The State of U.S. Science & Engineering

2022

Science & Engineering Indicators

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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.

Indicators provides information on the state of the U.S. science and engineering (S&E) enterprise over time and within a global context. The report is a policy-relevant, policy-neutral source of high-quality U.S. and international data. The indicators presented in the report are quantitative representations relevant to the scope, quality, and vitality of the S&E enterprise.

This report summarizes key findings from the nine thematic reports providing in-depth data and information on science, technology, engineering, and mathematics (STEM) education at all levels; the STEM workforce; U.S. and international research and development performance; U.S. competitiveness in high-technology industries; invention, knowledge transfer, and innovation; and public perceptions and awareness of science and technology. *Indicators* also includes an interactive, online tool that enables state comparisons on a variety of S&E indicators. This report, the nine thematic reports, and the online **State Indicators data tool** together comprise the full *Indicators* suite of products.

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Executive Summary

Key Takeaways

- Global research and development (R&D) performance is concentrated in a few countries, with the United States performing the most (27% of global R&D in 2019), followed by China (22%), Japan (7%), Germany (6%), and South Korea (4%).
- The global concentration of R&D performance continues to shift from the United States and Europe to countries in East-Southeast Asia and South Asia.
- Many middle-income countries, such as China and India, are increasing science and engineering (S&E) publication, patenting activities, and knowledge- and technology-intensive (KTI) output, which has distributed science and technology (S&T) capabilities throughout the globe.
- The proportion of total U.S. R&D funded by the U.S. government decreased from 31% in 2010 to an estimated 21% in 2019, even as the absolute amount of federally funded R&D increased.
- The U.S. science, technology, engineering, and mathematics (STEM) labor force represents 23% of the total U.S. labor force, involves workers at all educational levels, and includes higher proportions of men, Whites, Asians, and foreign-born workers than the proportions of these groups in the U.S. population.
- Blacks and Hispanics are underrepresented among students earning S&E degrees and among STEM workers with at least a bachelor's degree. However, their share of STEM workers without a bachelor's degree is similar to their share in the U.S. workforce.
- Disparities in K–12 STEM education and student performance across demographic and socioeconomic categories and geographic regions are challenges to the U.S. STEM education system, as is the affordability of higher education.
- The United States awards the most S&E doctorates worldwide. Among S&E doctorate students in the United States, a large proportion are international and over half of the doctorate degrees in the fields of economics, computer sciences, engineering, and mathematics and statistics are awarded to international students.

The State of U.S. Science and Engineering shows that strengthening the U.S. S&E enterprise is critical to maintaining the U.S. position as a lead performer and collaborator of S&T activities globally (see **Glossary** section for definition of terms used in this report). Currently, the United States leads the world on several S&E fronts. The successful development of COVID-19 vaccines demonstrates that the U.S. S&E enterprise is strong and can effectively collaborate internationally across sectors. Globally, the United States performed the most R&D ($656 billion, preliminary estimate) in 2019. However, the United States' role as the world's foremost performer of R&D is changing as Asia continues to increase its investments. Growth in R&D and S&T output by other countries, including China, outpaced that of the United States. Consequently, even as U.S. R&D has increased, the U.S. share of global R&D has declined, and the relative position of the United States in some S&T activities has either not changed or decreased even as absolute activities increased.

Globally and within the United States, the business sector both funds and performs the most R&D. However, in terms of share of total R&D funding, the federal government is the single largest funder of basic research (41%), followed by business (31%), nonfederal government and nonprofits (16%), and higher education (13%). The federal government also funds the greatest proportion of R&D performed by higher education institutions (50%). The proportion of U.S. R&D funded by the federal government has declined since 2010 in all sectors and in all research types—basic, applied, and experimental development. Because higher education institutions perform much of the nation's basic research and because they provide advanced training in S&E that is needed by many KTI industries, declining shares of federal support for higher education could limit the ability of the United States both to perform R&D and to develop a sufficiently expert STEM workforce.

The U.S. STEM workforce, those who work in jobs that typically require S&E knowledge and skills, is large: 16 million workers with at least a bachelor's degree and nearly 20 million workers in the skilled technical workforce (STW) who do not have a bachelor's degree. The uneven representation of demographic groups in the STEM workforce indicates that there are opportunities to increase the STEM workforce with domestic talent—particularly at the bachelor's degree level or higher.

Women and certain minority groups—Blacks, Hispanics, and Native American or Alaska Natives—are underrepresented in the STEM workforce relative to their proportion within the U.S. population. Women make up a greater proportion of the STEM workforce with at least a bachelor's degree than of the STW. In contrast, the underrepresentation of persons from minority groups in the STEM workforce is largely driven by their underrepresentation among STEM workers with a bachelor's degree or higher. These groups are more represented in the STW.

The STEM workforce relies heavily on foreign-born individuals, who account for about one-fifth of the STEM workforce (and higher proportions in certain fields). Among foreign-born STEM workers with an S&E degree, about 50% are from Asia, with most from India or China. In addition, large proportions of computer and mathematical scientists at both the bachelor's (25%) and doctorate (60%) degree levels were foreign-born STEM workers in 2019.

As an educator and collaborator, the United States facilitates the development of international S&T capability. U.S.-authored S&E articles are some of the most highly cited articles in the world. Additionally, 35% of the world's S&E articles with authors from multiple countries have at least one U.S. author. Even with the reduced mobility resulting from the COVID-19 pandemic, international students enrolled in S&E majors at U.S. higher education institutions exceeded 325,000 in 2020 (down from 406,000 the previous year). Most international students study engineering, economics, computer sciences, or mathematics and statistics.

Although the United States is internationally highly competitive in STEM education at the college level, U.S. students at the pre-college level performed only slightly above the Organisation for Economic Co-operation and Development (OECD) average in science and below average in math. Inequality persists in K–12 educational outcomes by race or ethnicity, socioeconomic status, and U.S. region. The gap in STEM test scores is widest between Asian students at the top and Black students at the bottom. STEM teachers with less experience are more prevalent in schools with high minority enrollments or with high concentrations of students living in poverty or in schools in the South and West.

Regional differences are not unique to K–12 education. U.S. S&T capabilities, KTI industries (see **Glossary** section for definition of KTI industries), universities with high innovation activity, and the STEM labor force are concentrated in a few geographic areas. U.S. patenting activity is concentrated along the coasts and in parts of the Great Lakes region, Texas, and the Rocky Mountains, a distribution similar to that of STEM employment and KTI industry production. In addition, affordability of higher education also varies across states. Enabling all Americans to receive high-quality STEM education and to pursue any S&E field of study or career are critical components of sustaining and growing the U.S. STEM labor force. Addressing regional differences in the U.S. S&E enterprise, including access to institutions of higher education, may offer potential avenues for enabling the country to meet existing and new challenges, like those presented by the COVID-19 pandemic.

COVID-19 substantially impacted the global economy, including the U.S. S&E enterprise. In the United States, the pandemic exacerbated pre-existing socioeconomic differences, such as a lack of access to computers and broadband at home for low-income and some minority students. The unemployment rate of STEM workers was lower than that of non-STEM workers, but women in STEM experienced higher unemployment than their male counterparts. Lack of access to technology for online learning was reported at higher rates for some minority groups. Enrollment at community colleges that serve low-income students declined sharply. The experience of the pandemic highlights challenges to the U.S. S&E enterprise, such as improving access to high-quality online education, while simultaneously showing the responsiveness of U.S. S&T capability in rapidly developing effective COVID-19 vaccines.

Introduction

The State of U.S. Science and Engineering summarizes key indicators that assess the status of the science and engineering (S&E) enterprise within the United States and that illustrate the U.S. global position in multiple aspects of the S&E enterprise. This includes information about the geographic distribution of S&E activities; science, technology, engineering, and mathematics (STEM) employment opportunities; geographic differences in STEM education; and the participation of demographic and socioeconomic groups in the S&E enterprise within the United States. (See Glossary section for definition of terms used in this report).

This year's report differs from the previous report in four major ways. First, analysis of the STEM workforce now combines two major components that were previously considered as separate: (1) S&E and S&E-related workers with a bachelor's or higher degree and (2) skilled technical workers without such a degree. Integrating these two components provides a better estimate of those using S&E skills and knowledge to support the U.S. S&E enterprise. Second, the report includes a sidebar on how the COVID-19 pandemic affected many aspects of the S&E enterprise—education, employment, innovation, collaboration, and the release of new products into the marketplace. Third, the data for analysis of global research and development (R&D) contributions were revised due to updated purchasing power parity (PPP) estimates, which convert a country's R&D expenditures in its own currency to dollar expenditures, as a common measure across all countries. This resulted in relatively larger changes in China's R&D estimates than in those of other countries, which is detailed in a sidebar. Fourth, the survey instrument used to capture U.S. business innovation changed to capture innovation more comprehensively, which resulted in large revisions to the innovation data.

This report provides high-level findings from detailed analyses in nine thematic reports that together make up *Science and Engineering Indicators 2022*. The thematic reports rely on publicly available data, surveys performed by the National Center for Science and Engineering Statistics (NCSES) within the National Science Foundation (NSF), and surveys and analysis performed by a range of other federal and international organizations.

Here, selected data from the nine reports are grouped into three major sections, and notes at the end of the report provide information about the specific reports that are the sources for each section. The first section describes the U.S. STEM education system from K–12 through doctoral level education and the STEM workforce, including the international composition of S&E degree-seeking students and the contribution of foreign-born workers. The second section is on R&D, which provides analysis of how various economic sectors fund and perform R&D activities and compares the United States to other top R&D-performing countries. This section also includes two sidebars: one on the revisions to the global R&D estimates and one on the effects of the COVID-19 pandemic on the U.S. S&E enterprise. The final section focuses on outputs of the S&E enterprise to provide insight into how U.S. S&E contributes to global knowledge, innovation, and products of knowledge- and technology-intensive (KTI) industries. Highlighting the global nature of the use of these outputs, this section focuses on comparisons between the United States and other major contributing regions, countries, or economies.

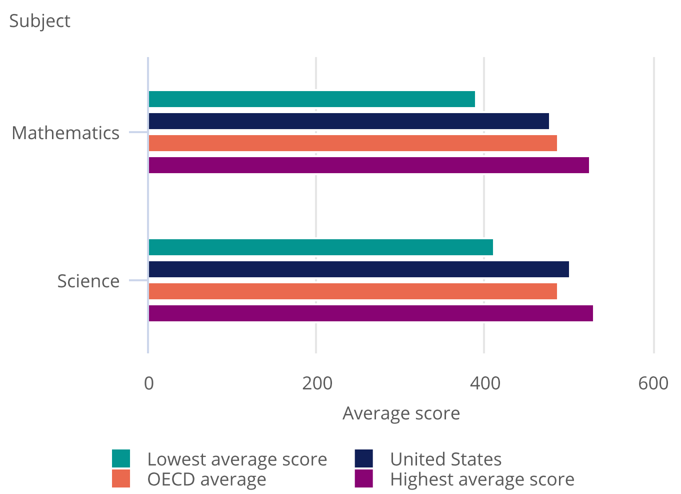
U.S. and Global STEM Education and Labor Force

The U.S. STEM workforce relies on STEM-trained workers with a broad range of educational credentials. STEM education equips Americans with the S&E skills and knowledge needed to participate in the STEM workforce. STEM education also leads to better public perceptions and understanding of science and the broader impact of its role in society.

Elementary and Secondary (K–12) Mathematics and Science

Elementary and secondary education in mathematics and science are the foundation for entry into postsecondary STEM majors and STEM-related occupations.[1] The United States ranks higher in science literacy (7th out of 37 Organisation for Economic Co-operation and Development [OECD] countries) than it does in mathematics literacy (25th of 37 OECD countries). The average U.S. mathematics score in 2018 was lower than the OECD average and has not measurably changed since 2003, whereas the average U.S science score was higher than the OECD average and has improved by 13 points since 2006 (Figure 1).[2]

Figure 1. Average scores of 15-year-old students on the PISA mathematics and science literacy scales, by OECD education system: 2018



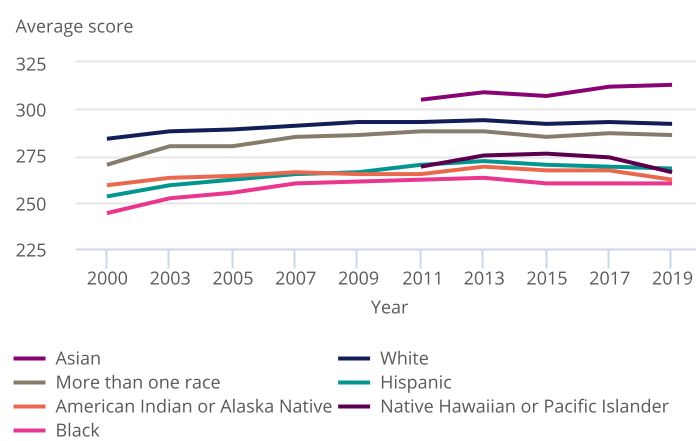
Note(s): OECD is Organisation for Economic Co-operation and Development. PISA is Program for International Student Assessment.

Source(s): OECD, PISA, 2018. *Indicators 2022: K–12 Education*

This low international ranking of the United States in mathematics is consistent with the lack of improvement in student achievement for more than a decade. Mathematics scores for Black, Hispanic, Native Hawaiian or Pacific Islander, and American Indian or Alaska Native students persistently lag behind the scores of their White and Asian peers. Among fourth graders in 2019, scores in mathematics were 18–25 points lower for students in these racial or ethnic minority groups than for White students; this gap was even wider (24–32 points) among eighth-graders (Figure 2).[3] Asian students consistently outperformed all other groups in both grades 4 and 8.

Teacher qualifications vary across student demographic groups and U.S. regions. In 2018, STEM teachers with less than 3 years of experience were more prevalent at schools with high-minority or high-poverty populations (Figure 3).[4] T hey also tend to be more prevalent in the southern and western regions of the United States.

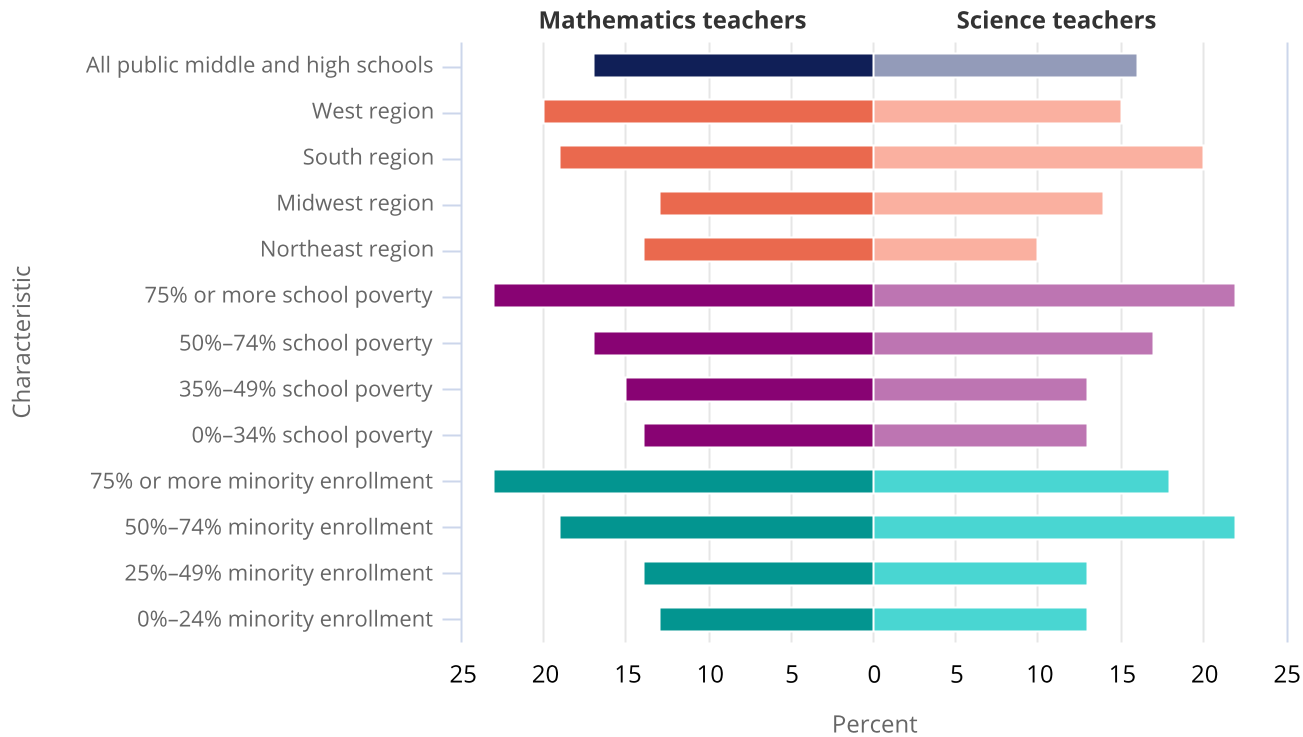
Figure 2. Average scores of U.S. students in grade 8 on the NAEP mathematics assessment, by race or ethnicity: 2000–19



Note(s): NAEP is National Assessment of Educational Progress. Data were not available for all years. The scale for NAEP mathematics assessment scores is 0–500 for grade 8.

Source(s): NCSES, special tabulations (2020) of the main NAEP 2000–19 mathematics assessments, NCES, ED. *Indicators 2022: K–12 Education*

Figure 3. Public middle and high school mathematics and science teachers with 3 years or less of teaching experience, by selected school characteristics: 2017–18



Note(s): School poverty level is the percentage of students in school qualifying for free or reduced-price lunch.

Source(s): NCSES, special tabulations (2020) of 2017–18 National Teacher and Principal Survey, NCES, ED. *Indicators 2022: K–12 Education*

S&E Higher Education in the United States

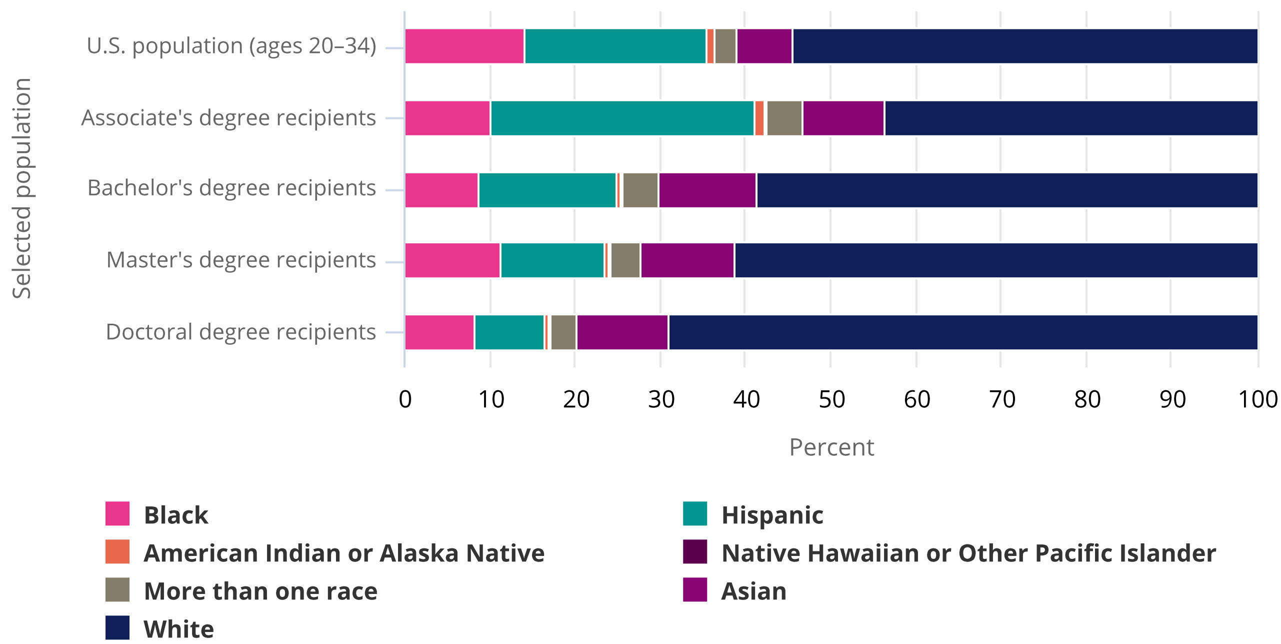
Although some students transition directly from high school to the STEM labor force, the nation's S&E enterprise depends heavily on recipients of higher education degrees in S&E fields (see Glossary section for list of S&E fields).[5] The number of degrees in S&E fields across all degree levels increased from 561,000 in 2000 to 1,087,000 in 2019, an increase in percentage share of S&E degrees from 24% to 27%. However, many groups of Americans remained underrepresented among S&E degree recipients. Blacks were underrepresented at all degree levels, whereas Hispanics and American Indians and Alaska Natives were underrepresented at all but the associate's degree level (Figure 4).[6]

Many students and their families invest in higher education, but increases in the cost of undergraduate education have far exceeded inflation or increases in average family income, contributing to concerns about affordability of higher education. The average undergraduate charge at public 4-year institutions as a percentage of per capita disposable personal income increased from around 33% in the early 2000s to 41% in 2019. Since 1994, this measure has increased in every state, and in 2019 ranged from a low of 26% in Wyoming to a high of 58% in Vermont, with eight states over 50%.

Many students enter higher education through the less expensive community college path. Among students who completed high school in 2018 and immediately enrolled in college, approximately two-fifths enrolled in community colleges. Community colleges prepare students to directly enter the workforce with associate's degrees or non-degree credentials such as certificates or to transition to 4-year institutions. In 2019, the United States awarded 104,000 associate's degrees in S&E fields and 123,000 in S&E technologies. Degrees in S&E technologies have a more applied focus than S&E degrees and include technician degree programs in engineering, health sciences, and other S&E fields. In addition, students can also earn certificates in S&E technologies. Community colleges awarded most (65%) of the 258,000 certificates awarded in S&E technologies in 2019. Students often earn one or more certificates alongside or instead of a degree.

Bachelor's degrees account for nearly 70% of all S&E degrees awarded, with the largest numbers awarded in social sciences, followed by biological and agricultural sciences. Master's degrees either prepare students for some STEM careers or mark a step toward obtaining a doctoral degree. The number of master's degrees awarded in S&E fields more than doubled from 2000 to 2019. Increases were most pronounced in computer sciences and engineering, largely driven by students on temporary visas. In 2019, S&E fields accounted for 65% of doctorates conferred by U.S. universities, with S&E doctorate awards rising faster since 2000 than total doctorate awards. Across fields, the largest percentage increases since 2000 occurred in engineering, computer sciences, and medical sciences.

Figure 4. Representation of race or ethnicity in the U.S. population and among S&E degree recipients: 2019



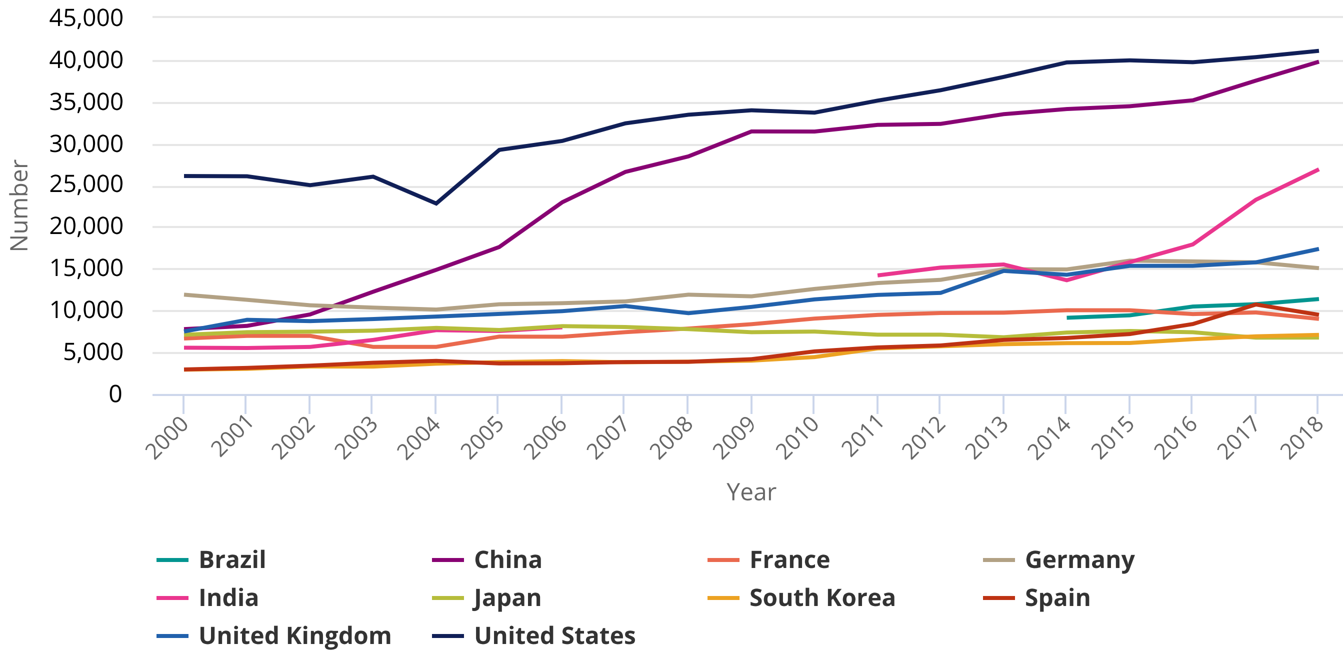
Source(s): U.S. Census Bureau, U.S. population data, 2019; NCES, IPEDS Completion Survey, 2019. *Indicators 2022: Higher Education*

International S&E Higher Education and Student Mobility

Consistent with their large populations, India and China lead the world in awarding S&E first-university degrees, which are roughly equivalent to bachelor's degrees (see Glossary section for definition of first-university degrees).[7] The United States is next, followed by Brazil, Mexico, the United Kingdom, Japan, Turkey, Germany, South Korea, and France. The number of first-university degrees awarded has risen since 2000 for all these countries except Japan.

For decades, the United States has led the world in the number of S&E doctorates awarded (41,000 in 2018); however, China is closing the gap (Figure 5).[8] Indeed, as of 2007, China surpassed the United States in awarding the most doctorate degrees in natural sciences and in engineering (excluding social and behavioral sciences; see Glossary section for definition of natural sciences). In 2018, China awarded nearly 38,000 doctorates in natural sciences and in engineering; the United States awarded 31,000. For most of the top countries or nations awarding S&E doctorates, the largest proportion was awarded in physical and biological sciences and mathematics and statistics. However, in China, South Korea, and Japan, engineering students receive the most S&E doctoral degrees.

Figure 5. S&E doctoral degrees, by selected countries: 2000–18



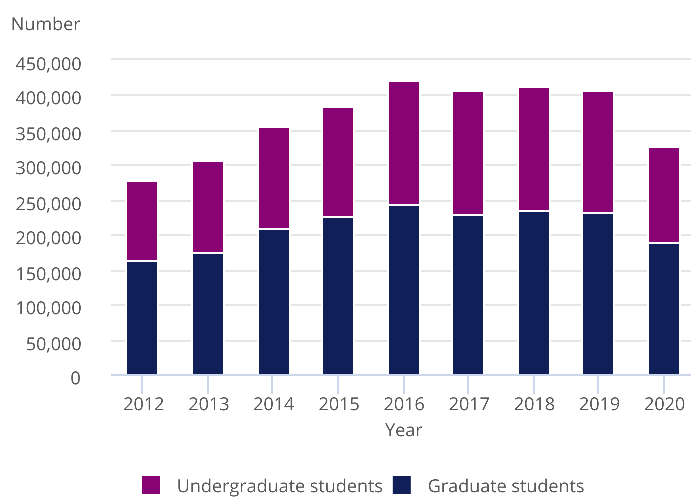
Note(s): Data are not available for all countries for all years.

Source(s): Educational statistics of OECD; Eurostat; MEXT (Japan); NBS and MOE (China); MHRD (India). *Indicators 2022: Higher Education*

More international students come to the United States than to any other country (18% of international students worldwide). Students on temporary visas studying in the United States earn a small proportion of S&E bachelor's degrees (7% in 2019, just under 50,000), but they are more likely than U.S. citizens and permanent residents to study S&E (49% of students on temporary visas study S&E versus 35% of U.S. citizens and permanent residents). At the master's level, students on temporary visas are earning increasing shares of S&E degrees: 36% (just under 75,000) in 2019 compared with 26% in 2011. During this period, the greatest increases were in engineering and computer sciences. In 2019, temporary visa holders earned 50% and 57% of total master's degrees in these fields, respectively. Students on temporary visas earned about one-third of S&E doctorates awarded in 2019, around the same proportion as in 2011. Differences by field also remained stable, regardless of representation of temporary visa holders in those fields. In 2019, temporary visa holders earned over half of U.S. doctoral degrees in economics, computer sciences, engineering, and mathematics and statistics but only around 20% of U.S. doctoral degrees in the social and behavioral sciences.

The coronavirus pandemic contributed to the decline of international higher education enrollment worldwide in 2020. The number of international S&E students enrolled at U.S. institutions of higher education declined by about 20% (80,000) from 2019 to 2020 (Figure 6).[9] The proportion of the pandemic-associated decline was larger for undergraduates than for graduate students, and it was larger for students studying non-S&E fields than for those studying S&E fields.

Figure 6. International students in S&E enrolled at U.S. higher education institutions, by academic level: 2012–20



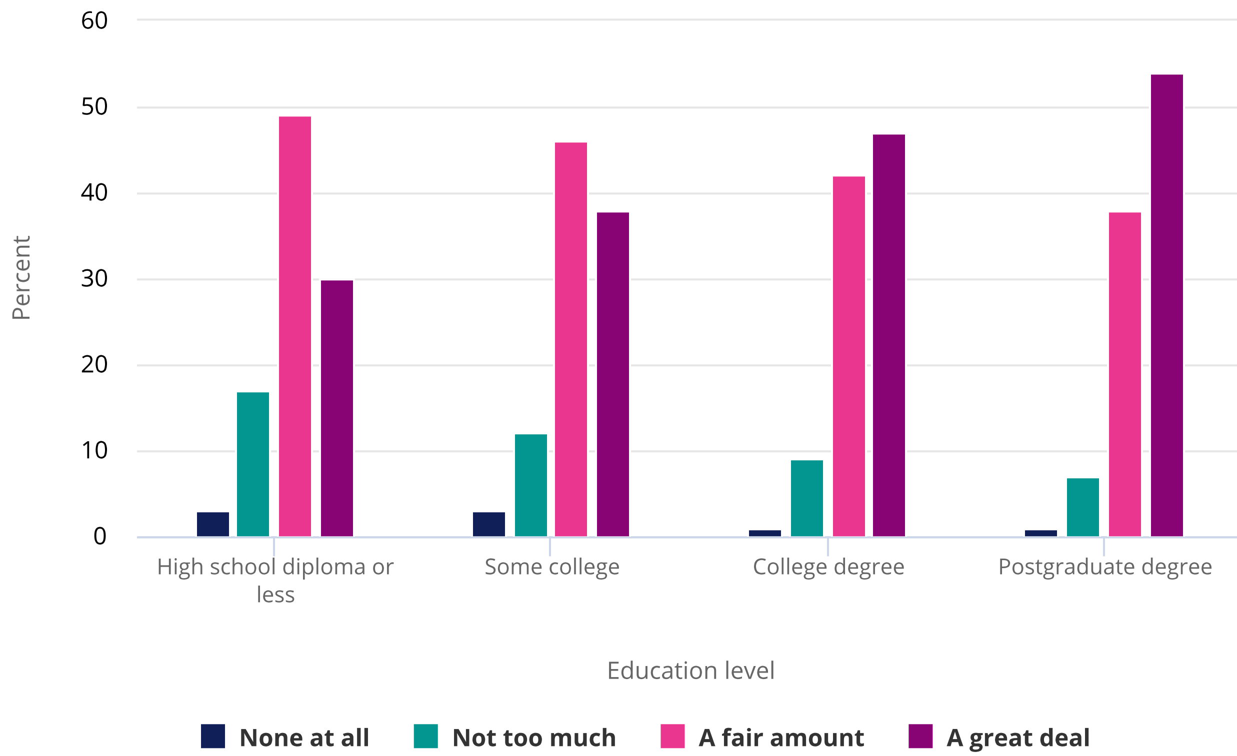
Note(s): Numbers are rounded to the nearest 10.

Source(s): DHS, ICE, special tabulations (2021), SEVIS database. *Indicators 2022: Higher Education*

Americans' Perceptions about Science

Americans' expressed trust in scientists varies by level of education.[10] Although 84% of U.S. adults overall expressed "a fair amount" or "a great deal" of confidence in scientists to act in the best interests of the public, this confidence varied slightly by education (Figure 7).[11] For example, 54% of U.S. adults with a postgraduate degree expressed a "great deal" of confidence in scientists, whereas 30% of U.S. adults with a high school diploma or less did. However, nearly half with a high school diploma or less had "a fair amount" of confidence in scientists. A full 20% of those with a high school diploma or less had "not too much" or "none at all" when asked about their level of confidence in scientists. A decline in this percentage was correlated with an increase in educational attainment.

Figure 7. Confidence in scientists to act in the best interests of the public, by education level of respondents: 2020



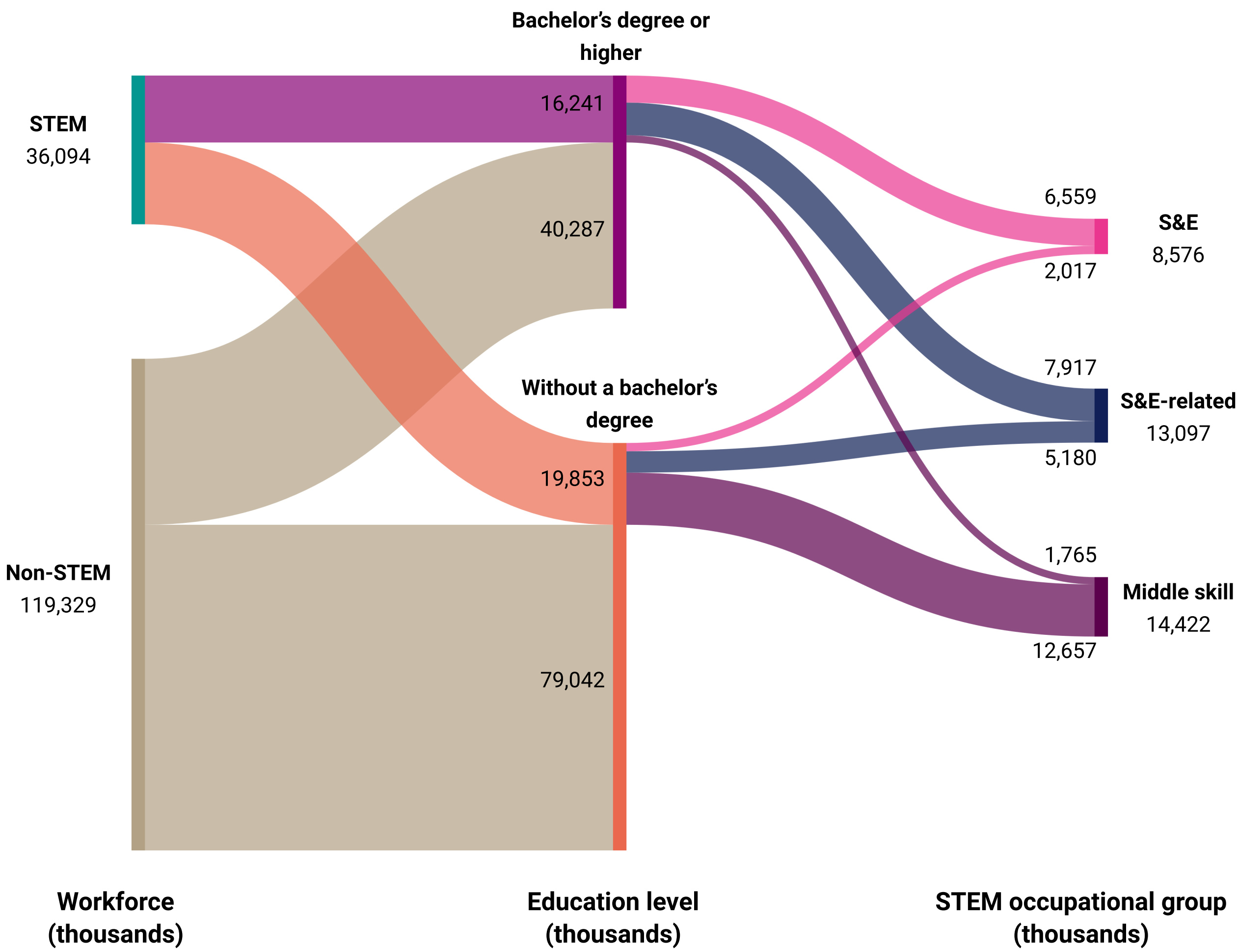
Note(s): Percentages may not add to 100% because the nonresponse category for level of confidence is not shown.

Source(s): Pew Research Center, American Trends Panel, 2020. *Indicators 2022: Public Perceptions*

The STEM Labor Market and the Economy

The U.S. STEM workforce—comprised of over 36 million people in diverse occupations that require STEM knowledge and expertise—constitutes 23% of the total U.S. workforce (Figure 8).[12,13] For this year, *Science and Engineering Indicators* introduced a new definition of the STEM workforce, which now encompasses all workers who use S&E skills in their jobs rather than defining the workforce mostly based on degree level. This new definition more than doubles the number of individuals classified within the STEM workforce by including 16 million workers with at least a bachelor's degree and 20 million workers without a bachelor's degree, also referred to as the STW.

Figure 8. U.S. workforce, by STEM occupational group and education level: 2019



Note(s): STEM is science, technology, engineering, and mathematics. Numbers are rounded to the nearest 1,000.

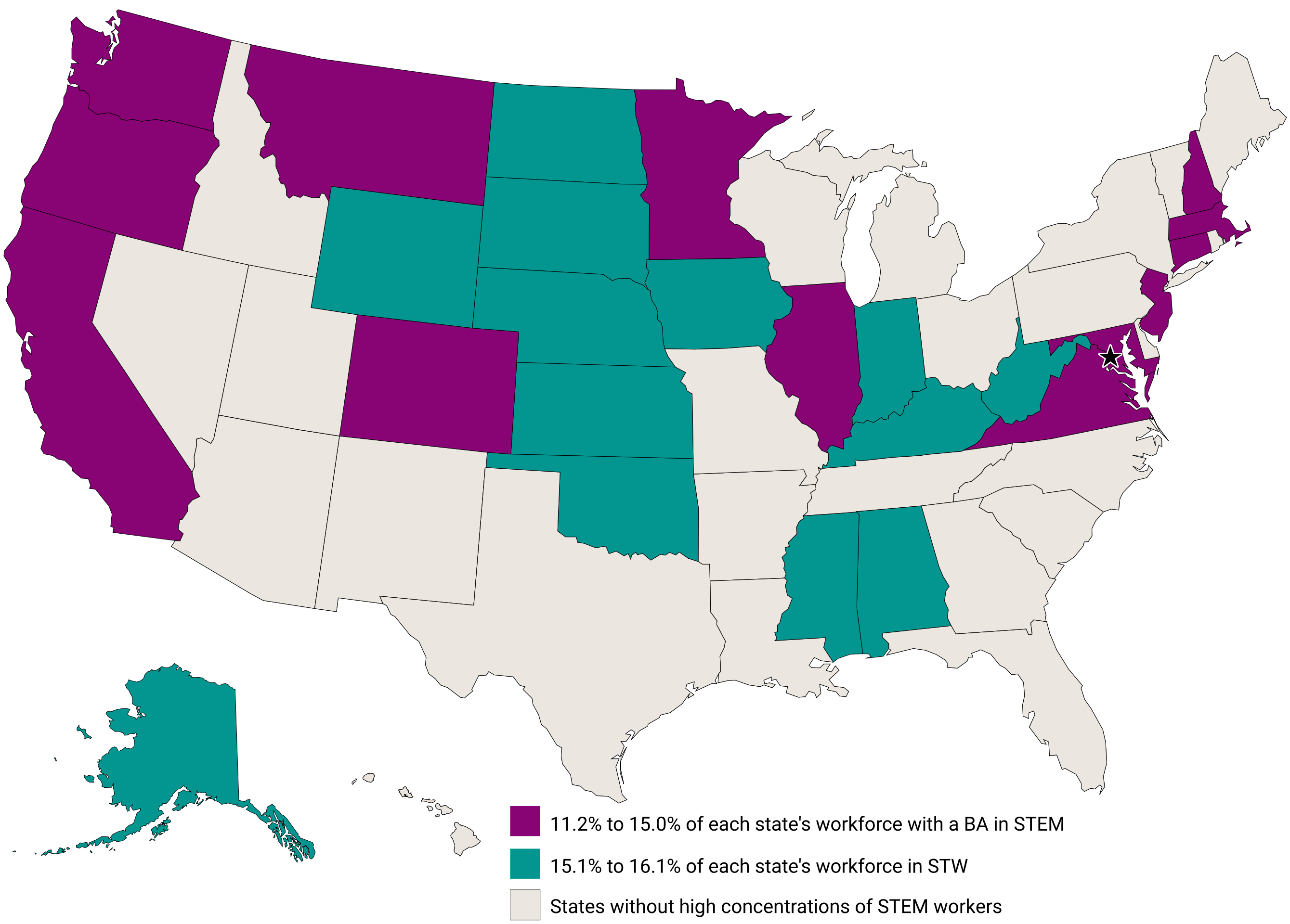
Source(s): U.S. Census Bureau, ACS, 2019. *Indicators 2022: Labor Force*

The STEM workforce includes occupations well understood to require STEM skills and expertise that typically require a bachelor's degree, referred to as S&E occupations and S&E-related occupations (see Glossary section for definitions of S&E occupations and S&E-related occupations). Of the 8.6 million STEM workers in S&E occupations, 6.6 million (76%) hold at least a bachelor's degree and 2 million do not have a bachelor's degree (Figure 8). Similarly, of the 13.1 million STEM workers in S&E-related occupations, 7.9 million (60%) hold at least a bachelor's degree or higher and 5.2 million do not have a bachelor's degree. In addition to S&E and S&E-related occupations, the STEM workforce also includes middle-skill occupations that require STEM skills but typically do not require a bachelor's degree for entry. Middle-skill occupations include those in the areas of installation, maintenance and repair, construction trades, and production. Of the 14.4 million middle-skill workers, 12.7 million (88%) do not have a bachelor's degree.

Workers in STEM occupations have higher median earnings and lower unemployment than their non-STEM counterparts. In 2019, STEM workers earned a median annual salary of $55,000, and non-STEM workers earned a median annual salary of $33,000. Also in 2019, unemployment was lower among the STEM labor force (2%) than the non-STEM labor force (4%). This pattern held during the economic downturn associated with the coronavirus pandemic (see sidebar Disruptions and Breakthroughs in S&E during the COVID-19 Pandemic).

STEM jobs have grown faster than non-STEM jobs since 2010, and many STEM jobs are projected to grow in the future. However, this projected growth may be unevenly distributed across the United States. In 2019, out of the total workforce in each state, a greater proportion of STEM workers with a bachelor's degree or higher were employed in coastal states and the Midwest region, whereas a greater proportion of the STW were employed in states in the South and the Midwest regions of the United States (Figure 9).[14]

Figure 9. High concentration of STEM workers, by state: 2019



Note(s): STEM is science, technology, engineering, and mathematics. STW is skilled technical workforce. The STW is made up of STEM workers without a bachelor's degree (BA). Concentration is measured as those employed in the STW or the STEM workforce with a bachelor's degree or above as a percentage of total employment in each state. High concentrations of STW or STEM workers with a bachelor's degree or above are the upper quartiles of the distributions of concentration for each (15.1% to 16.1% for STW and 11.2% to 15.0% for STEM workers with bachelor's degree or above). Data include workers ages 16–75 and exclude those in military occupations or currently enrolled in primary or secondary school.

Source(s): U.S. Census Bureau, ACS, 2019. *Indicators 2022: Labor Force*

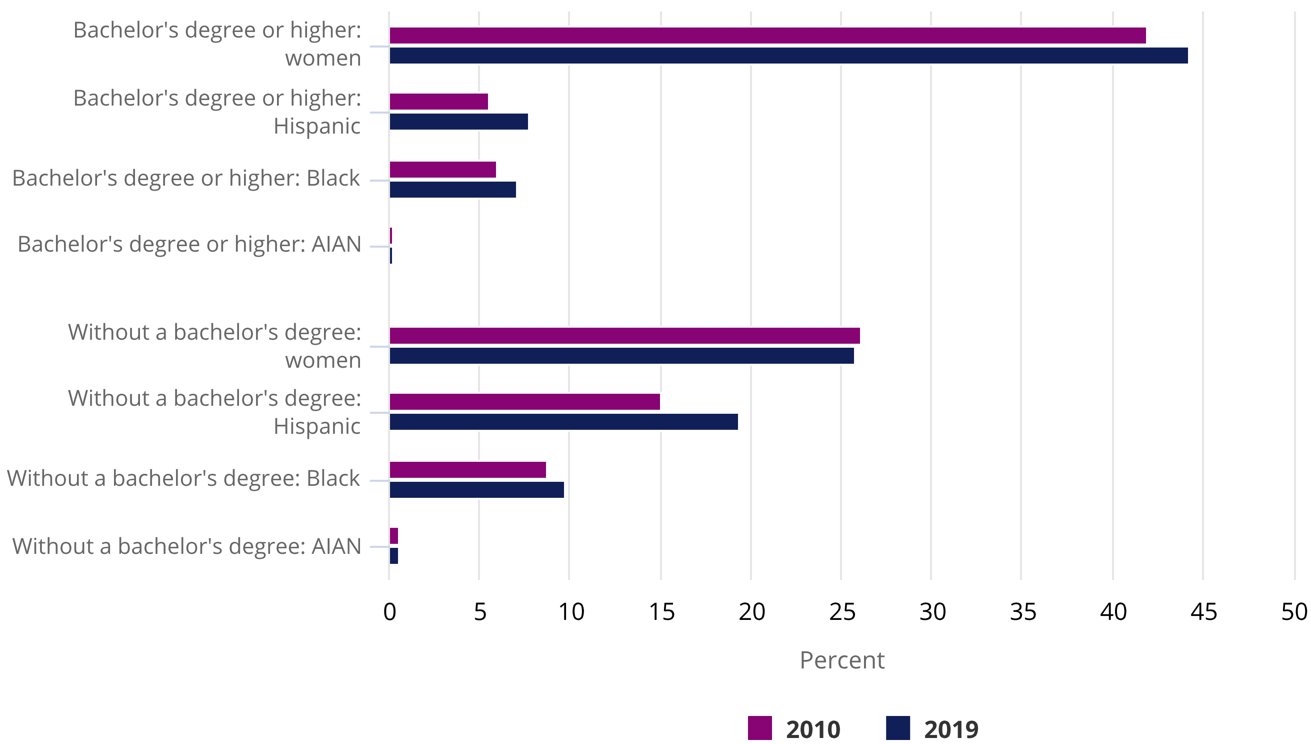
Demographic Composition of the STEM Workforce

Women make up about one-third of the STEM workforce, less than their representation in the employed U.S. population (48%).[15] The share of women in STEM grew from 32% in 2010 to 34% in 2019. However, this growth was due to the increase in the proportion of women with a bachelor's degree or higher in STEM, growing from 42% (5 million women) in 2010 to 44% (7 million women) in 2019 (Figure 10).[16] The proportion of women in the STW remained unchanged at around 26% in both 2010 and 2019.

Furthermore, the distribution of women with a bachelor's degree or higher was uneven among the different types of STEM occupations. In 2019, women accounted for 48% of life scientists and 65% of social scientists but only 35% of physical scientists, 26% of computer and mathematical scientists, and 16% of engineers. The distribution of women who earned degrees in S&E fields was similar to their distribution among S&E occupations at the bachelor's degree level or higher.

Blacks, Hispanics, and American Indians or Alaska Natives collectively represented 30% of the employed U.S. population but 23% of the total STEM workforce in 2019. Consequently, they were underrepresented in STEM, largely driven by their underrepresentation among STEM workers with a bachelor's degree or higher. The share of Hispanic or Latino workers in the STW (19%) was similar to their share of the U.S. workforce in 2019 (18%). However, they were underrepresented among STEM workers with at least a bachelor's degree (8%). The share of Blacks in the STEM workforce was similarly distributed with 10% in the STW and 12% in the U.S. working population, compared with 7% among STEM workers with a bachelor's degree or higher.

Figure 10. Demographic composition of the STEM workforce: 2010 and 2019



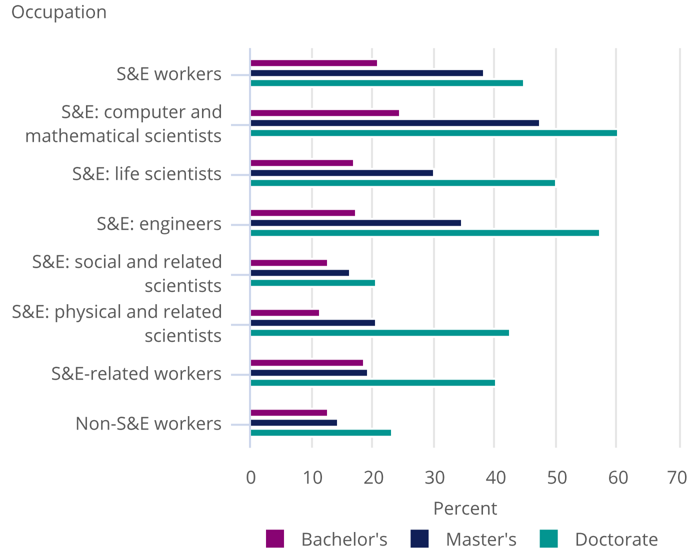
Note(s): AIAN is American Indian or Alaska Native. STEM is science, technology, engineering, and mathematics. Percentages may not add to 100% because of rounding.

Source(s): U.S. Census Bureau, ACS, 2019. *Indicators 2022: Labor Force*

Among STEM workers with a bachelor's degree, there was wide variation in the representation of Blacks and Hispanics across S&E occupations and women in S&E-related occupations in 2019. Compared with their share of S&E occupations overall (5%), Black workers were disproportionately higher among postsecondary teachers in the social and related sciences (9%), computer support specialists (10%), network and computer systems administrators (11%), and information security analysts (17%). Hispanics, who were 8% of workers in S&E occupations overall, had a relatively large presence among social scientists (12%). Within S&E-related occupations, women with a bachelor's degree or higher represented 70% of health care workers, but were disproportionately higher among registered nurses, pharmacists, dieticians, therapists, physical assistants, and nurse practitioners (82%); health technologists and technicians (66%); postsecondary teachers in health and related sciences (70%); and other health workers (70%).

In 2019, foreign-born workers (regardless of citizenship status) accounted for 19% of the STEM workforce, increasing from 17% in 2010. Foreign-born workers with a bachelor's degree or higher comprise a larger share of the STEM workforce (23%) than do those without a bachelor's degree (16%). Foreign-born workers with a bachelor's degree or higher accounted for 21% of workers in S&E occupations at the bachelor's degree level, 38% at the master's degree level, and 45% at the doctorate level, with the highest shares as computer and mathematical scientists for all degree levels (Figure 11). Foreign-born workers also make up a substantial portion (26%) of STEM workers at all education levels in knowledge- and technology-intensive (KTI) industries, but they are more concentrated among the pharmaceutical; computer, electronic and optical products; scientific R&D; software publishing; and information technology (IT) service industries.[17] Among foreign-born STEM workers in KTI industries, a little over half of them are U.S. citizens. About 50% of foreign-born workers in the United States whose highest degree was in an S&E field were from Asia, with India (22%) and China (11%) as the leading birthplaces.

Figure 11. Foreign-born workers with a bachelor's degree or higher, by highest degree level and major occupation: 2019



Source(s): NCSES, NSCG, 2019. *Indicators 2022: Labor Force*

Given that foreign-born workers make up 45% of the doctoral workers in S&E occupations, U.S.-trained S&E doctorate recipients who are on temporary visas at the time of graduation are a vital source of STEM workers. Temporary visa holders represented 37% of U.S. S&E doctoral recipients in 2019. For more than a decade, over 75% of these S&E doctorate recipients have stated that they intend to live in the United States in the year after graduation. However, the rate at which these graduates intend to stay in the United States after graduation varies by field of degree. Lower proportions of doctoral recipients in the social sciences (59%) intend to stay relative to those in the life, physical, and computer and mathematical sciences and in engineering (78% to 81%). Place of citizenship also affects intended stay rates (see Glossary section for definition of expected stay rate); students from China and India have relatively high expected stay rates compared with students from Europe and South Korea.[18]

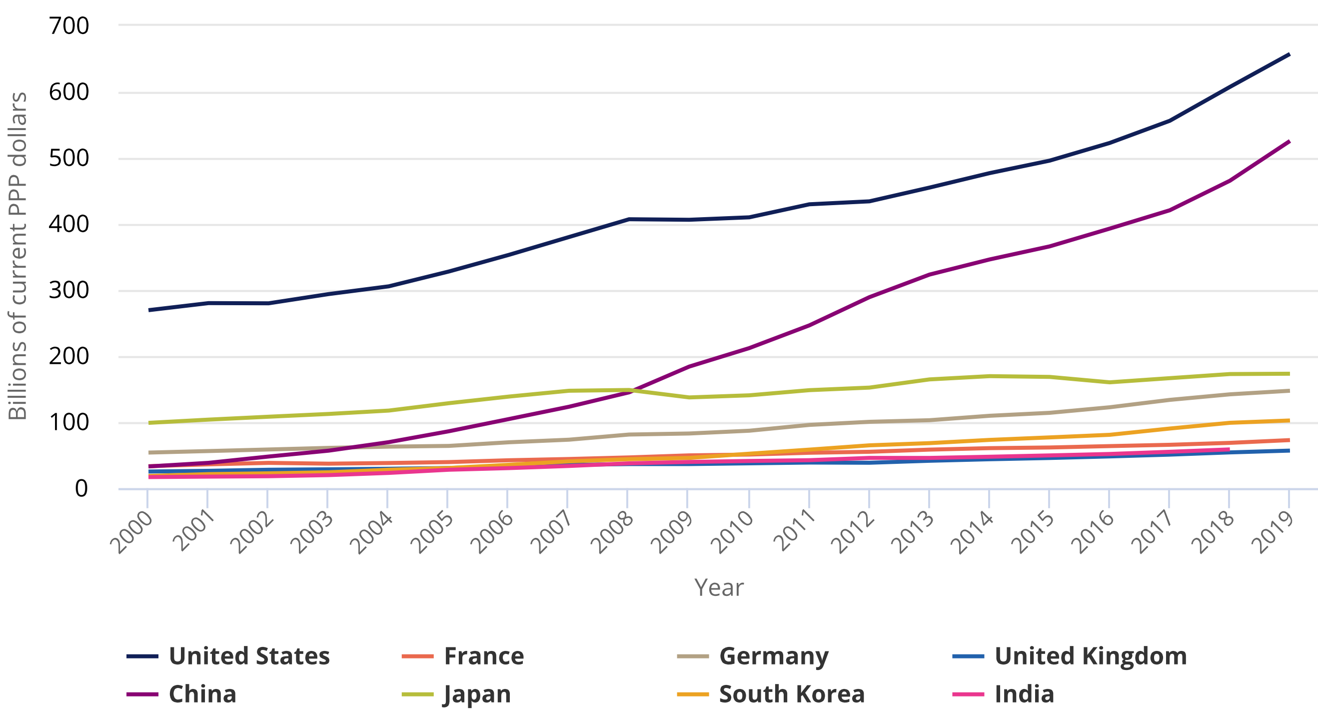
U.S. and Global Research and Development

A nation's innovative capacity is driven not only by development of a workforce equipped to perform technologically advanced activities but also by its investments in R&D. Global R&D expenditures tripled from $726 billion in 2000 to an estimated $2.4 trillion in 2019. Although the United States spent more on R&D than any other country in 2019, its global share has declined as R&D growth in several middle-income countries has outpaced that of the United States. Most growth in U.S. R&D performance and funding is attributable to the business sector. The U.S. government is the second-largest funder of R&D performance, but its proportion of total R&D has declined.

Global R&D

Based on R&D expenditures, a few countries perform most of the global R&D. In 2019, the United States (27% or $656 billion) and China (22% or $526 billion) performed about half of the global R&D (Figure 12).[19,20] These shares are markedly different from those reported in *Indicators 2020* because of revisions to the estimates of purchasing power parities (PPP), a measure which enables direct comparisons of R&D expenditures across countries (see sidebar Revisions to Global Research and Development for more details). Japan (7%), Germany (6%), and South Korea (4%) were also substantial performers. Other top-performing countries—for example, France, India, and the United Kingdom—account for about 2% to 3% each of the global total. Many other countries also conduct R&D, with annual expenditures well below these top countries.

Figure 12. Gross domestic expenditures on R&D, by selected country: 2000–19

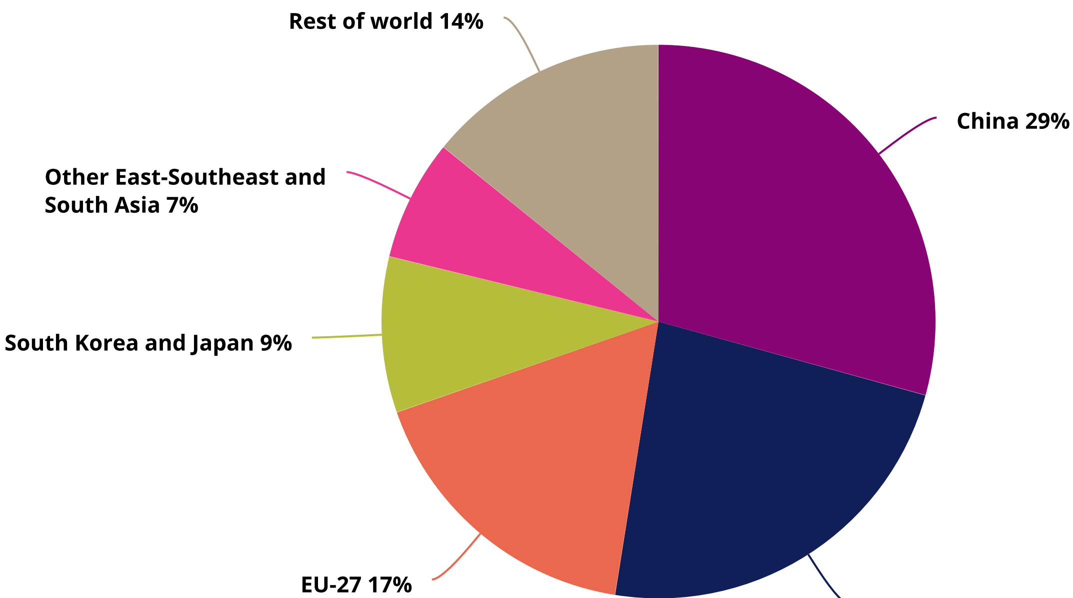


Note(s): PPP is purchasing power parity. Data are for the top eight R&D-performing countries. Data are not available for all countries for all years. Gross domestic expenditures on R&D were revised from those reported in previous years of *Science and Engineering Indicators*. These data revisions were mostly due to 2020 revisions of the PPP estimates. See sidebar Revisions to Global Research and Development for more details.

Source(s): NCSES, National Patterns of R&D Resources; OECD, MSTI March 2021 release; UNESCO, UIS, R&D dataset. *Indicators 2022: R&D*

A notable trend over the past decade has been the growth in R&D spending in the regions of East-Southeast Asia and South Asia, compared with the other major R&D-performing areas. The United States contributed 23% to growth in global R&D performance from 2000 to 2019, whereas countries in the regions of East-Southeast Asia and South Asia, including China, Japan, Malaysia, Singapore, South Korea, Taiwan, and India contributed 46% to the growth in global R&D during this period. China alone contributed 29% to growth in global R&D, buoyed by its high annual R&D growth (Figure 13). The annual increase of China's R&D, averaging 10.6% annually from 2010 to 2019, continues to greatly exceed that of the United States, with an annual average of 5.4% from 2010 to 2019. Consequently, the share of global R&D performed by the United States declined from 29% in 2010 to 27% in 2019, whereas the share by China increased from 15% to 22% (Figure 14). More recently, R&D growth in China has slowed to a rate that is similar to the United States.

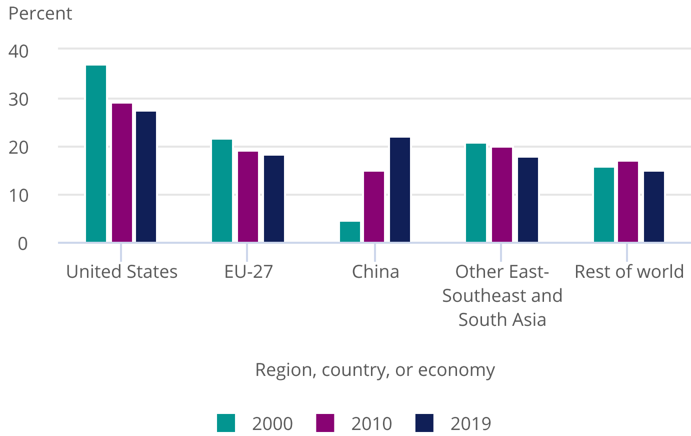
Figure 13. Contributions to growth of worldwide R&D expenditures, by selected region, country, or economy: 2000–19



Note(s): EU is European Union. Other East-Southeast and South Asia include Cambodia, India, Indonesia, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Taiwan, Thailand, and Vietnam.

Source(s): NCSES, National Patterns of R&D Resources; OECD, MSTI March 2021 release; UNESCO, UIS, R&D dataset. *Indicators 2022:* R&D

Figure 14. Shares of worldwide R&D expenditures, by selected region, country, or economy: 2000, 2010, and 2019



Note(s): EU is European Union. Other East-Southeast and South Asia includes Cambodia, India, Indonesia, Japan, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand, and Vietnam.

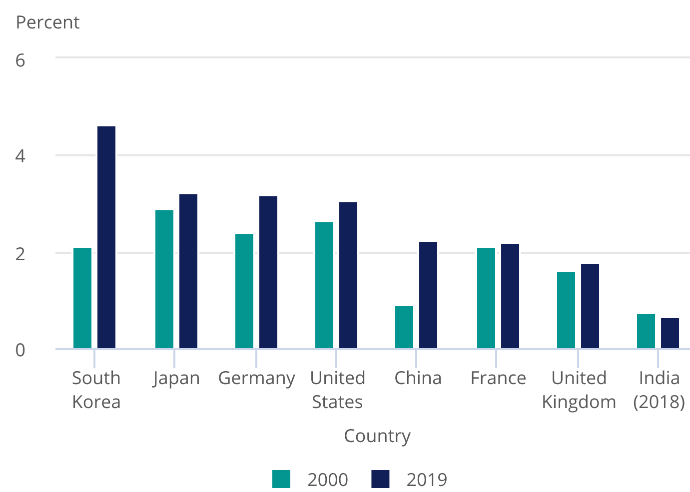
Source(s): NCSES, National Patterns of R&D Resources; OECD, MSTI March 2021 release; UNESCO, UIS, R&D dataset. *Indicators 2022: R&D*

Several countries with smaller economies, including Israel, South Korea, and Taiwan, have greater R&D intensities than the United States (see Glossary section for definition of R&D intensity). However, R&D intensity increased across several of the top R&D-performing countries from 2000 to 2019 (Figure 15). U.S. R&D intensity ranged from 2.5% to just under 3.0% for nearly 2 decades, with the most recent 2019 estimate exceeding 3.0% for the first time, based on a preliminary estimate of U.S. total R&D expenditures (Figure 15). From 2000 to 2019, South Korea and China had the most growth in R&D intensity, growing from 2.1% to 4.6% and from 0.9% to 2.2%, respectively. R&D intensity in Germany also grew from 2.4% to 3.2%.

Countries vary in the amount of R&D expenditures on basic research, applied research, and experimental development (see Glossary section for definitions of basic research, applied research, and experimental development). For example, the United States spends a higher share of R&D funding on basic research than does China, and China spends a higher share of R&D funding on experimental development than does the United States. In 2018, China spent 83% of its R&D expenditures on experimental development, compared with 64% in the United States. Although the shares spent on experimental development differed, the United States ($388.6 billion) and China ($387.9 billion) spent similar amounts. Overall, the United States spent $607.5 billion in R&D activity, with $101.1 billion (17%) of annual R&D spending classified as basic research, and China spent $26 billion (6%) of annual R&D spending on basic research. Other countries, such as France, spent a higher proportion of R&D funds on basic research, but none spend more than China or the United States in absolute amounts.

Within most of the top R&D-performing countries, the business sector funds the most R&D—60% or more in 2018. In each of the leading Asian countries—Japan, China, and South Korea—the business sector accounted for more than 75% of R&D funding. The business share of total R&D funding was lower but still more than 60% in the United States and Germany.

Figure 15. R&D intensity, by selected country: 2000 and 2019



Note(s): Data are for the top eight R&D-performing countries. R&D intensity is R&D expenditures in each country divided by gross domestic product in each country.

Source(s): NCSES, National Patterns of R&D Resources; OECD, MSTI March 2021 release; UNESCO, UIS, R&D dataset. *Indicators 2022: R&D*

SIDEBAR

Revisions to Global Research and Development

Global measures of R&D in this report were substantially revised from those reported in previous years of *Science and Engineering Indicators*. These data revisions were mostly due to 2020 revisions of the estimates of purchasing power parity (PPP), a measure that enables direct comparisons of R&D expenditures across countries. Although the PPP revisions resulted in comparatively large changes to the magnitude of China's R&D expenditures, the overall growth in China's R&D performance compared with other countries was similar to that before the PPP revisions.

The World Bank (2020) produces PPP estimates and periodically revises them to incorporate new and better-quality information and improved methods (for more details on the 2020 PPP revisions, see the forthcoming *Indicators 2022* report, "[2022] Research and Development: U.S. Trends and International Comparisons"). The OECD (2020) incorporated the revised PPP estimates for all years of the Main Science and Technology Indicators, the primary source of the cross-national comparisons of R&D performance in *Indicators 2022*. Hence, all global estimates of R&D performance reported in *Indicators 2022* were also revised to maintain comparability of estimates over time. According to the OECD (2020), the gap in R&D expenditures between China and the United States is more pronounced after incorporating the 2020 PPP revisions because the relative price of investment had been underestimated prior to the 2020 PPP revision.

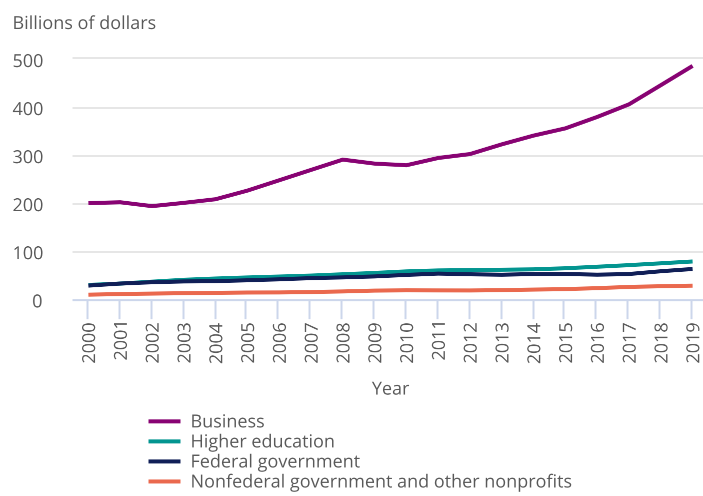
These latest PPP revisions had a more sizeable effect on China than on other countries. For example, *Indicators 2020* reported that the 2017 share of global R&D was 25% ($549 billion) for the United States and 23% ($496 billion) for China. In this report, the 2017 shares were revised to 27% ($556 billion) for the United States and 20% ($421 billion) for China. Overall, the PPP revisions affected the measure of R&D expenditures for China. However, as shown in past reports, China is still advancing from a smaller base compared with the United States, and the rate at which China expanded R&D prior to 2017 was much faster than that of the United States and other developed nations.

U.S. Performance and Funding Trends

Although the U.S. business sector performs (or conducts) the most R&D, other sectors—including federal, state, and local governments; higher education institutions; and non-academic nonprofit organizations—also perform and fund domestic R&D.[21] R&D performed in the United States totaled $606.1 billion in 2018, and according to preliminary estimates, $656 billion in 2019.[22] The business sector was the main driver of R&D performance, accounting for about 83% of the growth in R&D from 2010 to 2019 (Figure 16).[23]

Similarly, the U.S. business sector funds (or pays for) most R&D, and nearly all (98%) of the business sector's R&D funding supports R&D performance by businesses. In contrast, the federal government, the second-largest source of R&D funding (21%) (Figure 17), supports R&D performed by all sectors. Based on preliminary 2019 estimates, the federal government funded 50% of the R&D performed by the higher education sector, 31% by nonprofits, and 6% by businesses.

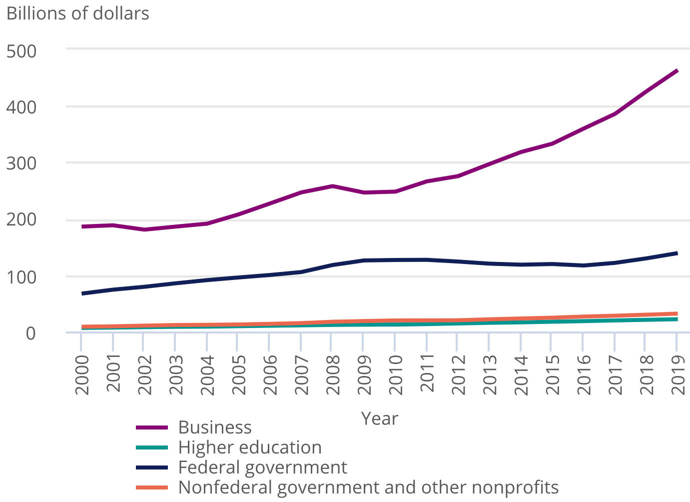
Figure 16. U.S. R&D expenditures, by performing sector: 2000–19



Note(s): The data for 2019 are estimates and will later be revised.

Source(s): NCSES, National Patterns of R&D Resources. *Indicators 2022: R&D*

Figure 17. U.S. R&D expenditures, by source of funds: 2000–19

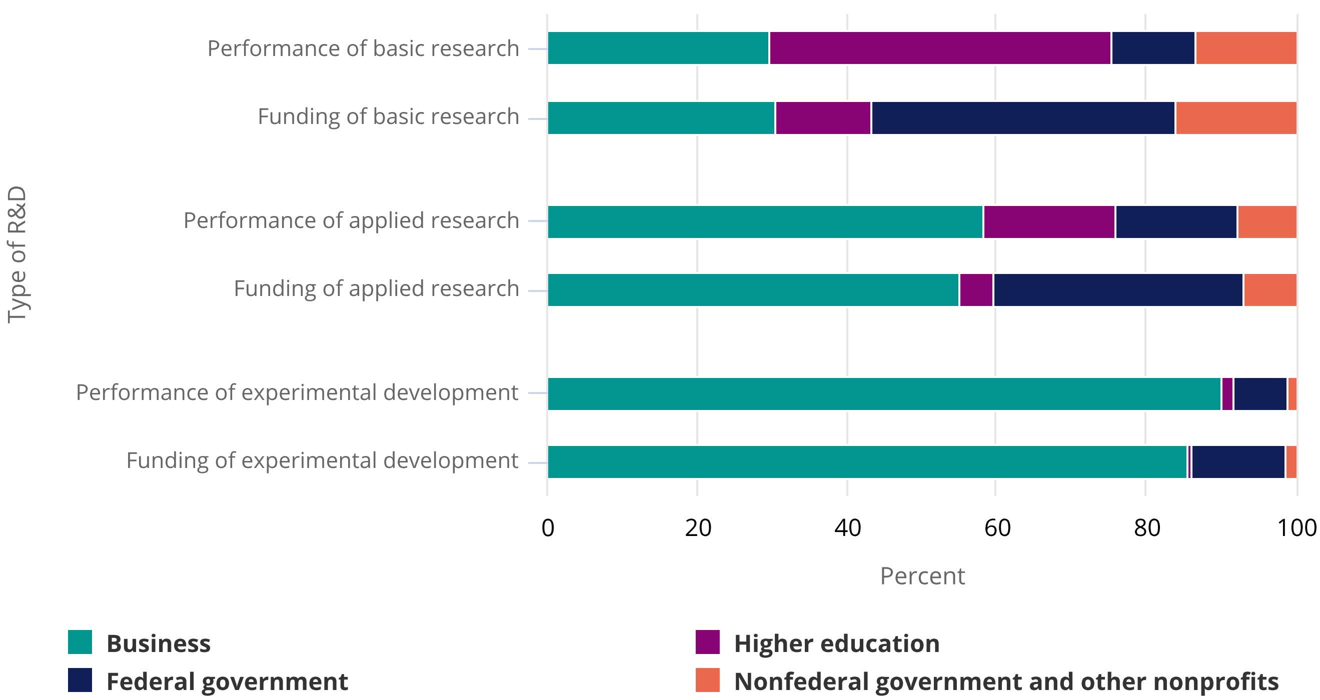


Note(s): The data for 2019 are estimates and will later be revised.

Source(s): NCSES, National Patterns of R&D Resources. *Indicators 2022: R&D*

The majority of R&D performance is in experimental development (65%) and applied research (19%), and the business sector dominates in both. With its focus on new and improved goods, services, and processes, the business sector performs 90% of experimental development, and 58% of applied research (Figure 18). Higher education institutions perform the largest proportion of basic research (46%). However, the share of basic research performed by the business sector increased from 18% in 2012 to an estimated 30% in 2019. Since 2010, a few industries—notably chemical manufacturing (including pharmaceuticals and medicine); computer and electronic products; transportation equipment; professional, scientific, and technical services; and information services—account for most R&D performed by the business sector.

Figure 18. U.S. R&D performance and funding, by type of R&D and sector: 2019



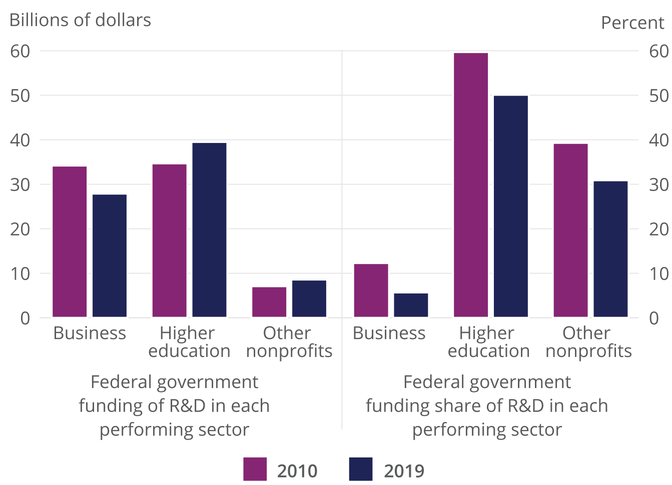
Note(s): The data for 2019 are estimates and will later be revised.

Source(s): NCSES, National Patterns of R&D Resources, 2019. *Indicators 2022: R&D*

Similar to its role in conducting R&D, the business sector funds most of applied research (55%) and experimental development (86%). The share of basic research funded by the business sector increased from 23% in 2010 to 31% in 2019 (preliminary). However, the federal government continues to be the largest source of funding of basic research (41%).

Although federal funding of R&D increased from $127 billion in 2010 to an estimated $139 billion in 2019, the share of total R&D funded by the federal government declined from 31% in 2010 to an estimated 21% in 2019. This decline occurred across all research types and sectors (Figure 19, Figure 20).

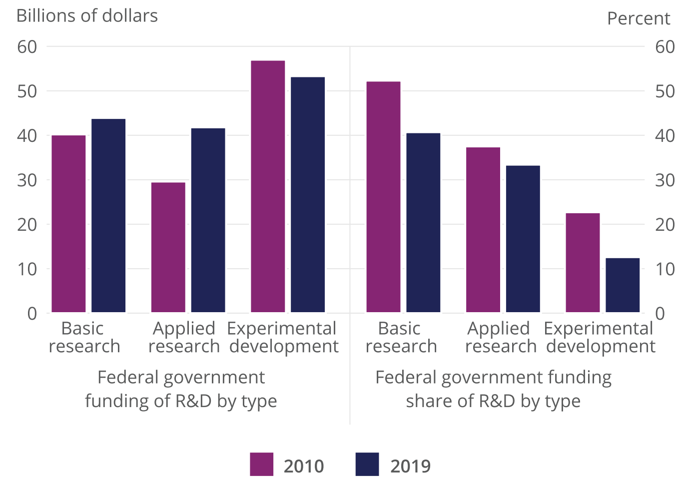
Figure 19. R&D performance funded by the federal government, by performing sector: 2010 and 2019



Source(s): NCSES, National Patterns of R&D Resources. *Indicators 2022: R&D*

Higher education institutions rely heavily on federal support for R&D. Although federal funding of research performed by the higher education sector increased in dollar amount from 2010 to 2019, the proportion funded by the federal government declined from 60% in 2010 to an estimated 50% in 2019 (Figure 19). In contrast, the proportion funded by higher education institutions increased. This proportional decline in federal funding has potential implications for graduate student training because many students in S&E fields are supported by federal R&D funding.

Figure 20. R&D performance funded by the federal government, by type of R&D: 2010 and 2019

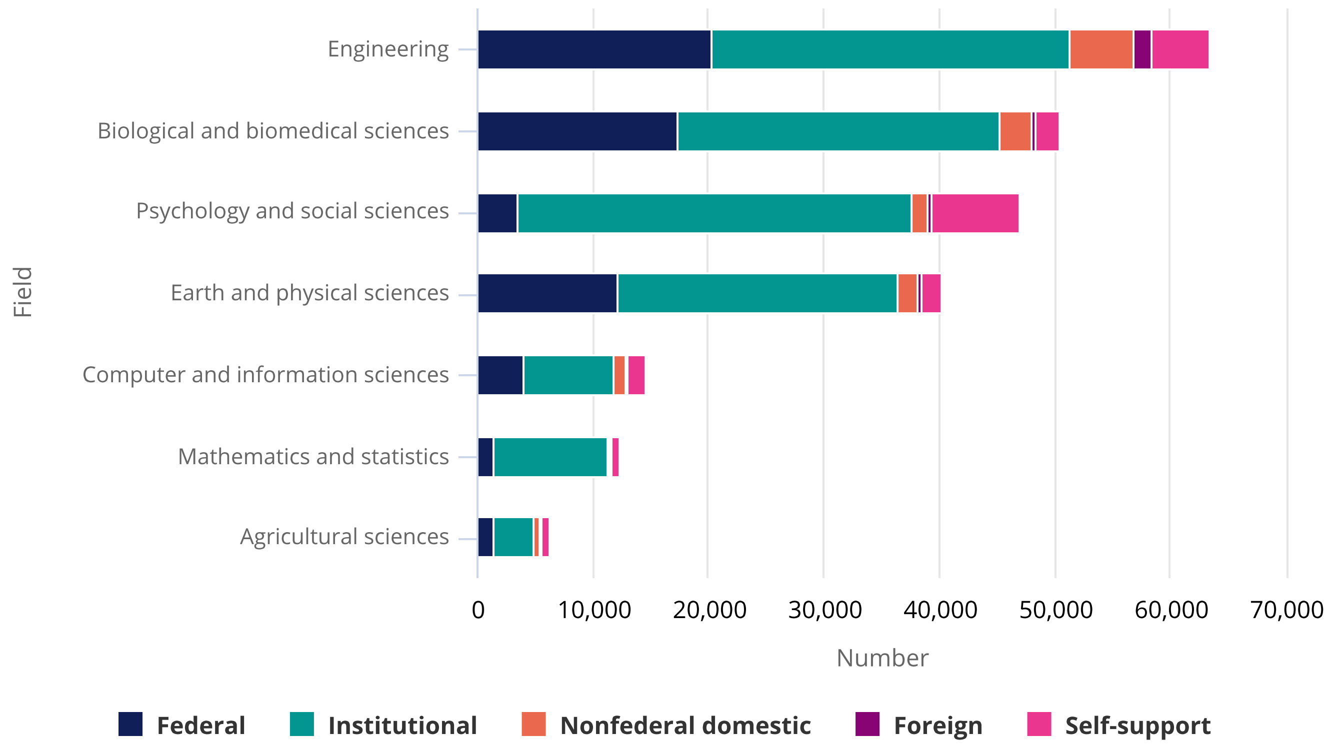


Source(s): NCSES, National Patterns of R&D Resources. *Indicators 2022: R&D*

The federal government supported 15% of full-time S&E graduate students (mostly doctoral students) in 2019, down from 19% in 2010.[24] Numbers of full-time doctoral students varied across fields with the highest concentration of federally funded students in engineering and in biological and biomedical sciences (Figure 21).[25] Although NSF supported substantial numbers of students across a range of fields, over 60% of those supported by the National Institutes of Health were in biological and biomedical sciences, 60% who were funded by the Department of Defense (DOD) studied engineering, and more than 90% who were funded by the Department of Energy (DOE) were in earth and physical sciences or engineering.

In 2019, the DOD received 40% of the federal R&D budget and directed the bulk of that budget toward experimental development. Most of the remaining 60% of the federal R&D budget went to the Department of Health and Human Services (HHS), DOE, National Aeronautics and Space Administration (NASA), NSF, and the Department of Agriculture (USDA). Consistent with the different missions of the departments and agencies, NASA distributes its budget evenly, with 60% going to basic and applied research and 40% to experimental development, whereas HHS, DOE, NSF, and USDA focus primarily on basic and applied research.

Figure 21. Full-time doctoral students in S&E, by field and primary source of support: 2019



Source(s): NCSES, GSS, 2019. *Indicators 2022: Academic R&D*

SIDEBAR

Disruptions and Breakthroughs in S&E during the COVID-19 Pandemic

The COVID-19 pandemic was a disruptive event for the entire world.* In the United States, unemployment rose sharply, and educational setbacks occurred across all levels of instruction. Populations historically underrepresented in S&E and low-income households suffered the most severe impacts, both in terms of job security and education. Yet, the pandemic showed the power of the S&E enterprise to address urgent global needs, with the United States collaborating extensively with other nations to collectively study the virus and develop effective vaccines.

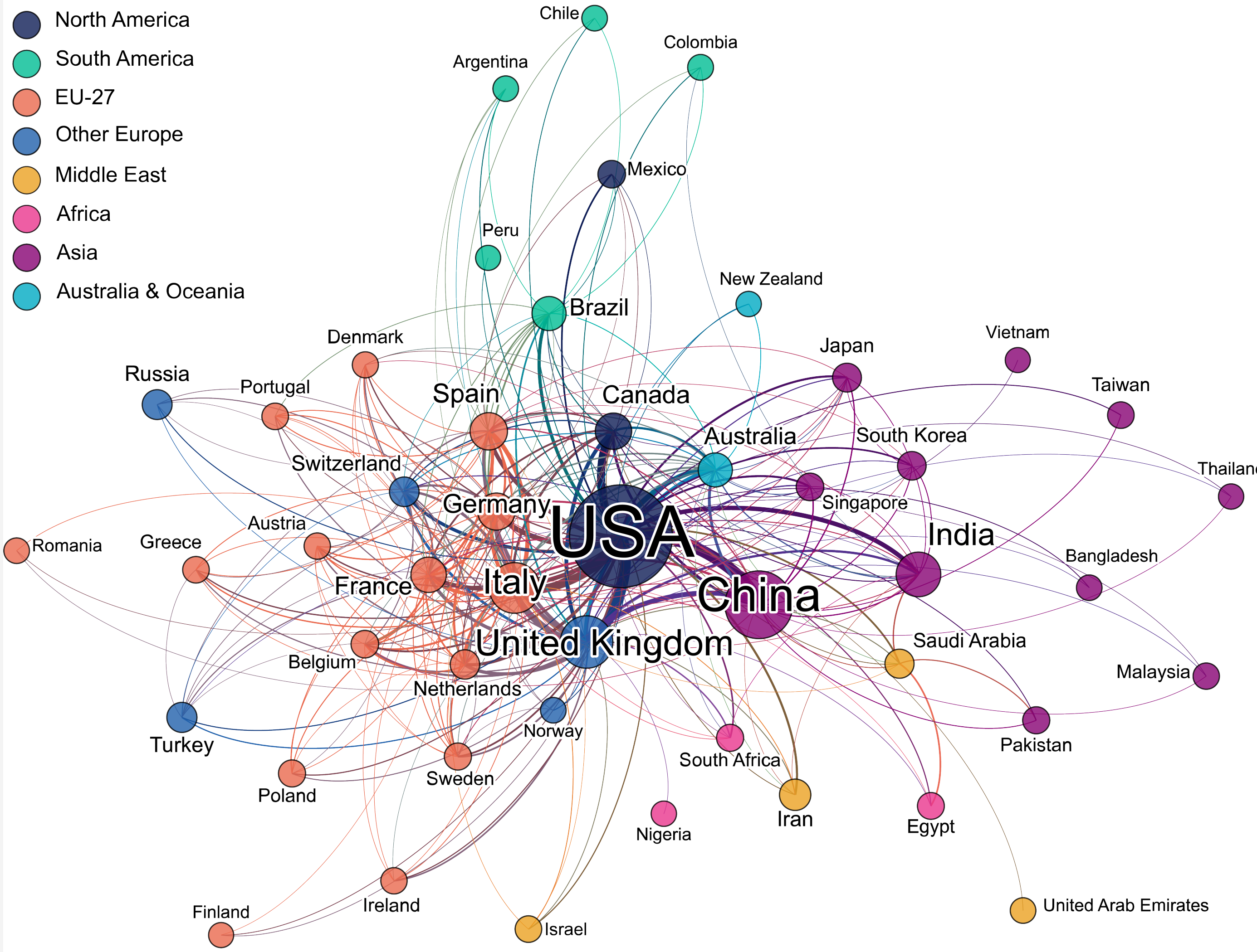
Science, technology, engineering, and mathematics (STEM) workers experienced lower unemployment rates than non-STEM workers during the pandemic. With businesses closed and many people socially distancing at home, STEM unemployment jumped from about 3% in March 2020 to 9% in April 2020—but for those in non-STEM occupations, unemployment shot up from about 5% to 16% during the same period. By September 2020, while still higher than before the pandemic, unemployment had declined for both STEM and non-STEM workers. STEM workers without a bachelor's degree and non-STEM workers with a bachelor's degree reached equivalent unemployment levels (about 6% each).

The abrupt transition to online learning in most K–12 districts and postsecondary institutions in the spring of 2020 created major challenges for both teachers and students. Sociodemographic differences among students at all levels were exacerbated. Access to computers with stable Internet connectivity varied greatly by race or ethnicity and income level. At the undergraduate level, larger proportions of Blacks, Hispanics, and American Indian or Alaska Natives than Whites reported that they lacked access to the technology required for online learning (Soria et al. 2020). For K–12 students, studies estimate that some students lost up to a full year of math learning. Enrollment declined sharply at community colleges that serve low-income students (down 10% in the fall of 2020), threatening students' educational aspirations, the financial viability of these schools, and the continued development of the skilled technical workforce (STW).

While the entire world struggled under the economic, educational, and societal implications of the pandemic, the strength and resiliency of the U.S. S&E base provided the springboard upon which vaccines were developed and made available in record time. The U.S. federal government, universities, pharmaceutical and other private companies, and nonprofit organizations intensively partnered to develop, test, produce, and begin to distribute effective vaccines within 1 year from the release of the first DNA sequence of the coronavirus that causes COVID-19. This extremely rapid success resulted from many years of research in coronaviruses and the molecular biology of DNA and RNA, as well as technological advances in DNA sequencing.

More broadly, the pandemic revealed the collaborative nature of the global S&E enterprise. Coronavirus-related published research reveals extensive international collaboration networks and the central role of the United States (Figure A). The network analysis shows the centrality of the major research countries—United States, China, the United Kingdom, European Union (EU)-27 countries, and Japan. Other countries, such as Iran and Russia, are less integrated into the network. The diagram also shows strong collaboration between the United States and authors in China, the UK, and Canada.

Figure A. Collaboration network on coronavirus-related articles, by country: 2020



Note(s): In the network diagram, the color indicates region; node size is proportional to the total number of coronavirus-related articles written by each country, the thickness of the links between nodes is proportional to the quantity of cowritten papers, and the distance between nodes indicates the relatedness (similarity in terms of network properties) of the countries (Jacomy et al. 2014). Data for the diagram were pulled from the 50 countries that produced the most coronavirus-related research and also cowrote 50 articles or more, using whole counting. Coronavirus article counts refer to publications from a selection of conference proceedings and peer-reviewed journals in S&E fields from Scopus. Articles are classified by their year of publication and are assigned to a country on the basis of the institutional address(es) of the author(s) listed in the article. Links are only shown in a single direction, dictated by alphabetical order.

Source(s): NCSES, special tabulations (2021) by SRI International and Science-Metrix of Elsevier's Scopus abstract and citation database. *Indicators 2022: Publications Output*

The experience of the pandemic highlights the inequities in both U.S. STEM education and the U.S. STEM workforce, while simultaneously showing the need for a strong and resilient S&E enterprise able to rapidly meet urgent global crises. Amidst the disruptions and breakthroughs due to the pandemic, the public's overall trust in science and how the media portrayed COVID-19 research appeared to influence U.S. public support for COVID-19 science. In January 2021, a national U.S. survey by the U.S. Census Bureau found among Americans who had not been vaccinated 22% said they would not or definitely would not get a COVID-19 vaccine; in that group, about one-third cited a lack of trust in the COVID-19 vaccines or in the government as considerations for the decision.

* This sidebar draws on data and sources from the *Indicators 2022* thematic reports.

U.S. and Global Science and Technology Capabilities

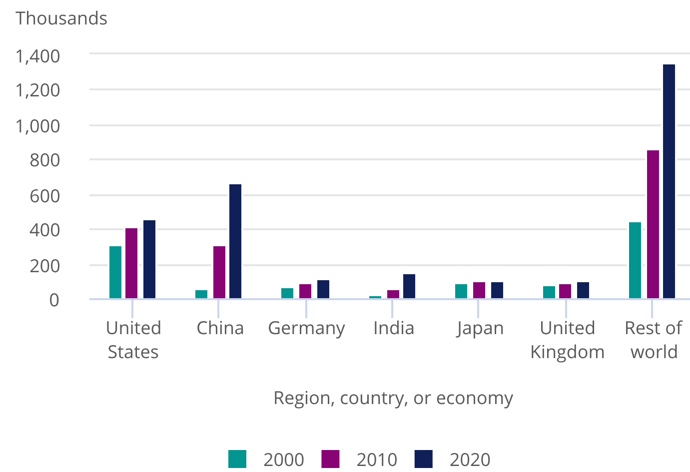
Investment in R&D and a workforce equipped to perform technologically advanced activities enables scientific discovery, which produces new S&E knowledge useful for enhancing science and technology (S&T) capabilities. S&T capability, as indicated by publications output, patent activity, and KTI industry output, continues to grow globally. The United States continues to serve as a leader and collaborator in advancing S&T capabilities around the world while middle-income countries, such as China and India, are rapidly developing their S&T capabilities.

Research Publications

Publication of research in peer-reviewed literature is a primary mechanism for disseminating new S&E knowledge, enabling the use of discoveries for invention and innovation to expand S&T output.[26] Globally, six countries produce more than 50% of the worldwide peer-reviewed S&E publications: China (23%), the United States (16%), India (5%), Germany (4%), the United Kingdom (4%), and Japan (3%) (Figure 22).[27] From 2000 to 2020, publication output growth for high-income countries, such as the United States, Germany, and the United Kingdom, was slower than that of upper middle-income countries, such as China, Russia, and Brazil (see **Glossary** section for definition of high- and middle-income countries). However, upper middle income countries' publication output grew from a smaller base compared to high income countries. Overall, publication output of the upper middle-income countries grew at an annual average rate of 11% from 2000 to 2020, while output for high-income countries grew at an annual average rate of 3%.

The distribution of publications by field and region, country, or economy is one indicator of research priorities and capabilities. In the United States, the European Union (EU-27), the United Kingdom, and Japan, the largest proportion of journal articles was in the field of health sciences (see **Glossary** section for definition of EU-27). In China, the largest proportion was in engineering. In India, the largest proportion was in computer and information sciences.

Figure 22. S&E articles, by selected region, country, or economy: 2000, 2010, and 2020

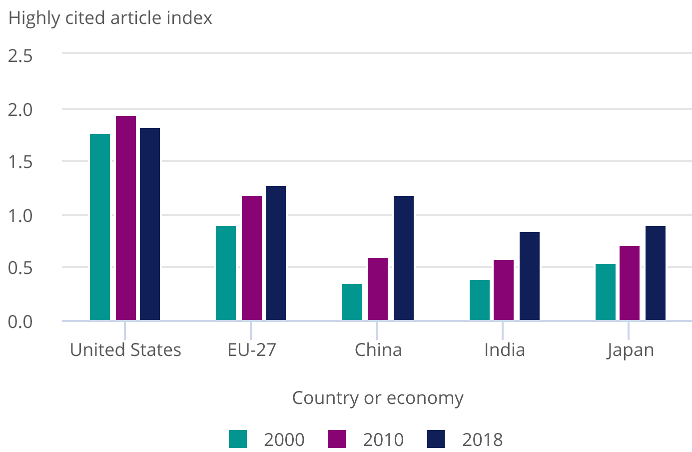


Note(s): Articles are fractionally counted and classified by publication year and assigned to a region, country, or economy by author's institutional address(es).

Source(s): NCSES, special tabulations (2021) by SRI International and Science-Metrix of Elsevier's Scopus abstract and citation database. *Indicators 2022: Publications Output*

U.S. publications are highly impactful, as measured by citations. From 2000 to 2018, the index of highly cited articles (see **Glossary** section for definition of index of highly cited articles) for the United States was stable at around 1.8. This means that the United States contributed nearly twice as many highly cited articles as would be expected given the overall publication output of the United States (Figure 23).[28] In contrast, during the same period, the index increased for other countries; specifically, the index for the EU-27 increased from 0.9 to 1.3, and China's index increased from 0.4 to 1.2.

Figure 23. Highly cited article index, by selected country or economy: 2000, 2010, and 2018

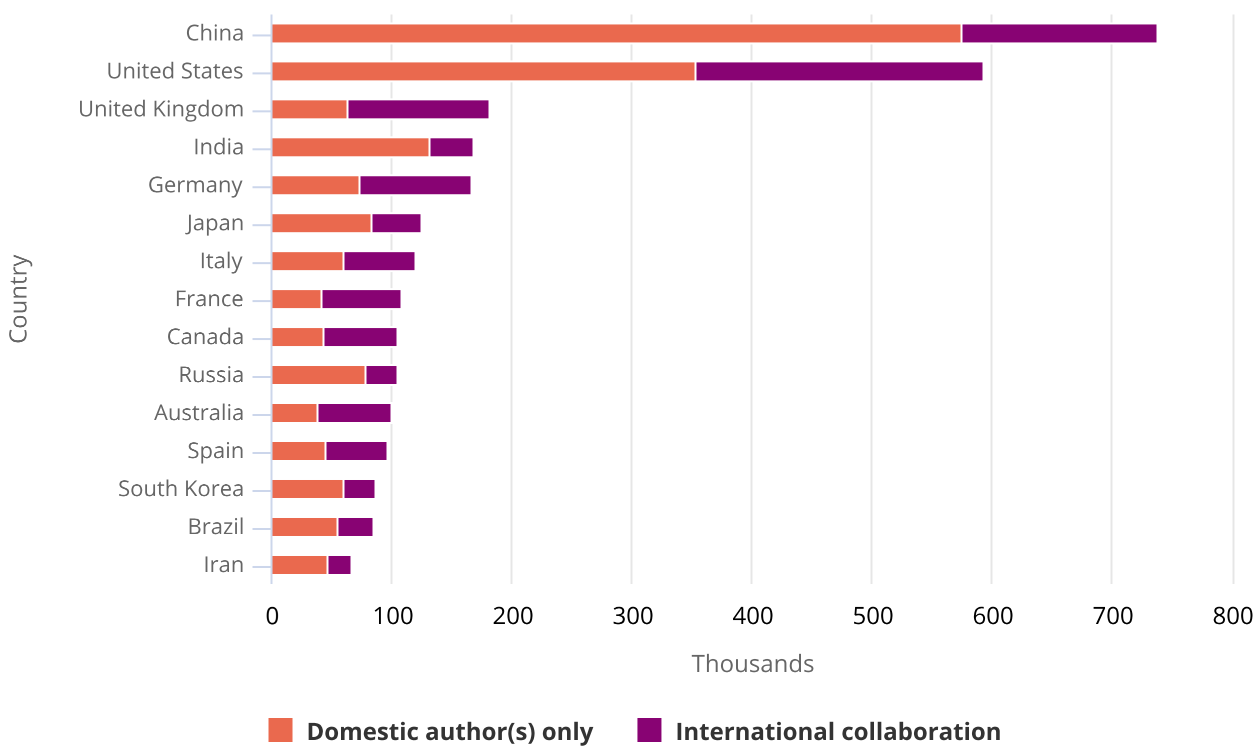


Note(s): EU is European Union. The highly cited article index is a country's share of the top 1% most-cited S&E publications divided by the country's share of all S&E publications.

Source(s): NCSES, special tabulations (2021) by SRI International and Science-Metrix of Elsevier's Scopus abstract and citation database. *Indicators 2022: Publications Output*

Another indicator of the influence of the United States is reflected by international collaboration in publication coauthorship. In 2020, 35% of the world's S&E articles with authors from multiple countries included a U.S. author. Authors from China, the United States, the United Kingdom, and Germany coauthored the most S&E publications with other countries (Figure 24).[29] Among the 15 largest producers of S&E articles, the United States, China, the United Kingdom, Germany, France, Australia, Canada, Italy, and Spain had a majority of their S&E articles with international collaboration. Although the United States had international collaboration rates that were lower than the ones in these countries, U.S. publications with international collaboration increased from 19% in 2000 to 40% in 2020.

Figure 24. International collaboration on S&E articles for the 15 largest producers of S&E articles, by country: 2020



Note(s): Articles are whole-counted and classified by publication year and assigned to a country by listed institutional address(es).

Source(s): NCSES, special tabulations (2021) by SRI International and Science-Metrix of Elsevier's Scopus abstract and citation database. *Indicators 2022: Publications Output*

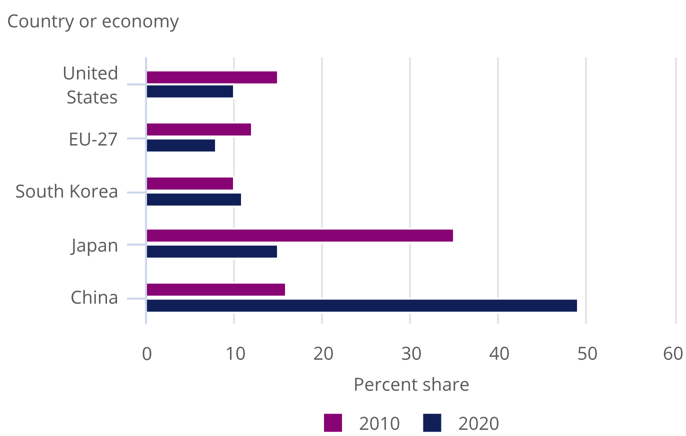
Invention and Innovation

The global S&E enterprise regularly produces new basic knowledge and other outputs with direct benefits for society and the economy. These outputs include inventions (creation of new and useful products and processes as well as their improvement) and innovations (implementation of a new or improved product or business process that differs significantly from previous products or processes).[30] Patents are one way governments support invention by providing legal mechanisms for intellectual property protection. Patent documents provide detailed information that is widely used to understand invention activity.

Many middle-income countries, led by China (see Glossary section for definition of middle-income countries), continue to increase patenting activities, resulting in a shift in patenting away from high-income countries like the United States. From 2010 to 2020, the proportion of international patents (see Glossary section for definition of international patents) granted to inventors from high-income countries fell from 78% to 48%. The U.S. share of international patents declined from 15% to 10%. The same share declined from 35% to 15% for Japan and 12% to 8% for the EU-27 (Figure 25).[31] In contrast, China's share of international patents increased from 16% in 2010 to 49% in 2020.

Globally and domestically, patenting activity varies by industry and by inventor demographics. Across all countries, 56% of international patents are related to electrical and mechanical engineering, reflecting the role of these fields in global invention. These two fields of engineering represent 63% of all international patents granted to U.S. inventors in 2020. The high rates of patenting in engineering and the relatively low proportion of U.S. women with engineering degrees or working in engineering occupations are consistent with the low rates of overall patenting activities by female inventors in the United States. In 2019, an estimated 17% of Patent Cooperation Treaty applications (see Glossary section for Patent Cooperation Treaty application) in the United States included at least one woman as an inventor (Figure 26).[32] China (32%) and South Korea (27%) had the highest estimated proportion of patent applications with at least one woman inventor.

Figure 25. Shares of international patents granted to inventors, by selected country or economy: 2010 and 2020



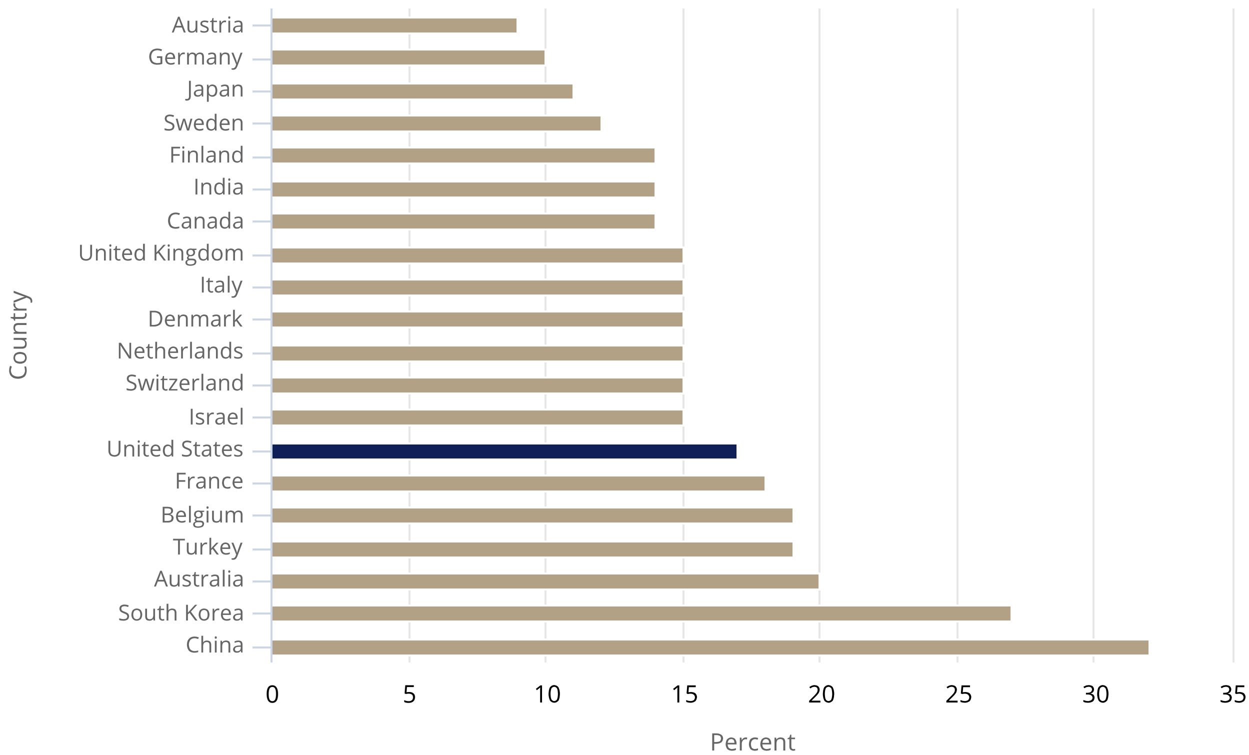
Note(s): EU is European Union. China includes Hong Kong.

Source(s): NCSES, special tabulations (2021) by SRI International and Science-Metrix of PATSTAT. *Indicators 2022: Innovation*

Patents granted by the U.S. Patent and Trademark Office (USPTO) have increased both to domestic inventors and to inventors residing in other countries (see Glossary section for definition of USPTO patents). Patents granted to U.S. inventors by the USPTO increased from 107,000 in 2010 to 164,000 in 2020. Reflecting the geographic distribution of STEM workers, domestic patenting intensity (see Glossary section for definition of patent intensity) was higher along both coasts, in areas around the Great Lakes, in the Rocky Mountain West, and in parts of Texas. Despite the increase in USPTO patents granted to U.S. inventors from 2010 to 2020, the proportion of patents granted to inventors in foreign countries increased from 51% in 2010 to 54% in 2020.

U.S. universities frequently leverage their intellectual property by licensing protected discoveries to outside entities, often to newly established startup companies spun off from university research activity. In 2019, U.S. universities executed almost 8,000 new technology licenses or options, with 19% of them executed with startup companies and 59% with small companies (those with fewer than 500 employees). New university-associated startups increased from 388 in 2000 to 1,029 in 2019.

Figure 26. Share of Patent Cooperation Treaty applications with at least one woman listed as inventor, by country: 2019



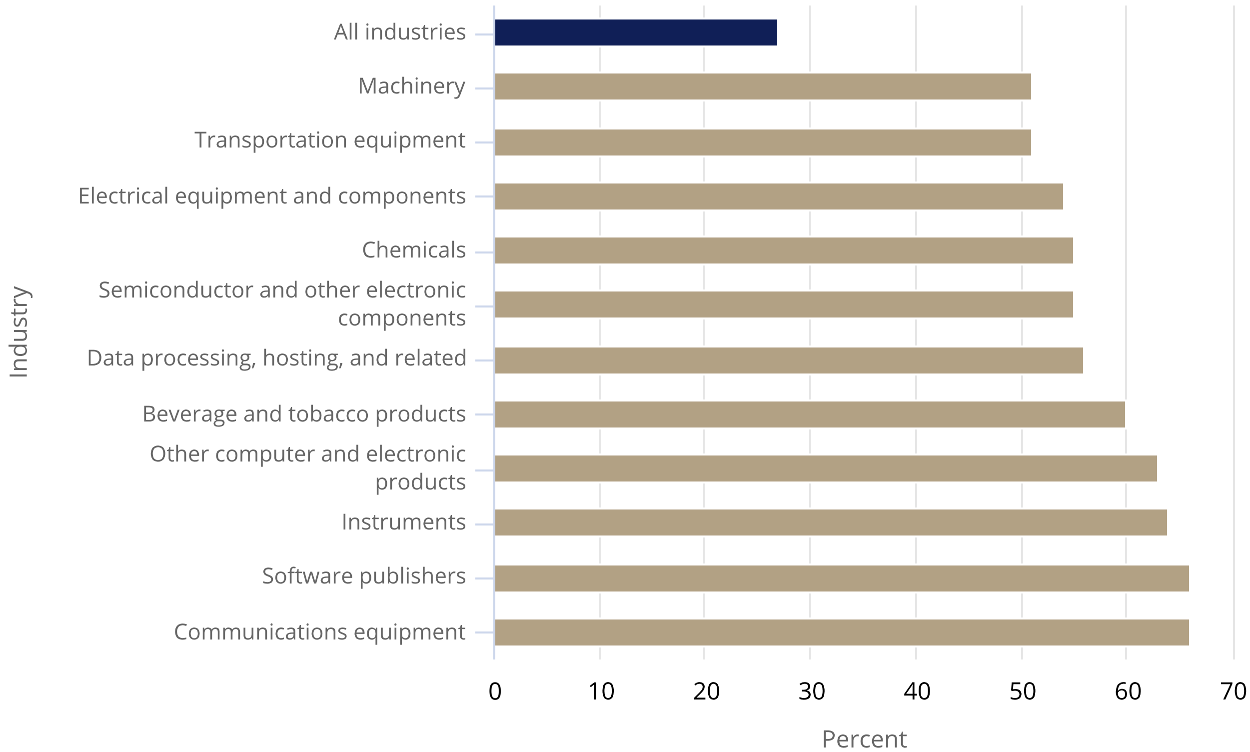
Source(s): WIPO, Statistics Database, 2019. *Indicators 2022: Innovation*

While invention is the creation of something new and useful, innovation is its implementation. An average of 26.5% of businesses introduced a new product or process from 2015 to 2017 (Figure 27).[33] Most of the industries with the highest innovation rates are among those that rely most heavily on R&D, including information and communication technology (ICT) industries (see **Glossary** section for definition of ICT industries).

Similar to their underrepresentation in the S&E education and STEM workforce, women, Blacks, and Hispanics represent a small proportion of business owners in the United States. From 2015 to 2017, firms with majority ownership by women accounted for 20% of all firms, those with majority ownership by Blacks accounted for 2%, and those with such ownership by Hispanics accounted for 5%. Notwithstanding these low rates of business ownership, businesses owned by these groups reported higher rates of product or process innovation than the average for all businesses. Innovations were reported to be introduced by 27.5% of majority woman-owned businesses, 28.7% of majority Hispanic-owned businesses, and 28.0% of majority Black-owned business. This compares with 26.5% for all businesses.

The United States received 47% ($129 billion) of global venture capital in 2020, financing that is essential to translate new knowledge into innovations. Although this amount is large, the U.S. share of global venture capital dropped from 76% in 2000–05 as China and South Asia (particularly India) increasingly received more venture capital funding. Global venture capital investment in China was $60 billion dollars in 2020, rebounding after steep declines between 2018 and 2019 that broke a decade-long trend of rapid growth. Venture capital in the United States was focused primarily in ICT and healthcare industries (e.g., healthcare devices and supplies, health services, healthcare technology systems, and pharmaceuticals and biotechnology). In China, ICT industries received the most venture capital funding (40%) in 2020.

Figure 27. Share of U.S. companies reporting product or process innovation, by selected industry: 2015–17



Note(s): Statistics are representative of companies located in the United States. Electrical equipment includes appliances. Other computer and electronic products excludes semiconductors and instruments. Instruments includes navigational, measuring, electromedical and control instruments.

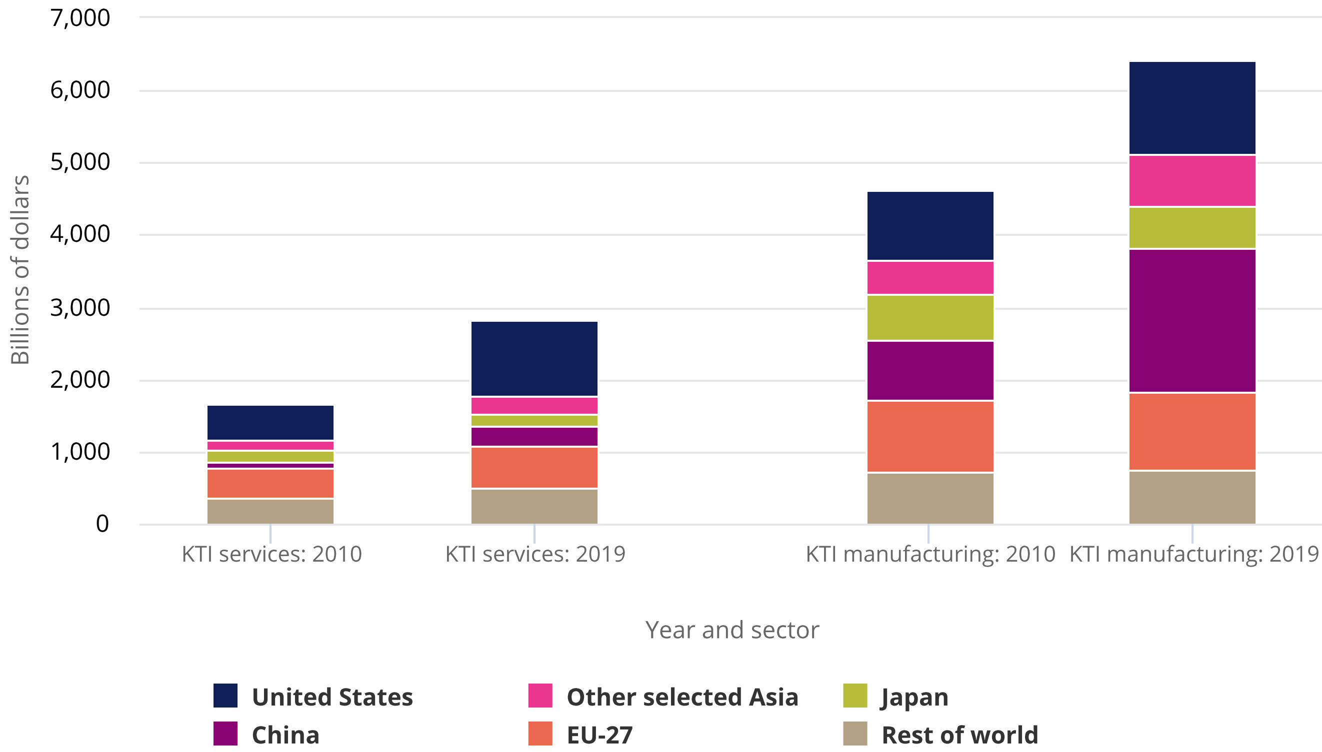
Source(s): NCSES, ABS, 2017. *Indicators 2022: Innovation*

Knowledge- and Technology-Intensive Industry Output

Production of output by KTI industries—that is, industries that globally have high R&D intensities (see Glossary section for definition of R&D intensity)—indicates the translation of S&E capabilities into the marketplace.[34] In addition, output of KTI industries is a significant source of U.S. productivity. The value-added output (see Glossary section for definition of value-added output) produced by these industries is the additional value created from transforming inputs at different stages of the production process.

Globally, KTI industry value-added output more than doubled from 2002 ($3.4 trillion) to 2019 ($9.2 trillion). In 2019, $2.8 trillion was produced by KTI services industries (information technology [IT] services, scientific R&D services, and software publishing) and $6.4 trillion was produced by KTI manufacturing industries (aircraft; computer, electronic and optical products; pharmaceuticals; chemicals [excluding pharmaceuticals]; transportation equipment [excluding aircraft]; electrical and other machinery and equipment; and scientific instruments) (Figure 28).[35]

Figure 28. Output of KTI industries for selected region, country, or economy, by sector: 2010 and 2019



Note(s): EU is European Union. KTI is knowledge- and technology-intensive. Other selected Asia includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam.

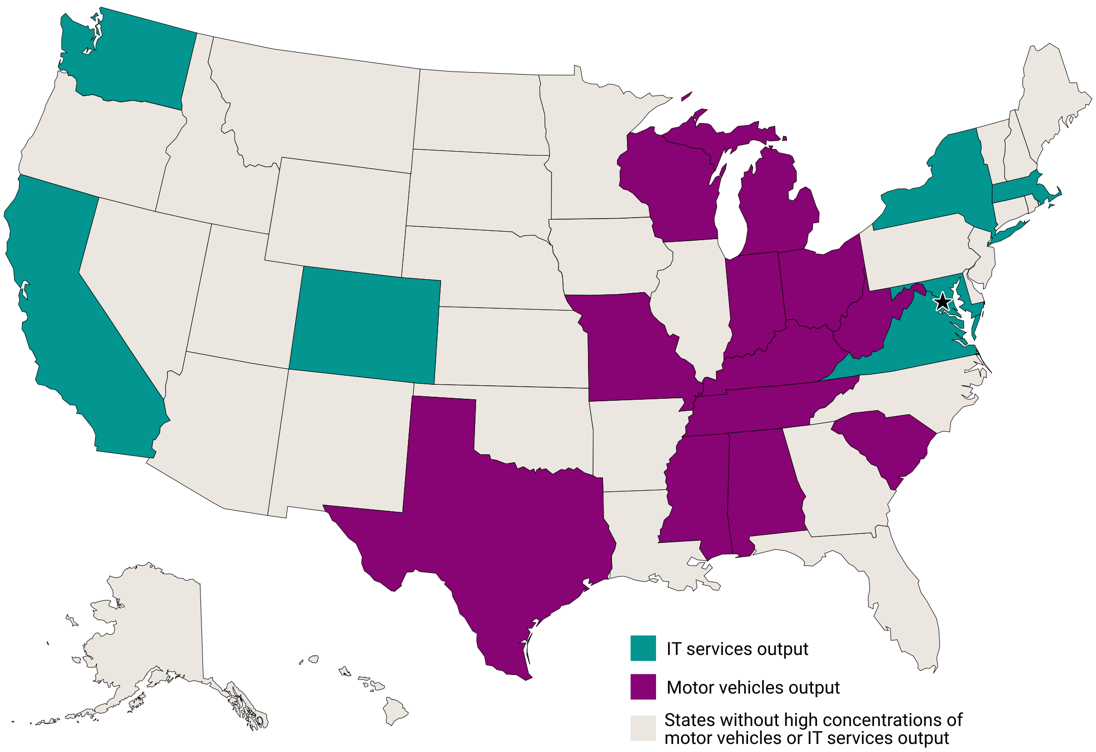
Source(s): IHS Markit, special tabulations (2021) of the Comparative Industry Service database. *Indicators 2022: Industry Activities*

China surpassed the United States to become the world's largest producer of KTI manufacturing output in 2011, and China has been the driving force behind the rapid increase of this output for many KTI industries over the past decade. China's global share of KTI manufacturing output has increased from 18% in 2010 to 31% in 2019. Although U.S. KTI manufacturing output continues to increase and the United States continues to be the largest global producer of output of three KTI manufacturing industries (aircraft, medical equipment, and pharmaceuticals), its global share has fluctuated between 19% and 21% since 2010. During this period, the United States has increased its global share of KTI services output from 31% in 2010 to 37% in 2019, and it is currently the largest producer of IT services, the largest global KTI industry.

U.S. KTI output is highly concentrated and specialized across the United States. California (25%), Texas (8%), Washington (6%), and New York (5%) contribute the most to total U.S. domestic production of KTI output. However, the contribution of KTI output to each state's gross domestic product (GDP) varies widely across states. U.S. KTI industry output contributes 11% to U.S. GDP, whereas output of these industries contributes 13%–24% to the economies in Oregon, North Carolina, Michigan, Indiana, Massachusetts, California, and Washington.

Specialization in production of KTI industry output also varies by state (Figure 29). The location quotient (LQ) measures each state's specialization in KTI industry output (see Glossary for definition of location quotient). The LQ analysis reveals that states on the coasts are relatively more specialized in IT services, and those in the Midwest are more specialized in the production of motor vehicles.[36] In particular, California's IT services output as a share of its GDP is more than two times the national average. Virginia and Washington produce IT services output as a share of their GDPs close to twice that of the national average. Michigan, Indiana, Kentucky, Tennessee, and Alabama produce motor vehicle manufacturing output as a share of their GDPs at more than three times the national average; South Carolina, Mississippi and Ohio produce two to three times the national average.

Figure 29. High concentration of motor vehicle manufacturing and information technology (IT) services output, by state: 2020



Note(s): The location quotient (LQ) is the ratio of knowledge- and technology-intensive industry's share of a state's GDP to the corresponding industry's share of national GDP. States with high concentration of motor vehicle or IT services outputs are those with a LQ that is greater than 1.0.

Source(s): BEA, special tabulations, October 2021. *Indicators 2022: Industry Activities*

Conclusion

The importance of a strong global S&E enterprise was epitomized during the COVID-19 pandemic, which had devastating consequences for the global and U.S. economy while requiring rapid, collaborative, and effective S&E innovation activity. Evidence presented in this report supports the view that the global position of the U.S. S&E enterprise has shifted due to rapid growth in Asia's R&D investments and S&T capabilities. The high rate of growth in several countries, including China, is not surprising because of their low starting position in these activities. As their growth outpaces U.S. growth in R&D investment, S&E publications, patenting activity, and the output of some KTI industries, these activities are less concentrated in the United States than they were at the turn of the century, despite increases in absolute dollars spent on R&D by the United States. However, the United States remains a key collaborator in the global S&E enterprise, a role that was clear during the COVID-19 pandemic.

This report highlights potential areas in which building, broadening, and diversifying S&E capacity could strengthen the U.S. S&E enterprise for meeting future challenges. The data indicate some capacity-building areas in the U.S. S&E enterprise as (1) investing in R&D and supporting innovation activities that translate the resulting knowledge into products and services, (2) improving STEM education at the K–12 level, (3) increasing participation in STEM fields of study and careers to include all socioeconomic and demographic groups and U.S. geographic regions, and (4) building a strong STEM labor force by training and educating domestic talent and by recruiting and retaining foreign talent.

Federal support for R&D and innovation activity is important to the U.S. S&E enterprise. Despite increasing amounts of federal funding for R&D, the overall proportion of R&D funded by the government has declined over the past 9 years. Federal funding is particularly important for basic research and research performed at institutions of higher education. Beyond directly funding research, the federal government supports activities that prevent cyber theft, enhance intellectual property protection, and promote technology transfer.

The U.S. S&E enterprise depends on a large STEM labor force. Building the STEM labor force through strengthening U.S. STEM education at the K–12 level will increase S&E capacity. Performance of U.S. K–12 students in STEM has been stagnant, and persistent achievement gaps remain among sociodemographic groups. Reducing these gaps would provide more students with STEM skills who can either pursue higher education in a STEM field or enter the STEM labor force. In addition, the U.S. higher education system is highly valued. However, higher education is expensive, posing a barrier for many families. Affordable U.S. higher education has the potential to expand the domestic STEM labor force by increasing opportunities for everyone.

STEM careers are concentrated in a few parts of the country. Employment of the STW is greater in states in the South and Midwest where many manufacturing KTI industries are located. Workers with a bachelor's degree or higher are concentrated in states on the East and West Coasts where services-oriented KTI industries, some manufacturing-oriented KTI industries, and many of the nation's most research-intensive universities are located. Reducing this uneven geographic distribution presents an opportunity to increase equitable representation in the STEM workforce.

The U.S. STEM labor force depends heavily on foreign talent. At the doctorate level, the United States trains many of these workers. Most U.S.-trained S&E doctorate recipients expect to stay in the United States after graduation. Maintaining pathways for foreign talent and providing educational opportunities for international students are critical to sustaining the STEM workforce.

This report reveals challenges to building U.S. S&E capacity but also presents data that highlight ways in which the United States can address these challenges. The data show the importance of building capacity by investing in R&D, enhancing education and training opportunities, and bringing underrepresented groups into a STEM-educated labor force that reflects the nation's diversity.

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: (Definition applies to R&D section of report.) Consists of both private enterprises (regardless of whether they are publicly listed or traded) 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).

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

European Union (EU-27): Twenty-seven member nations after Brexit in 2020, including 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, and Sweden.

Expected stay rate: The proportion of foreign recipients of U.S. S&E doctorates who expect to stay in the United States after receiving their doctorate one year later.

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).

First-university degree: A terminal undergraduate degree program; these degrees are classified within level 6 (bachelor's degree or equivalent) or level 7 (master's degree or equivalent, including long first degrees) in the 2011 International Standard Classification of Education.

Foreign-born workers: Those born outside of the United States, regardless of citizenship. Foreign-born workers can be U.S. citizens or permanent residents.

Government sector: (Definition applies to R&D section of the report.) Consists of all federal, state, and local governments, except those that provide higher education services, and all non-market nonprofit institutions controlled by government entities that are not part of the higher education sector. This sector excludes public corporations, even when all of the equity of such corporations is owned by government entities. Public enterprises are included in the business sector (see *Business sector*) (OECD 2015).

Higher education sector: (Definition applies to the R&D section of the report.) Consists of all universities, colleges of technology, and other institutions providing formal tertiary education programs, whatever their source of finance or legal status, as well as 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).

High-income countries: Countries with a gross national income per capita of $12,696 or more in 2020 (World Bank 2021a).

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.

Information and communication technologies (ICT) industries: Industries classified under the International Standard Industrial Classification Revision Code 4 (ISIC, Rev.4) in 26 computer, electronic, and optical products; 582 software publishing; 61 telecommunications; and 62–63 information technology (IT) and other information services (OECD 2017).

Innovation: A new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process). The *unit* is a generic term to describe the actor responsible for innovations. It refers to any institutional unit in any sector, including households and their individual members, according to the Oslo Manual, Revision 4 (OECD Eurostat 2018).

International patents: Original patents issued by any international jurisdiction, adjusted to count only the first issuance of a series or family of related patents. The unit of measurement is a patent family that shares a single original invention in common. All subsequent patents in a family refer to the first patent filed, or priority patent and the indicator provides an unduplicated count of original or priority patents in any individual jurisdiction. The organization of these international patents around a single initial invention means that there may be fewer international patents than individual patents.

Invention: Any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof (U.S. Patent and Trademark Office 2020).

Knowledge- and technology-intensive (KTI) industries: Industries classified by the OECD as high-R&D-intensive and medium-high-R&D-intensive industries based on R&D intensity (see *R&D intensity*).

Location quotient (LQ): Ratio of an industry's share of a state's gross domestic product (GDP) to the corresponding industry's share of domestic GDP.

Middle-income and upper-middle income countries: Countries in the World Bank's (2021a) (1) lower middle-income economies (those with a gross national income per capita between $1,046 and $4,095) and (2) upper middle-income economies (those with a gross national income per capita between $4,096 and $12,695) in 2020.

Middle-skill occupations: Occupations that require a high level of scientific and technical knowledge, although these occupations do not typically require a bachelor's degree for entry. Middle-skill occupations are primarily in construction trades, installation, maintenance, and production.

Natural sciences: The combined group of physical and biological sciences, mathematics and statistics, computer sciences, agricultural sciences, and earth, atmospheric, and ocean sciences.

Patent Cooperation Treaty applications: An international agreement that allows entities to seek patent protection for an invention simultaneously in each of a large number of countries by filing an "international" patent application. Such an application may be filed by anyone who is a national or a resident of a contracting state (WIPO 2021). Patent Cooperation Treaty applications include USPTO patent applications (see *USPTO patent*).

Patent intensity: Number of patents per population in a geographic location.

Purchasing power parity (PPP): The price of a common basket of goods and services in each participating economy, measuring what an economy's local currency can buy in another economy (World Bank 2021b). PPPs convert different currencies to a common currency while adjusting for differences in price levels between economies, and thus they enable direct comparisons of R&D expenditures across countries.

Research and development (R&D) funding (funders): Expenditures (or those that use expenditures) to pay the costs of R&D performance. For example, the federal government provides funding to laboratories at higher education institutions to perform R&D at the laboratories. R&D funders may differ from R&D performers (see *R&D performance*).

Research and development (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, or company). Examples include R&D-to-GDP (gross domestic product) ratio used in R&D cross-national comparisons and R&D-to-value-added output ratio used to classify industries as knowledge and technology intensive.

Research and development (R&D) performance (performers): Intramural expenditures (or those that use intramural expenditures) to conduct R&D. For example, laboratories at higher education institutions perform R&D with funding from the federal government. R&D performers may differ from R&D funders (see *R&D funding*).

Research and [experimental] development (R&D): 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.

Science and engineering (S&E) fields: Degrees awarded in the following 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 the degree data used to classify these sciences correspond to the doctor's research or scholarship degree level, which are research-focused degrees.

Science and engineering (S&E) occupations: A subset of occupations that includes 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 (see *S&E-related occupations*) and are not included in S&E.

Science and engineering (S&E)-related occupations: Occupations that require science and technology (S&T) expertise but are not part of the five major categories of the S&E occupations (see *S&E occupations*), including these four minor occupations: (1) health, (2) S&E managers, (3) S&E precollege teachers, and (4) technologists and technicians.

Science and engineering (S&E) technology fields: Degrees awarded to prepare students for occupations requiring an associate's degree or certificate; these fields include technician programs in engineering, health sciences and other S&E fields and have more of an applied focus compared to S&E fields (see *S&E fields*).

Science, technology, engineering, and mathematics (STEM) occupations: A subset of the U.S. workforce comprised of S&E (see *S&E occupations*), S&E-related (see *S&E-related occupations*), and STEM middle-skill occupations (see *Middle-skill occupations*).

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

South Asia: Includes Cambodia, India, Mongolia, Myanmar, Nepal, Pakistan, and Sri Lanka.

U.S. Patent and Trademark Office (USPTO) patent: A property right granted by the U.S. government to an inventor "to exclude others from making, using, offering for sale, or selling the invention throughout the United States or importing the invention into the United States" for a limited time in exchange for public disclosure of the invention when the patent is granted (USPTO 2021). USPTO applications are included in Patent Treaty Cooperation applications (see *Patent Cooperation Treaty applications*).

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

ABS: Annual Business Survey

ACS: American Community Survey

AIAN: American Indian or Alaska Native

BEA: Bureau of Economic Analysis

DHS: Department of Homeland Security

DOD: Department of Defense

DOE: Department of Energy

ED: Department of Education

EU: European Union

GDP: Gross domestic product

GSS: Survey of Graduate Students and Postdoctorates in Science and Engineering

ICE: Immigration and Customs Enforcement

ICT: Information and communication technology

INPADOC: International Patent Documentation

IPEDS: Integrated Postsecondary Education Data System

IT: Information technology

KTI: Knowledge and technology intensive

LQ: Location quotient

MEXT: Ministry of Education, Culture, Sports, Science and Technology (Japan)

MHRD: Ministry of Human Resources Development (India)

MOE: Ministry of Education (China)

MSTI: Main Science and Technology Indicators

NAEP: National Assessment of Educational Progress

NASA: National Aeronautics and Space Administration

NBS: National Bureau of Statistics (China)

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

PISA: Program for International Student Assessment

PPP: Purchasing power parity

R&D: Research and [experimental] development

S&E: Science and engineering

S&T: Science and technology

SEVIS: Student and Exchange Visitor Information System

STEM: Science, technology, engineering, and mathematics

STW: Skilled technical workforce

UIS: Institute for Statistics

UNESCO: United Nations Educational, Scientific and Cultural Organization

USDA: Department of Agriculture

USPTO: U.S. Patent and Trademark Office

WIPO: World Intellectual Property Organization

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Notes

1 The section "**Elementary and Secondary (K–12) Mathematics and Science**" draws on data and sources in the *Indicators 2022* report, "[2022] Elementary and Secondary STEM Education."

2 Detailed notes and full list of OECD countries for Figure 1 are available in Figure K12-5 in the *Indicators 2022* report, "[2022] Elementary and Secondary STEM Education."

3 Detailed notes for Figure 2 are available in Figure K12-2 in the *Indicators 2022* report, "[2022] Elementary and Secondary STEM Education."

4 For Figure 3, minority enrollment includes students who are Black, Hispanic, Asian, Native Hawaiian or Pacific Islander, American Indian or Alaska Native, and more than one race. Hispanic may be any race; race categories exclude Hispanic origin.

5 The section "**S&E Higher Education in the United States**" draws on data and sources in the forthcoming *Indicators 2022* report, "[2022] Higher Education in Science and Engineering." The Higher Education report also provides further breakout by sex and race or ethnicity.

6 For Figure 4, the U.S. population data reflect the percentage of people in each racial and ethnic group in the U.S. population from ages 20 to 34 on 1 July 2019. Hispanic may be any race; race categories exclude Hispanic origin. Degree totals may differ from those elsewhere in the report; degrees awarded to people of unknown or other race were excluded, as were degree earners on temporary visas.

7 The section "**International S&E Higher Education and Student Mobility**" draws on data and sources in the forthcoming *Indicators 2022* report, "[2022] Higher Education in Science and Engineering."

8 For Figure 5, to facilitate international comparison, data for the United States are those reported to OECD, which varies slightly from the NCSES classification of fields presented in other sections of the report.

9 For Figure 6, the data reflect fall enrollment in a given year and include students with "active" status as of 15 November of that year. Data include active foreign national students on F-1 visas and exclude those on optional practical training. Undergraduate level includes associate's and bachelor's degrees; graduate level includes master's and doctoral degrees.

10 The section "**Americans' Perceptions about Science**" draws on data and sources in the forthcoming *Indicators 2022* report, "[2022] Science and Technology: Public Perceptions, Awareness, and Information Sources."

11 For Figure 7, responses are to the following: *How much confidence, if any, do you have in [scientists] to act in the best interests of the public?*

12 Detailed notes for Figure 8 are available in Figure LBR-2 in the *Indicators 2022* report, "[2022] The STEM Labor Force of Today: Scientists, Engineers, and Skilled Technical Workers."

13 The section "**The STEM Labor Market and the Economy**" draws on data and sources in the *Indicators 2022* report, "[2022] The STEM Labor Force of Today: Scientists, Engineers, and Skilled Technical Workers."

14 The observed rankings of state estimates provide useful context. However, a state having a highest or lowest rate does not imply that the state's rate is significantly higher or lower than the rate of the next highest or lowest state. For a full list of state estimates, see Figure LBR-D and Figure LBR-E in the *Indicators 2022* report, "[2022] The STEM Labor Force of Today: Scientists, Engineers, and Skilled Technical Workers."

15 Unless otherwise noted, the section "**Demographic Composition of the STEM Workforce**" draws on data and sources in the *Indicators 2022* report, "[2022] The STEM Labor Force of Today: Scientists, Engineers, and Skilled Technical Workers." The Labor Force report also provides further breakout by sex and race or ethnicity.

16 Detailed notes for Figure 10 are available in Figure LBR-24 in the *Indicators 2022* report, "[2022] The STEM Labor Force of Today: Scientists, Engineers, and Skilled Technical Workers."

17 See data and sources in the forthcoming *Indicators 2022* report, "[2022] Production and Trade of Knowledge- and Technology-Intensive Industries."

18 For data on the 5- and 10-year stay rates, see the *Indicators 2020* report "[2020] The State of U.S. Science and Engineering 2020" and the report "[2020] **Science and Engineering Labor Force.**"

19 Data for the United States in Figures 12 – Figures 15 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.

20 The section "Global R&D" draw on data and sources in the forthcoming *Indicators 2022* report, "[2022] Research and Development: U.S. Trends and International Comparisons,"—refer to this report and the section on Research and Development at the NCSES website for the latest data as estimates in this section may be subject to revision.

21 Unless otherwise noted, the section "U.S. Performance and Funding Trends" draws on data and sources in the forthcoming *Indicators 2022* report, "[2022] Research and Development: U.S. Trends and International Comparisons"—refer to this report and the section on Research and Development at the NCSES website for the latest data as estimates in this section may be subject to revision.

22 Data for the United States in Figure 16 and Figures 17 reflect NCSES's protocol for tallying U.S. total R&D, which varies slightly from the international standards for calculating gross expenditures on R&D.

23 U.S. business R&D is the R&D performed by companies domiciled in the United States. It includes the R&D performed by the company and paid for by the company itself (from company-owned, U.S.-located units or from subsidiaries overseas). It also includes the R&D performed by the company and paid for by others, such as other companies (domestic or foreign, including parent companies of foreign-owned subsidiaries located in the United States), the U.S. federal government, nonfederal government (state and local or foreign), and nonprofit or other organizations (domestic or foreign).

24 See data and sources in the *Indicators 2022* report, "[2022] Academic Research and Development." Because graduate students receive funding from a variety of sources, a decline in the percentage of S&E graduate students who receive federal funding does not equate to a decline in overall financial support for graduate students.

25 Detailed notes for Figure 21 are available in Figure URD-24 in the *Indicators 2022* report, "[2022] Academic Research and Development."

26 Unless otherwise noted, the section "Research Publications" draws on data and sources in the *Indicators 2022* report "[2022] Publications Output: U.S. Trends and International Comparisons."

27 Detailed notes for Figure 22 are available in Figure PBS-2 in the *Indicators 2022* report "[2022] Publications Output: U.S. Trends and International Comparisons."

28 Detailed notes for Figure 23 are available in Figure PBS-7 in the *Indicators 2022* report "[2022] Publications Output: U.S. Trends and International Comparisons."

29 Detailed notes for Figure 24 are available in Figure PBS-4 in the *Indicators 2022* report "[2022] Publications Output: U.S. Trends and International Comparisons."

30 The section "Invention and Innovation" draws on data and sources in forthcoming the *Indicators 2022* report, "[2022] Invention, Knowledge Transfer, and Innovation."

31 For Figure 25, data are counted according to the year of the first granted patent in the patent family. Patent families are allocated according to patent inventorship information found on the priority patent of the INPADOC families. To account for missing ownership information in PATSTAT for some offices, a method designed by de Rassenfosse et al. (2013) is used to fill missing information on priority patents using information in successive filings within the families. Patent families are fractionally allocated among regions, countries, or economies based on the proportion of residences of all named inventors.

32 For Figure 26, WIPO used a sex-name dictionary based on information from 13 different public sources to assign sex to inventors' names recorded in Patent Cooperation Treaty applications. Sex is attributed to a given name on a country-by-country basis because certain names can be considered male in one country but female in another.

33 For Figure 27, industry classification is from the 2017 North American Industry Classification System codes and based on the dominant establishment payroll. Industries shown are those for which more than half of the companies reported an innovation from 2015 to 2017.

34 The section "Knowledge- and Technology-Intensive Industry Output" draws on data and sources in the forthcoming *Indicators 2022* report, "[2022] Production and Trade of Knowledge- and Technology-Intensive Industries."

35 For Figure 28, output is measured on a value-added basis.

36 These two industries were chosen to illustrate the specialization in KTI output across states.

Acknowledgments and Citation

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Cover Image Credit

The cover for *Science and Engineering 2022: The State of U.S. Science and Engineering* shows molecules leaving the solvation shell and integrating into the crystal surface. Using computer-based simulations to analyze how atoms and molecules move in a solution, researchers at the University of Illinois Chicago identified a general mechanism governing crystal growth that scientists can manipulate when developing new materials. In this illustration, local fluctuations allow molecules to leave the solvation shell and integrate into the crystal surface (This research was supported by National Science Foundation grant CBET 1706921.)

Credit: Meenesh R. Singh\Department of Chemical Engineering\University of Illinois at Chicago

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