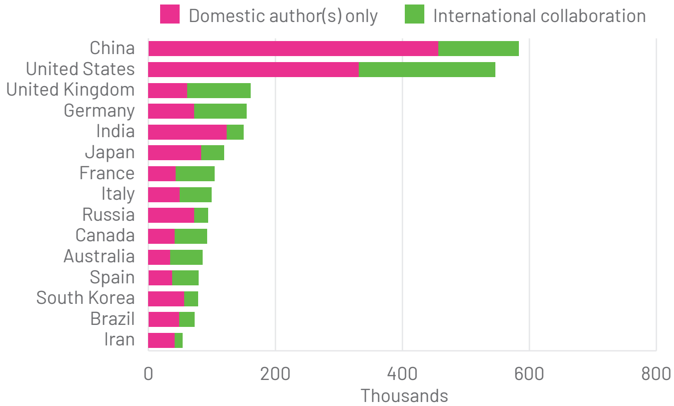


NOTES: Citation counts for a year are the number of citations in the peer-reviewed literature for articles published in that year. At least 2 years of data after publication are needed for a meaningful measure. See p. 22.

SOURCE: NCSES, special tabulations (2019) of Elsevier's Scopus database.

Indicators 2020: Publication Output

Figure 23. International collaboration on S&E articles, for the 15 largest producers of S&E articles, by country or economy: 2018

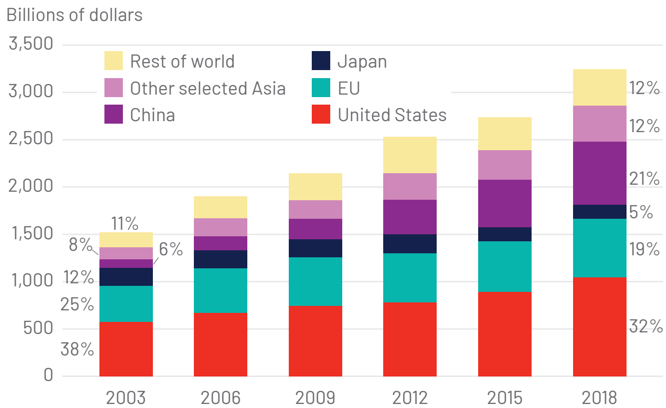


NOTES: Articles are whole-counted and classified by publication year and assigned to a country or economy by listed institutional address(es). See p. 23.

SOURCE: NCSES, special tabulations (2019) of Elsevier's Scopus database.

Indicators 2020: Publication Output

Figure 24. Value-added output of high R&D intensive industries by selected region, country, or economy: Selected years, 2003–18

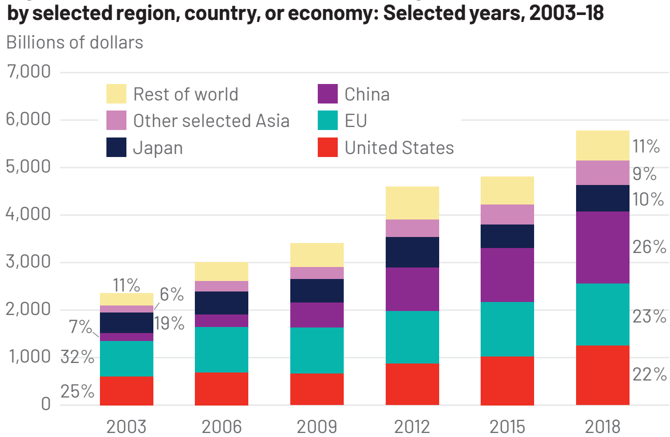


NOTES: Other selected Asia includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. Percentages shown represent share of global value-added output of high R&D intensive industries. See p. 23.

SOURCE: IHS Markit, special tabulations (2019) of the Comparative Industry Service.

Indicators 2020: Industry Activities

Figure 25. Value-added output of medium-high R&D intensive industries by selected region, country, or economy: Selected years, 2003–18



NOTES: Other selected Asia includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. Percentages shown represent share of global value-added output of medium-high R&D intensive industries. See p. 23.

SOURCE: IHS Markit, special tabulations (2019) of the Comparative Industry Service.

Indicators 2020: Industry Activities

with international collaboration—that is, by authors from at least two countries—has grown from 14% in 2000 to 23% in 2018. Most of the large producers of S&E scholarly articles in 2018 were highly collaborative (Figure 23): the UK (62%), Australia (60%), France (59%), Canada (56%), Germany (53%), Spain (53%), and Italy (50%) have relatively high international collaboration rates. In 2018, 39% of U.S. articles were developed through international collaboration, up from 19% in 2000. U.S. authors collaborated most frequently with authors from China (about 26% of U.S. internationally coauthored articles in 2018). Since 2000, international collaboration grew for most of the top 15 largest producers of S&E articles.

Knowledge- and Technology-Intensive Industry Output

Knowledge and technology intensity within an industry can be measured in several ways, including an industry's employment of highly skilled workers and its R&D intensity. Using R&D intensity as a measure, the most R&D-intensive industries globally are manufacturing of aircraft; pharmaceuticals; computer, electronic, and optical products; computer software publishing; and scientific R&D. In these industries, global value-added output in 2018 was more than $3.2 trillion. Between 2003 and 2018, U.S. output increased from about $570 billion to $1.04 trillion, while the U.S. global share declined from 38% to 32%. Over this period, the EU's and Japan's global shares declined, whereas China's share rose rapidly (Figure 24). The collective share for several other Asian countries and economies rose more moderately.

Industries with lower but still appreciable levels of R&D intensity include chemicals (excluding pharmaceuticals), transportation equipment (excluding aircraft), electrical and other machinery and equipment, information technology services, and scientific instruments. In these medium-high R&D-intensive industries, global output in 2018 was nearly $5.8 trillion. Although U.S. output increased from about $600 billion to $1.25 trillion between 2003 and 2018, its global share decreased slightly (Figure 25). China, starting from a low base in 2003, now produces 26% of the global output. The EU and Japan saw declining shares.

Many knowledge- and technology-intensive industries depend on powerful computers, known as supercomputers. They are one contributor to S&T capacity, including the capacity for developing artificial intelligence (AI) technologies. China is building its supercomputing capacity from a low base; its share of the worldwide 100 most powerful computers rose from 5% to 9% between 2010 and 2019. The United States had the largest share in 2019 (37%). However, the U.S. share has declined since 2010 (43%).

Invention, Innovation, and Perceptions of Science

Inventors from China, Japan, and South Korea receive the majority of patents for unique inventions across all countries and regions, based on patent family statistics. Engineering-related inventions made up more than half of all these global patent families in 2018. In the United States, industries producing digital and health-related products and technologies report above-average innovation rates. Overall, Americans view S&T positively. Most Americans believe that science creates more opportunities for the next generation and that the federal government should provide funds for scientific research. However, a considerable share also think that science makes life change too fast.

Invention

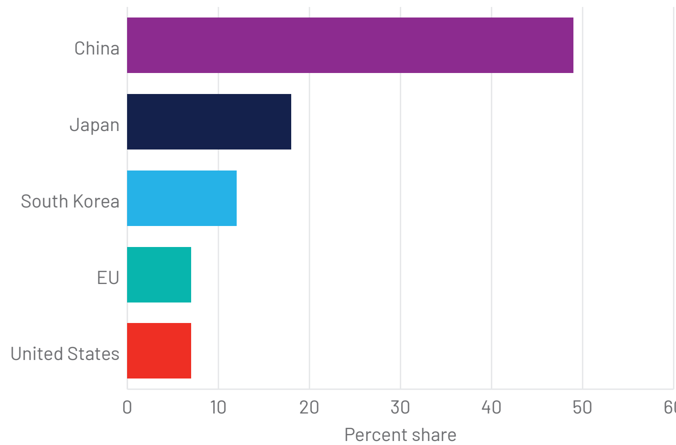
Scientific discovery and R&D increase the storehouse of knowledge, which then enables invention, innovation, and societal and economic benefits. Patents grant novel, useful, and nonobvious inventions legal ownership rights for a specified period. Utility patents are an internationally comparable indicator of invention. However, they are an incomplete indicator because not all inventions are protected by patents. Many inventions are patented in multiple international jurisdictions as inventors operate and seek patent protection in these markets. Data on patent families provide a broad unduplicated measure of such global inventions. Based on these data, inventors in China accounted for about half (49%) of such patent families in 2018 (Figure 26). Electrical and mechanical engineering-related patents made up more than half (56%) of these patent families in 2018, including those granted to inventors in the United States, the EU, South Korea, Japan, and China (Figure 27).

In contrast, U.S. Patent and Trademark Office (USPTO) patents show the geographic distribution of inventions protected in the U.S. market; high-income countries and regions predominate. U.S. inventors receive nearly half of USPTO patents (47%); considerable shares are also received by Japan (16%), South Korea (6%), and the EU (15%), while China receives 5%.

Innovation

While invention is the creation of something new and useful, innovation is its implementation. Between 2014 and 2016, approximately 17% of U.S. firms (with five or more employees) introduced an innovation—that is, a new or improved product or process. Industries that produce products and services for the digital economy through information and communication technologies (ICT), both within and outside of the manufacturing sector, have some of the highest innovation rates. For example, innovations were reported by 61% of software publishing companies, 53% of computer and electronic products manufacturing companies, and 47% of

Figure 26. Shares of worldwide patent families granted to inventors, by selected region, country, or economy: 2018

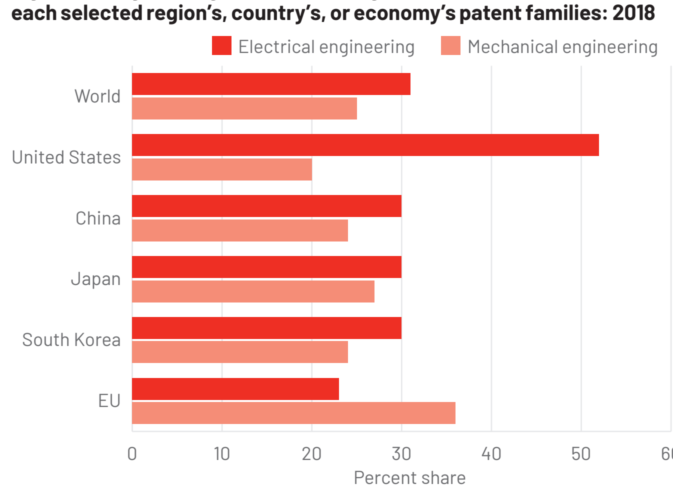


NOTES: Patent families refer to groups of patents that have one unique invention in common. See p. 23.

SOURCE: NCSES, special tabulations (2019) of PATSTAT, European Patent Office.

Indicators 2020: Innovation

Figure 27. Engineering patent families granted to inventors as a share of each selected region's, country's, or economy's patent families: 2018

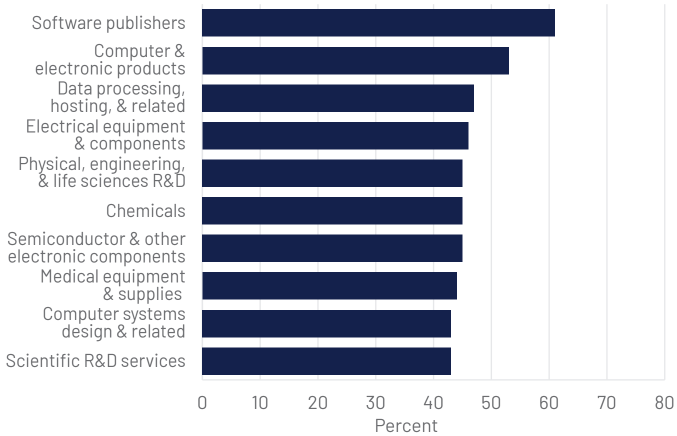


NOTES: Patent families refer to groups of patents that have one unique invention in common. Electrical and mechanical engineering patents exclude patents in civil engineering. See p. 23.

SOURCE: NCSES, special tabulations (2019) of PATSTAT, European Patent Office.

Indicators 2020: Innovation

Figure 28. U.S. companies reporting product or process innovation, by selected industry: 2014–16



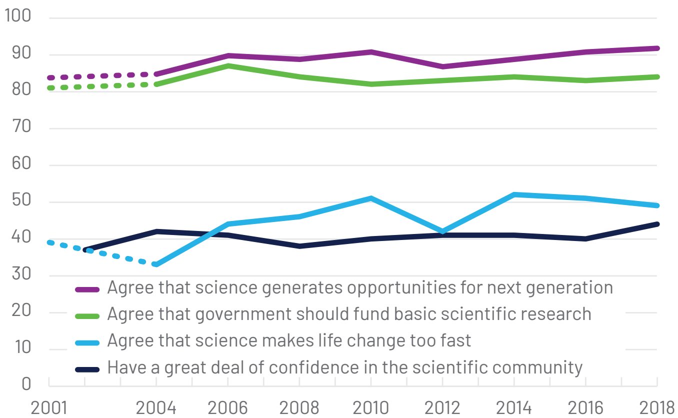
NOTES: Electrical equipment includes appliances. Physical, engineering, and life sciences R&D excludes biotechnology.

SOURCE: NCSES, 2016 BRDIS.

Indicators 2020: Innovation

Figure 29. Americans' views of science: Selected years, 2001–18

Percent with a particular view of science



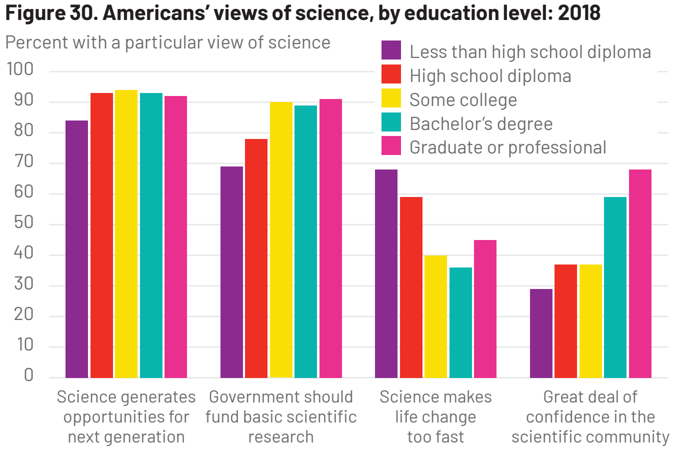
NOTES: Questions were not fielded in all years. See p. 23.

SOURCES: NCSES, special tabulations (2019) of the 2001 S&T Public Attitudes Survey, NCSES; the 2004 Survey of Consumer Attitudes, U. Michigan; and the 2006–16 General Social Survey, NORC at U. Chicago.

Indicators 2020: Public Attitudes and Understanding

Figure 30. Americans' views of science, by education level: 2018

Percent with a particular view of science



NOTE: See p. 23.

SOURCE: NCSES, special tabulations (2019) of the 2018 General Social Survey, NORC at U. Chicago.

Indicators 2020: Public Attitudes and Understanding

data processing and hosting companies (Figure 28). Industries that produce health-related products and technologies also report above-average innovation rates, including medical equipment and supplies (44%), chemicals (45%), and scientific R&D services (43%). Companies that produced navigational, medical, and other instruments, under the broader computer and electronic products industry category, also report an above average innovation rate (60%).

Data on venture capital investment show emerging areas where investors see potential commercial impacts. In 2018, most of the global venture capital funds were received by the United States (44%) and China (36%). In the United States, venture capital is focused primarily in areas that rely on software, including mobile technologies, AI, big data, industrials, and financial technology. Among these technologies, AI investment grew the most since 2013. AI technologies include machine learning, autonomous robotics and vehicles, computable statistics, computer vision, language processing, virtual agents, and neural networks. In China, ICT, which includes software, accounted for slightly more than half of total investment.

Americans' Perceptions about Science

Public perceptions of S&T can influence social acceptance of innovations as well as the progress of science. For example, such perceptions could influence willingness to fund S&T through public investment (Besley 2018; Miller, Pardo, and Niwa 1997; Muñoz, Moreno, and Luján 2012), as well as young people's willingness to pursue S&E careers (Besley 2015; Losh 2010). Americans overwhelmingly believe that science creates more opportunities for the next generation (92% in 2018) and that the federal government should provide funds for scientific research (84%) (Figure 29). Many Americans continue to have a "great deal of confidence" in the scientific community (44%). This perception has remained stable since 1973 (37%) and is second only to confidence in the military (59%). A substantial percentage of Americans also think science makes life change too fast (49%).

Attitudes toward science vary by level of education and other demographic groups. Almost all Americans across all education levels report that they believe science will benefit future generations and favor federal support for scientific research (Figure 30). However, a "great deal of confidence" in the scientific community is higher among those with more advanced education (68% of graduate degree holders, compared with 29% of those with less than a high school diploma) as well as among men (50%, compared with 39% of women) and those with higher income (55% in the highest income quartile, compared with 37% in the lowest income quartile). About 68% of those with less than a high school diploma agree that science makes life change too fast. For those with a graduate degree, 45% share this view (Figure 30).

Conclusion

This report, *The State of U.S. Science and Engineering*, describes trends in and the relative global position of the U.S. S&E enterprise, including S&E education and workforce, R&D, R&D-intensive commercial output, and innovation. The data show mixed trends for the United States. Women, blacks, Hispanics, and American Indians or Alaska Natives are underrepresented in the U.S. S&E workforce compared to their presence in the overall population, even though their participation in absolute numbers has grown. In international mathematics and science assessments, U.S. eighth grade students rank in the middle of advanced economies. Furthermore, U.S. eighth grade students' average mathematics scores have been relatively flat over the past decade. U.S. universities continue to award the most S&E doctoral-level degrees in the world, as well as to receive the largest number of internationally mobile students. Foreign student enrollment in U.S. universities, however, has declined since 2016. International students receive a considerable proportion of U.S. S&E doctorates, and many of these students remain in the United States for years after graduating. As such, the U.S. S&E enterprise includes not only domestic resources, but also the contributions of international students and workers, international collaborations in research, and global markets and trade in R&D-intensive products.

Since the turn of the century, R&D expenditures have grown more rapidly in several Asian economies, particularly China, compared to more moderate growth in the United States and the EU. In 2017, the economies of East-Southeast and South Asia collectively accounted for 42% of global R&D expenditures, higher than the United States (25%) and the EU (20%). The United States continues to spend the most on R&D of any single country. R&D funding and performance patterns within the United States, however, have changed. The share of U.S. R&D funded by the federal government has declined since 2000. This decline is notable as federally funded R&D is an important source of support, particularly for the higher education sector and for the basic research enterprise of the United States.

The United States is among the top global producers in R&D-intensive industry output and S&E publications. However, its global share has declined or stayed relatively flat because of faster growth in China as well as other middle-income countries. The citation impact of China's publications has also risen rapidly, although it is lower than that of the United States and the EU.

International collaborations in producing S&E publications have risen since 2000. U.S. authors collaborate most frequently with authors from China. The data in this report also indicate region-specific focus or specialization in subject matter, as well as highlight the importance of engineering, ICT, and health-related technologies for innovation. For example, the S&E publication data show that the United States and the EU each lead in the production of biomedical sciences articles, while China surpassed each individually in the production of engineering articles and now produces twice as many engineering articles as the United States. Within the United States, industries that produce health-related products and technologies as well as ICT industries report above average innovation rates. Furthermore, more than half of the international patents are engineering related.

Although this report does not forecast future outcomes, the data show the evolution of the United States in the global S&E enterprise. The United States continues to lead globally in R&D expenditures, S&E doctoral-level degree awards, and production of highly cited research publications. At the same time, other nations, particularly China, are rapidly developing their S&E capacity. As a result, the United States has seen its relative share of global S&T activity flatten or shrink, even as its absolute activity levels kept rising. As more countries around the world develop R&D and human capital infrastructure to sustain and compete in a knowledge-oriented economy, the United States is playing a less dominant role in many areas of S&E activity.

Glossary

Definitions

Applied research: Original investigation undertaken to acquire new knowledge; directed primarily, however, toward a specific, practical aim or objective (OECD 2015).

Basic research: Experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view (OECD 2015).

Business sector: For the R&D sections of the report, the business sector as defined by the 2015 Frascati manual consists of both private enterprises (either publicly listed or traded, or not) and government-controlled enterprises that are engaged in market production of goods or services at economically significant prices. Nonprofit entities such as trade associations and industry-controlled research institutes are also classified in the business sector (OECD 2015).

Development (or experimental development): Systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving existing products or processes (OECD 2015).

East-Southeast Asia: The East-Southeast Asia region includes China, Indonesia, Japan, South Korea, Malaysia, Philippines, Singapore, Taiwan, Thailand, and Vietnam.

European Union (EU): The EU comprises 28 member nations: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, 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 nations.

Government sector: For the R&D sections of the report, the government sector as defined by the 2015 Frascati manual includes all federal, state, and local governments, except those that provide higher education services, and all non-market nonprofit institutions that are controlled by government entities that are not part of the higher education sector. This sector excludes public corporations, even when all the equity of such corporations is owned by government entities. Public enterprises are included in the business sector defined above (OECD 2015).

High- and middle-income countries: The World Bank defines a high-income country as one with a gross national income per capita of US$12,235 or more in 2018. Middle-income countries are defined as lower middle-income economies (those with a gross national income per capita between $1,006 and $3,955); and upper middle-income economies (those with a gross national income per capita between $3,956 and $12,235) in 2018. Examples of high-income countries include the United States, Japan, United Kingdom, France, and Spain, and examples of middle-income countries include China, Vietnam, and India (see http://databank.worldbank.org/data/download/site-content/CLASS.xls for a full list of countries in each category).

Higher education sector: For the R&D sections of the report, the higher education sector as defined by the 2015 Frascati manual includes all universities; colleges of technology and other institutions providing formal tertiary education programs, whatever their source of finance or legal status; and all research institutes, centers, experimental stations, and clinics that have their R&D activities under the direct control of, or are administered by, tertiary education institutions (OECD 2015).

Information and communication technologies (ICT) industries: The OECD (2017) defines ICT industries as consisting of the following industries classified under the International Standard Industrial Classification Revision Code 4 (ISIC Rev 4): 26 Computer, electronic, and optical products; 582 Software publishing; 61 Telecommunications; and 62-63 IT and other information services.

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 the UNESCO Institute for Statistics, OECD, and Eurostat, and it excludes students who travel for credit mobility.

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 S&E publications. An index greater than 1.00 means that a country contributed a larger share of highly cited publications; an index less than 1.00 means a smaller share.

Invention: The development of something new that has a practical bent—potentially useful, previously unknown, and nonobvious.

Innovation: The implementation of a new or improved product or business process that differs significantly from previous products or processes and that has been introduced in the market or brought into use by the firm (OECD/Eurostat 2018). Data presented in this report are based on an earlier standard definition (OECD/Eurostat 2005).

Knowledge- and technology-intensive industries: Industries classified by the OECD as high-R&D intensive and medium-high R&D intensive industries. The OECD defines R&D intensity as the ratio of an industry's business R&D expenditures to its value-added output.

Research and development (R&D): Research and experimental development comprise creative and systematic work undertaken to increase the stock of knowledge—including knowledge of humankind, culture, and society—and its use to devise new applications of available knowledge. R&D performance and funding estimates are expressed in current dollars and at purchasing power parity for cross-country comparisons.

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-to-GDP ratio and R&D-to-value-added output ratio.

Science and engineering (S&E) fields: Degree award data cover degrees in the following S&E fields: astronomy, chemistry, physics, atmospheric sciences, earth sciences, ocean sciences, mathematics and statistics, computer sciences, agricultural sciences, biological sciences, psychology, social sciences, and engineering. At the doctoral level, the medical and health sciences are included under S&E because these data correspond to the doctor's research/scholarship degree level, which are research-focused degrees.

Science and engineering (S&E) occupations: Biological, agricultural, and environmental life scientists; computer and mathematical scientists; physical scientists; social scientists; and engineers, including postsecondary teachers in these fields. S&E managers and technicians and health-related occupations are categorized as S&E-related and are not included in S&E.

Skilled technical workforce: Workers in occupations that use significant levels of S&E expertise and technical knowledge and whose educational attainment is less than a bachelor's degree.

South Asia: The South Asia region includes Cambodia, India, Mongolia, Myanmar, Nepal, Pakistan, and Sri Lanka.

Stay rate: The proportion of foreign recipients of U.S. S&E doctorates who stay in the United States after receiving their doctorate. The 5-year stay rate is discussed in this report.

Underrepresented minorities (URM): This category comprises three racial or ethnic minority groups (blacks or African Americans, Hispanics or Latinos, and American Indians or Alaska Natives) whose representation in S&E education or occupations is smaller than their representation in the U.S. population.

Value-added output: 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 double-counting of the country, industry, firm, or other entity purchases of domestic and imported supplies and inputs from other countries, industries, firms, and other entities.

Key to Acronyms and Abbreviations

ACS: American Community Survey

AI: Artificial intelligence

BRDIS: Business R&D and Innovation Survey

DHS: Department of Homeland Security

ED: Department of Education

EU: European Union

FFRDC: federally funded R&D center

GDP: gross domestic product

GSS: General Social Survey

ICE: Immigration and Customs Enforcement

ICT: information and communication technologies

IMF: International Monetary Fund

INPADOC: International Patent Documentation

NAEP: National Assessment of Educational Progress

NCES: National Center for Education Statistics

NCSES: National Center for Science and Engineering Statistics

NSCG: National Survey of College Graduates

NSF: National Science Foundation

OECD: Organisation for Economic Co-operation and Development

PATSTAT: Patent Statistical Database of the European Patent Office

PPP: purchasing power parity

R&D: research and [experimental] development

ROW: rest of world

S&E: science and engineering

S&T: science and technology

SESTAT: Scientists and Engineers Statistical Data System

SEVIS: Student and Exchange Visitor Information System

STEM: science, technology, engineering, and mathematics

TIMSS: Trends in International Mathematics and Science Study

UNESCO: United Nations Educational, Scientific and Cultural Organization

UN: United Nations

URM: underrepresented minority

USPTO: U.S. Patent and Trademark Office

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Detailed Figure Notes

Figure 1: TIMSS participants include both countries, which are complete, independent political entities, and non-national entities (e.g., Hong Kong). Developed economies are based on the International Monetary Fund (IMF) designation of advanced economies (Table A, pg. 132 in *World Economic Outlook: Challenges to Steady Growth*, 2018). IMF classifies Russia as a developing economy, but it is included in this analysis because it is a large economy with high levels of student achievement. See Martin et al. (2016) and Mullis et al. (2016) for more details on the TIMSS performance.

Figure 2: For more information on NAEP, see https://nces.ed.gov/nationsreportcard/.

Figure 3: To facilitate international comparison, data for the United States are those reported to the OECD, which vary slightly from the NCSES classification of fields presented in other sections of the report. Data are not available for all countries or economies for all years. The EU top 6 total includes aggregated data for the six EU countries producing the highest number of S&E first university degrees in 2016: France, Germany, Italy, Poland, Spain, and the United Kingdom. The data source for Japan changed in 2014, which may potentially result in a time series break.

Figure 4: Dotted line connects across missing data. To facilitate international comparison, data for the United States are those reported to the OECD, which vary slightly from the NCSES classification of fields presented in other sections of the report. Data are not available for all countries or economies for all years. The EU top 6 total includes aggregated data for the six EU countries producing the highest number of S&E doctoral degrees in 2016: France, Germany, Italy, Spain, Sweden, and the United Kingdom. EU top 6 includes estimated data for some countries and some years when country data are not available.

Figure 5: Data include active foreign national students on F-1 visas and exclude those on optional practical training. Numbers are rounded to the nearest 10. Detail may not add to total because of rounding. The data reflect fall enrollment in a given year and include students with "active" status as of November 15 of that year. For more information on the SEVIS database, see https://www.ice.gov/sevis/overview.

Figures 11 and 15: Data for the United States in this figure reflect international standards for calculating gross expenditures on R&D, which vary slightly from the NCSES's protocol for tallying U.S. total R&D.

Figure 21: Article counts are from a selection of journals in S&E from Scopus. Articles are credited on a fractional count basis (i.e., for articles from multiple regions, countries, or economies, each area receives fractional credit on the basis of the author's institutional address). Some articles have incomplete address information for coauthored publications in the Scopus database and cannot be fully assigned to a region, country, or economy. These unassigned counts, 0.1% of the world total in 2018, are used to calculate this figure but are not shown. For more information on Elsevier's Scopus database, see https://www.elsevier.com/solutions/scopus.

Figure 22: 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, referred to as the "index of highly cited articles." It is computed as follows: $Sx = HCAx/Ax$, where Sx is the share of output from country x in the top 1% most cited articles; $HCAx$ is the number of articles from country x that are among the top 1% most-cited articles in the world; and Ax is the total number of articles from country x in the database that were published in 2016 or earlier. At least 2 years of data after 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 are assigned to a region, country, or economy on the basis of the institutional address(es) listed in the article. The world average stands at 1.00 for each period and field. For more information on Elsevier's Scopus database, see https://www.elsevier.com/solutions/scopus.

Figure 23: Articles refer to publications from a selection of journals and conference proceedings in S&E indexed in Scopus. Articles are credited on a whole-count basis (i.e., each collaborating country or economy is credited with one count). An article is considered an international collaboration when there are institutional addresses for authors from at least two different countries. Domestic author(s) only include articles with a single author or multiple authors with institutional addresses from only one country. The numbers of articles from the "international collaboration" and "domestic author(s) only" categories do not sum to the total whole-count article number because some coauthored publications have incomplete address information in the Scopus database and sometimes cannot be reliably identified as international or domestic collaborations. For more information on Elsevier's Scopus database, see https://www.elsevier.com/solutions/scopus.

Figures 24 and 25: 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 materials and inputs. For more information on the Comparative Industry Service Forecast database available at IHS Markit, see https://ihsmarkit.com/.

Figures 26 and 27: For more information on PATSTAT data, see https://www.epo.org/searching-for-patents/business/patstat.html#tab-1.

Figures 29 and 30: Dotted line connects across missing data (Figure 29). The most recent attitudes data are from the General Social Survey (GSS) 2018 (available at https://gss.norc.org/getthedata/Pages/Home.aspx), conducted by NORC at the University of Chicago. Historical attitudes data are from the Survey of Consumer Attitudes, conducted by the University of Michigan, and from the Survey of Public Attitudes Toward and Understanding of Science and Technology, conducted by NCSES (both available at https://www.icpsr.umich.edu/icpsrweb/ICPSR/studies/28368). The following questions from these surveys are used in these figures:

- Agree that science generates opportunities for next generation: Data show responses of "strongly agree" and "agree" with the statement, *Because of science and technology, there will be more opportunities for the next generation*.
- Agree that government should fund basic scientific research: Data show responses of "strongly agree" and "agree" with the statement, *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*.
- Agree that science makes life change too fast: Data show responses of "strongly agree" and "agree" with the statement, *Science makes our way of life change too fast*.
- Have a great deal of confidence in the scientific community: Data show respondents expressing a "great deal of confidence" when asked, *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?*

Explore Further

The *Indicators 2020* thematic reports provide more detailed analysis and fuller discussion of the related topics presented in *The State of U.S. Science and Engineering*. Each topic presented in this report and its corresponding *Indicators 2020* thematic report or reports are listed below. The *State Indicators* data tool also provides detailed information on selected S&E indicators for states.

U.S. and Global Education

- "Elementary and Secondary Mathematics and Science Education" by Susan Rotermund (RTI International) and Karen White (National Center for Science and Engineering Statistics [NCSES]). Available at https://ncses.nsf.gov/pubs/nsb20196/.
- "Higher Education in Science and Engineering" by Josh Trapani (NCSES) and Katherine Hale. Available at https://ncses.nsf.gov/pubs/nsb20197/.
- "The Skilled Technical Workforce: Crafting America's Science and Engineering Enterprise." Available at https://www.nsf.gov/nsb/publications/2019/nsb201923.pdf

U.S. S&E Workforce

- "U.S. Science and Engineering Labor Force" by Amy Burke (NCSES). Available at https://ncses.nsf.gov/pubs/nsb20198/.

Global R&D

- "Research and Development: U.S. Trends and International Comparisons" by Mark Boroush (NCSES). Available at https://ncses.nsf.gov/pubs/nsb20203/.

U.S. R&D Performance and Funding

- "Research and Development: U.S. Trends and International Comparisons" by Mark Boroush (NCSES). Available at https://ncses.nsf.gov/pubs/nsb20203/.
- "Academic Research and Development" by Josh Trapani (NCSES) and Michael Gibbons (NCSES). Available at https://ncses.nsf.gov/pubs/nsb20202/.

Global S&T Capabilities

- "Publication Output: U.S. Trends and International Comparisons" by Karen White (NCSES). Available at https://ncses.nsf.gov/pubs/nsb20206/.
- "Production and Trade of Knowledge- and Technology-Intensive Industries" by Derek Hill (NCSES). Available at https://ncses.nsf.gov/pubs/nsb20205/.

Invention, Innovation, and Perceptions of Science

- "Invention, Knowledge Transfer, and Innovation" by Carol Robbins (NCSES), Mark Boroush (NCSES) and Derek Hill (NCSES). Available at https://ncses.nsf.gov/pubs/nsb20204/.
- "Science and Technology: Public Attitudes, Knowledge, and Interest" (forthcoming) by John Besley (University of Michigan) and Derek Hill (NCSES). Available at https://ncses.nsf.gov/pubs/nsb20207/.

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National Institutes of Health

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U.S. Geological Survey

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Cover Image Credit

The cover for *Science and Engineering Indicators 2020: The State of U.S. Science and Engineering* shows a trefoil knot, an iconic topological object, coming out of a tunnel with an image of superconducting qubit chips reflected on its surface.

Starting early this century, scientists have been working hard to exploit the strangeness of quantum mechanics and make a quantum computer. The superior computational processing power of quantum bits (qubits) is poised to have revolutionary impacts on diverse fields ranging from chemistry to economics. In the race to find a reliable platform for making quantum computers, superconducting qubits are among the leading ones.

In 2014, scientists at the University of California, Santa Barbara, in collaboration with Boston University, used one of these chips to study quantum topology and showed how superconducting qubits can help to make topological concepts tangible. Topology, despite its abstract mathematical constructs, often manifests itself in physics and has a pivotal role in the understanding of natural phenomena. Notably, the discovery of topological phases in condensed-matter systems has changed the modern conception of phases of matter. In their research, the scientists found a novel method to directly measure topological properties of quantum systems. [This research was supported in part by the National Science Foundation (grants DMR 09-07039 and DMR 10-29764).]

Credit: *P. Roushan\Martinis lab\UC Santa Barbara*

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NSB-2020-1