THE STATE OF U.S. SCIENCE & ENGINEERING

2024

Science & Engineering Indicators

NATIONAL SCIENCE BOARD

National Science Board

National Science Board
Science & Engineering Indicators

2024

The State of U.S. Science and Engineering 2024

March 2024 | NSB-2024-3

Preface

The National Science Board (Board, NSB) is required under the National Science Foundation (NSF) Act, 42 U.S.C. § 1863 (j) (1) to prepare the biennial *Science and Engineering Indicators* (*Indicators*) report for and transmit it 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 summary report, *The State of U.S. Science and Engineering,* details key findings from the nine thematic reports that make up *Indicators,* providing in-depth data and information on science, technology, engineering, and mathematics (STEM) education at all degree levels; the STEM workforce; public perceptions and awareness of science and technology; U.S. and international research and development performance; invention, knowledge transfer, and innovation; and U.S. competitiveness in high-technology industries. *Indicators* also includes an interactive, online tool that enables state comparisons on a variety of S&E indicators. This summary report, the nine thematic reports, and the online **State Indicators data tool** together make up the full *Indicators* suite of products.

Table of Contents

Key Takeaways

- National assessments show a sharp decline in elementary and secondary student mathematics performance since the COVID-19 pandemic. From 2019 to 2022, average mathematics scores of fourth and eighth grade students dropped to levels last measured approximately 20 years ago.
- Enrollment of international science and engineering (S&E) graduate students at U.S. institutions has rapidly increased from approximately 200,000 in 2020, a pandemic-era low point, to nearly 310,000 in 2022. International students on temporary visas accounted for about a third of S&E master's and doctoral degree recipients at U.S. institutions in 2021.
- The U.S. science, technology, engineering, and mathematics (STEM) workforce comprised 36.8 million people in diverse occupations that require STEM knowledge and expertise in 2021, accounting for 24% of the total U.S. workforce. Just over half of STEM workers did not have bachelor's degrees or higher. Foreign-born individuals made up 19% of all STEM workers and 43% of doctorate-level scientists and engineers.
- Women account for lower shares of degree recipients in engineering and computer and information sciences than men. Women are underrepresented in the STEM workforce, and they accounted for 35% of all STEM workers in 2021. Hispanic or Latino, Black or African American, and American Indian or Alaska Native individuals are underrepresented among S&E degree recipients at the bachelor's degree level and above and also among STEM workers with at least a bachelor's degree.
- The United States is the largest performer of research and development (R&D), with $806 billion in gross domestic expenditures on R&D in 2021. Other top R&D-performing countries include China ($668 billion), Japan ($177 billion), Germany ($154 billion), and South Korea ($120 billion). The United States is also among the world's most R&D-intensive economies, with R&D expenditures equaling 3.5% of its gross domestic product in 2021.
- The absolute amount of federally funded R&D increased from 2011 to 2021; however, due to significant growth in R&D funded by businesses, the share of total U.S. R&D funded by the federal government decreased from 30% in 2011 to 19% in 2021. The business sector now funds 36% of basic research, close to the 40% share of basic research funded by the federal government.
- The federal government is the largest supporter of academic R&D, funding 52% of all R&D performed by higher education institutions and supporting 15% of full-time S&E graduate students in 2021.
- S&E articles published in open-access journals increased over 50-fold in the past two decades, from 19,000 articles published in 2003 to 992,000 articles in 2022.
- Indicators of global science, technology, and innovation (STI) capabilities, such as S&E research publications, patenting, and knowledge- and technology-intensive (KTI) industry output, are concentrated in the United States, East and Southeast Asia, and Europe. Over the past decade, China has significantly increased its share of global STI capabilities.
- China is the top overall producer of S&E publications and international patents and has the greatest KTI manufacturing output. The United States, which has a greater share of its publications among the most highly cited S&E research, is the world leader in KTI services. These two countries are the largest contributors to a global network of artificial intelligence (AI) research publishing.
- Like K–12 education outcomes, innovation capabilities and the STEM labor force are not uniform across the United States. 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.

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 illustrate the U.S. global position in multiple aspects of the S&E enterprise. This report provides high-level findings from the nine thematic reports that make up *Science and Engineering Indicators 2024*. Selected data from the nine thematic reports are grouped here into three major sections that relate to the S&E enterprise: talent, discovery, and translation. These three components collectively support U.S. global competitiveness in science, technology, and innovation (STI), in that science, technology, engineering, and mathematics (STEM) talent contributes to scientific discovery, which in turn is translated to society and the economy through innovation.

The first section of the report describes the status of the U.S. STEM education system from elementary through the doctoral level and the STEM workforce, including the contributions of international students and workers. It also details the American public's perceptions about scientists. The second section, on research and development (R&D), discusses the position of the United States among the top R&D-performing countries and analyzes patterns of U.S. R&D funding and performance among economic sectors and by type of R&D. The third and final section focuses on outputs of the S&E enterprise to provide insight into how the United States and other major countries and regions contribute to global knowledge and innovation. Finally, the report contains a sidebar with select indicators of national investments and capabilities in critical and emerging technologies (see sidebar **Critical and Emerging Technologies**).

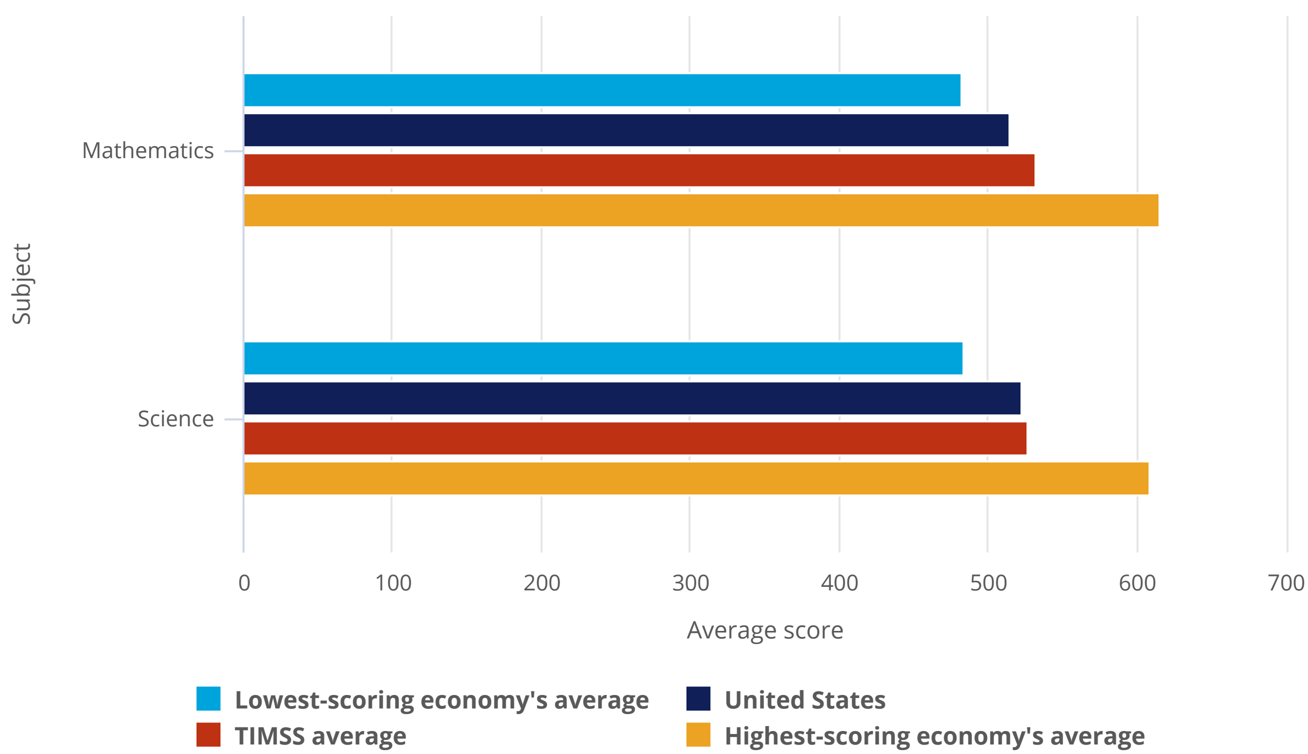
Talent: U.S. and Global STEM Education and Labor Force

A globally competitive STEM education system equips Americans with the skills and knowledge needed to participate in the STEM workforce. STEM workers with a broad range of educational credentials sustain the U.S. research enterprise and drive innovation in critical and emerging technologies, supporting the nation's competitiveness in the global economy.

Elementary and Secondary 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] Prior to the COVID-19 pandemic, the United States ranked near the middle of advanced economies based on international mathematics and science assessments of students (Figure 1). In 2019, average Trends in International Mathematics and Science Study (TIMSS) assessment scores of U.S. eighth grade students in mathematics (515) and science (522) were similar to the average among advanced economies (532 in mathematics and 527 in science). Average scores of students from advanced economies in East and Southeast Asia—Singapore, Taiwan, South Korea, Japan—were among the highest and were significantly higher than average scores of U.S. students in both mathematics and science.[2]

Figure 1. Average TIMSS mathematics and science scores of students in grade 8 among participating advanced economies: 2019

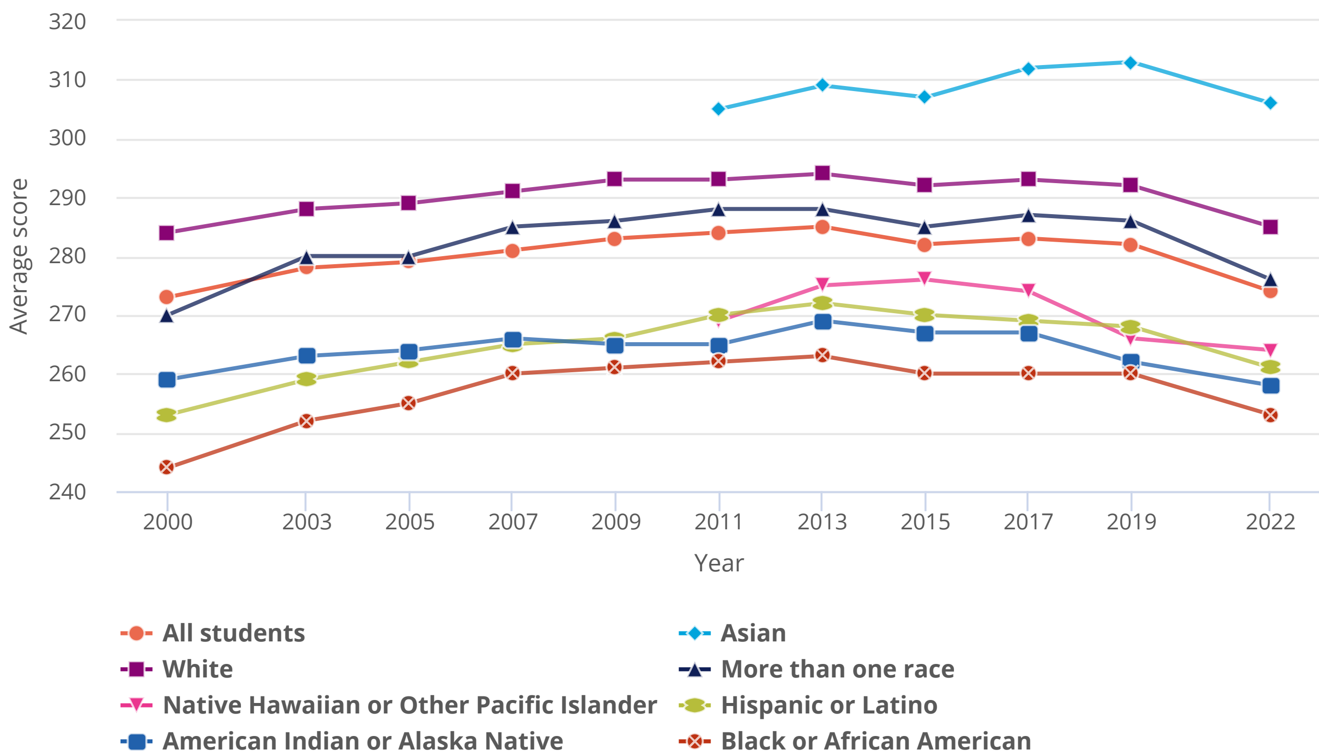


Note(s): TIMSS is Trends in International Mathematics and Science Study. The scale for TIMSS scores is 0–1,000.

Source(s): International Association for the Evaluation of Educational Achievement, TIMSS, 2019. *Indicators 2024: K–12 Education*

The COVID-19 pandemic led to severe disruptions in elementary and secondary student learning in the United States, beginning with the abrupt switch to remote instruction for many students in March 2020. Student mathematics performance showed a sharp decline in 2022, compared with pre-pandemic performance in 2019. From 2019 to 2022, the overall average scores for eighth graders on the main National Assessment of Educational Progress (NAEP) mathematics assessment dropped for all students, although the decline was not statistically significant for all racial and ethnic groups (Figure 2).[3] Average scores in mathematics for all students in 2022 were lower than all previous assessments since 2005 for fourth graders and since 2003 for eighth graders.

Figure 2. Average scores of U.S. students in grade 8 on the main NAEP mathematics assessment, by race or ethnicity: 2000–22

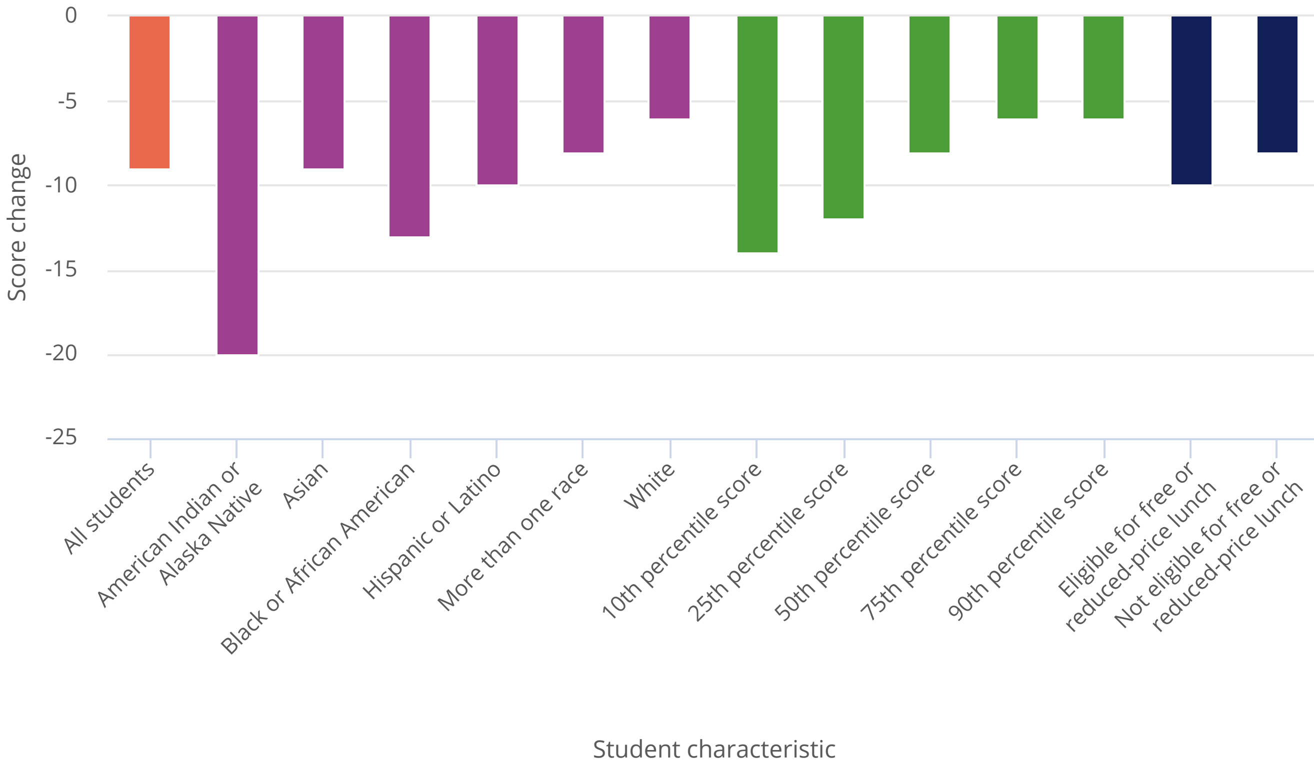


Note(s): NAEP is National Assessment of Educational Progress. Data are not available for all years. The scale for NAEP mathematics assessment scores is 0–500 for grade 8. Hispanic or Latino may be any race; race categories exclude Hispanic origin. Average scores declined from 2019 to 2022 by statistically significant amounts for all racial and ethnic groups shown except for American Indians or Alaska Natives and Native Hawaiians or Other Pacific Islanders.

Source(s): NCSES, special tabulations (2022) of the main NAEP 2000–22 mathematics assessments, NCES. *Indicators 2024: K–12 Education*

The NAEP long-term trend mathematics assessment, another national assessment of mathematics, also shows a significant post-pandemic decline in student scores (Figure 3). From 2020 to 2023, the average score for all 13-year-old students dropped by 9 points. Among student racial and ethnic groups, score declines included a 20-point drop for American Indian or Alaska Native students and a 6-point drop for White students. Scores for students in the 10th percentile—those scoring near the low end of all assessment takers—dropped by 14 points, whereas scores for students in the 90th percentile dropped by 6 points. As a result, the gap between students scoring in the 10th percentile (213) and the 90th percentile (322) widened to 109 points, the largest it has been since the assessment began in 1978. With respect to student socioeconomic status, students eligible for free or reduced-price lunch—a commonly used indicator of family poverty—scored significantly lower in 2023 (253) than students ineligible for the program (287). Both groups of students experienced significant declines in test scores from 2020 to 2023.

Figure 3. Change in average student scores for 13-year-old students on the NAEP long-term trend mathematics assessment, by student characteristic: 2020–23



Note(s): NAEP is National Assessment of Educational Progress. Hispanic or Latino may be any race; race categories exclude Hispanic origin. Data for Native Hawaiian or Other Pacific Islander students are suppressed for reasons of confidentiality and/or reliability. Changes in average scores from 2020 to 2023 for all groups shown are statistically significant at the 0.10 level.

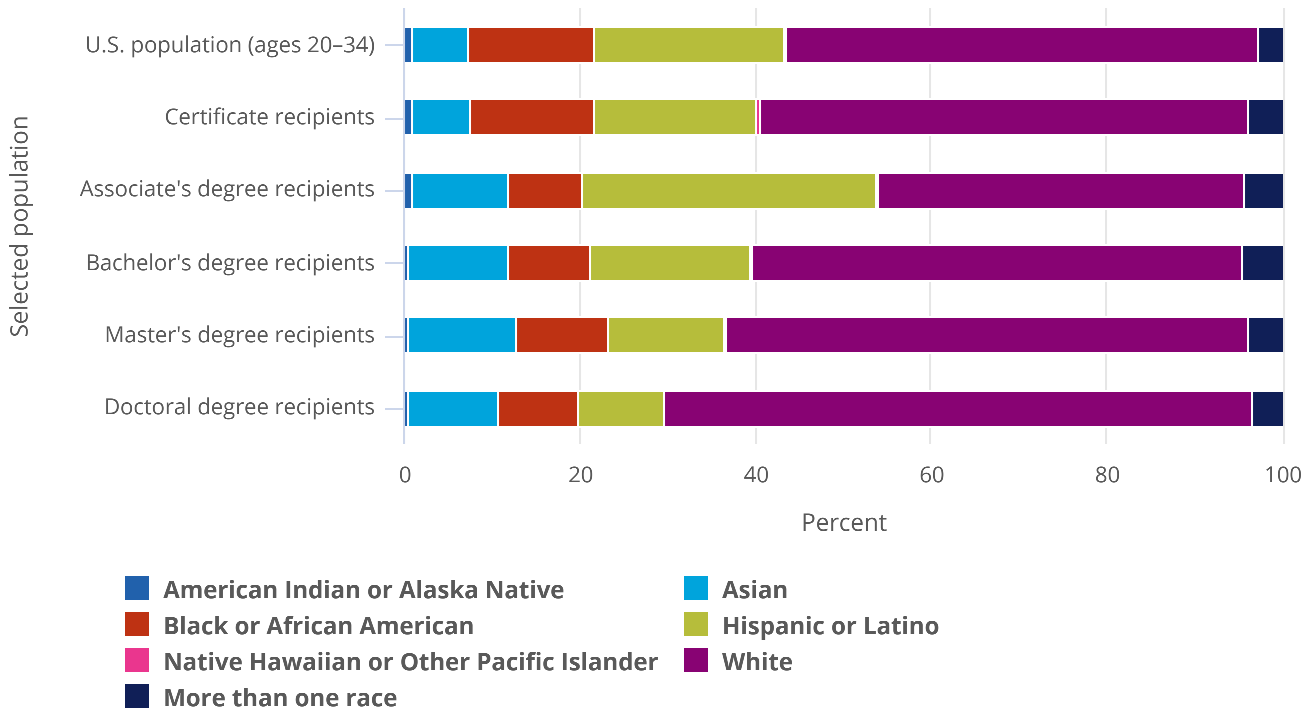
Source(s): NCSES, special tabulations (2023) of the 2020 and 2023 NAEP long-term trend mathematics assessments, NCES. *Indicators 2024: K–12 Education*

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 a list of S&E fields).[4] The number of certificates and degrees awarded in S&E fields increased at each degree level in the past decade, with total S&E awards (including all certificates and associate's, bachelor's, master's, and doctoral degrees) increasing from 982,000 in 2012 to 1,310,000 in 2021. The share of degrees awarded in S&E fields increased for all levels except doctoral degrees; however, the share of degrees awarded in S&E fields was the highest at the doctoral level, with 66% of doctoral degrees awarded in S&E fields.

Many groups of Americans remained underrepresented among S&E degree recipients when compared to their share of the U.S. population ages 20–34 years old. The percentage of women varied significantly depending on S&E field, with women accounting for the lowest shares of degree recipients in engineering (24% of bachelor's degrees in 2021) and computer and information sciences (22%). In 2021, American Indian or Alaska Native, Black or African American, and Hispanic or Latino students were underrepresented among S&E degree recipients at the bachelor's level and above. Hispanic or Latino students were overrepresented among S&E associate's degree recipients (Figure 4).[5]

Figure 4. Race or ethnicity in the U.S. population and among S&E certificate and degree recipients: 2021



Note(s): Hispanic or Latino may be any race; race categories exclude Hispanic origin.

Source(s): Census Bureau, U.S. population data, 2021; NCES, IPEDS Completion Survey, 2021. *Indicators 2024: Higher Education*

Many students enter higher education through community colleges, which specialize in providing relatively affordable programs of study, including certificate and associate's degree programs that require 2 years or less to complete. These institutions prepare students to enter the workforce directly or to transition to primarily 4-year institutions. Community colleges awarded half (50%) of the 79,000 S&E certificates and three-fourths (76%) of the 155,000 S&E associate's degrees awarded by U.S. institutions in 2021.

The number and growth of higher education degrees awarded in S&E fields vary depending on the degree level. Bachelor's degrees accounted for 66% of all S&E degrees awarded in 2021, with the largest numbers of bachelor's degrees awarded in social sciences, followed by psychology, biological and biomedical sciences, and engineering. Master's degrees either prepare students for advanced STEM careers or mark a step toward obtaining a doctoral degree. The number of master's degrees awarded in S&E fields increased by 41% from 2012 to 2021, the greatest percentage growth of all degree levels. Master's degrees awarded in computer and information sciences—53% of which went to students on temporary visas in 2021—increased rapidly during this time to reach 54,000, surpassing the number awarded in engineering (47,000). Engineering was the most common field of S&E doctorate in 2021 (11,000 awarded), and health sciences was the fastest-growing field of S&E doctorate, increasing from over 4,000 degrees in 2012 to over 7,000 in 2021.

The cost of higher education, levels of student borrowing required to pay this cost, and students' ability to repay student loan debt are topics of discussion among the public and policymakers. In 2020, the median amount borrowed among all 2015–16 bachelor's degree recipients who had taken out federal student loans was $30,000 and the average was $41,000, indicating that some students borrowed much higher amounts. The total amount borrowed includes borrowing for education after completing the 2015–16 bachelor's degree: graduates who had enrolled for an additional postsecondary degree or certificate had borrowed a median amount of $43,500, compared with a $27,000 median amount among students who had no further enrollment. By 2020, the median amount that 2015–16 bachelor's degree recipients owed in education loans was 92% of what they had borrowed. Progress in repaying loans for this group of bachelor's degree recipients differed by S&E degree field. For example, in 2020, median amounts owed were 59% of the amount borrowed for engineering and engineering technology, 74% for computer and information sciences, and 101% for social sciences.

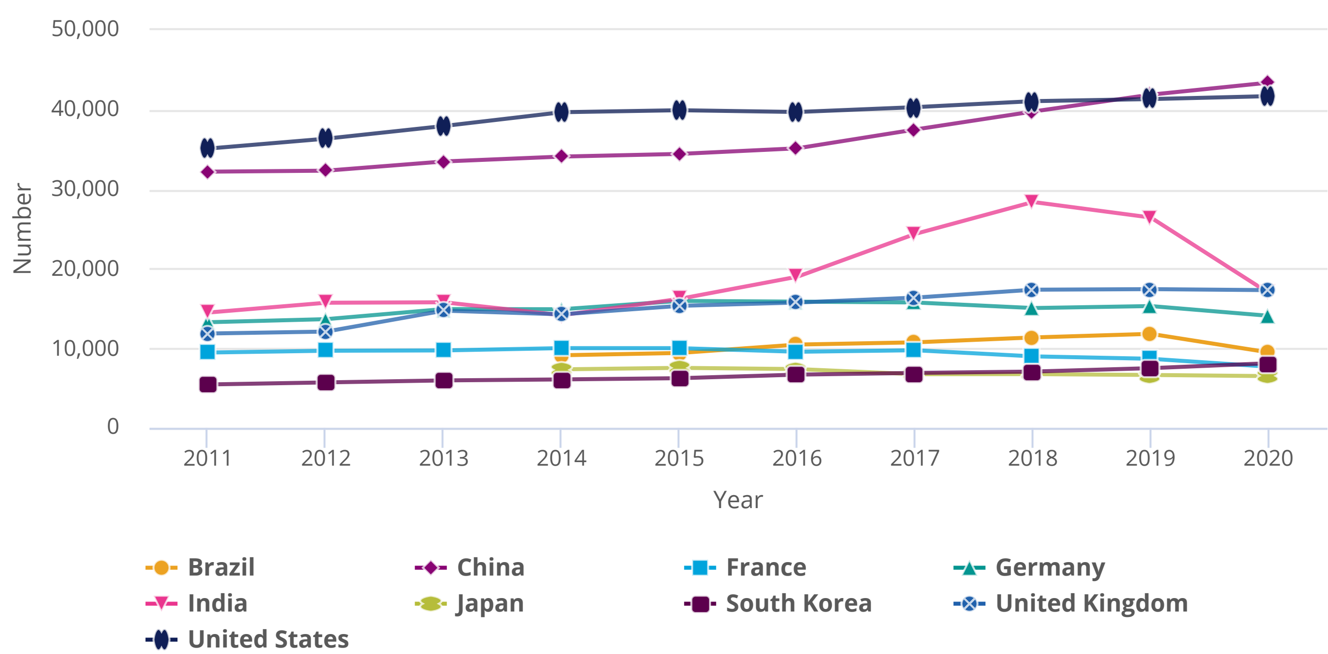
Most S&E doctorate recipients do not incur student debt to support their graduate education. In 2021, large majorities (73% and above) of doctorate recipients in the following fields reported holding no debt related to their graduate education: physical sciences; computer and information sciences; mathematics and statistics; engineering; biological and biomedical sciences; geosciences, atmospheric sciences, and ocean sciences; multidisciplinary and interdisciplinary sciences; and agricultural sciences and natural resources (NCSES 2022a). These are also fields that tend to receive the support of the federal government and academic institutions. In social sciences and in health sciences, the proportion of doctorate recipients with no debt ranged between 53% and 63%; in psychology, it was 48%.

International S&E Higher Education and Student Mobility

The world's three most populous countries award the highest numbers of S&E first university degrees, roughly equivalent to bachelor's degrees (see Glossary section for definition of first university degrees).[6] India awarded 2.5 million first university degrees in S&E in 2020, followed by China (2.0 million) and the United States (900,000). On a percentage basis, Mexico and Turkey experienced the most rapid growth in S&E first university degree awards from 2011 to 2020.

The United States had been a long-standing world leader in S&E doctorate awards but was surpassed by China in 2019. In 2020, China awarded 43,000 S&E doctorates, followed closely by the United States with 42,000 S&E doctorates awarded (Figure 5).[7] China has been the top producer of doctorates in the natural sciences fields (i.e., S&E fields excluding social and behavioral sciences) and engineering since 2007. The number of S&E doctorates awarded in India grew rapidly in the mid-2010s but dropped from 26,000 in 2019 to 17,000 in 2020 amid COVID-19 pandemic-related disruptions—slightly below the number awarded in the United Kingdom. The United States measures far higher than China and India in the share of its postsecondary-age population (individuals ages 20–34 years old) earning S&E degrees; however, the share of the U.S. population earning S&E doctorates is lower than that of the United Kingdom or Germany.

Figure 5. S&E doctoral degrees awarded, by selected country: 2011–20



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

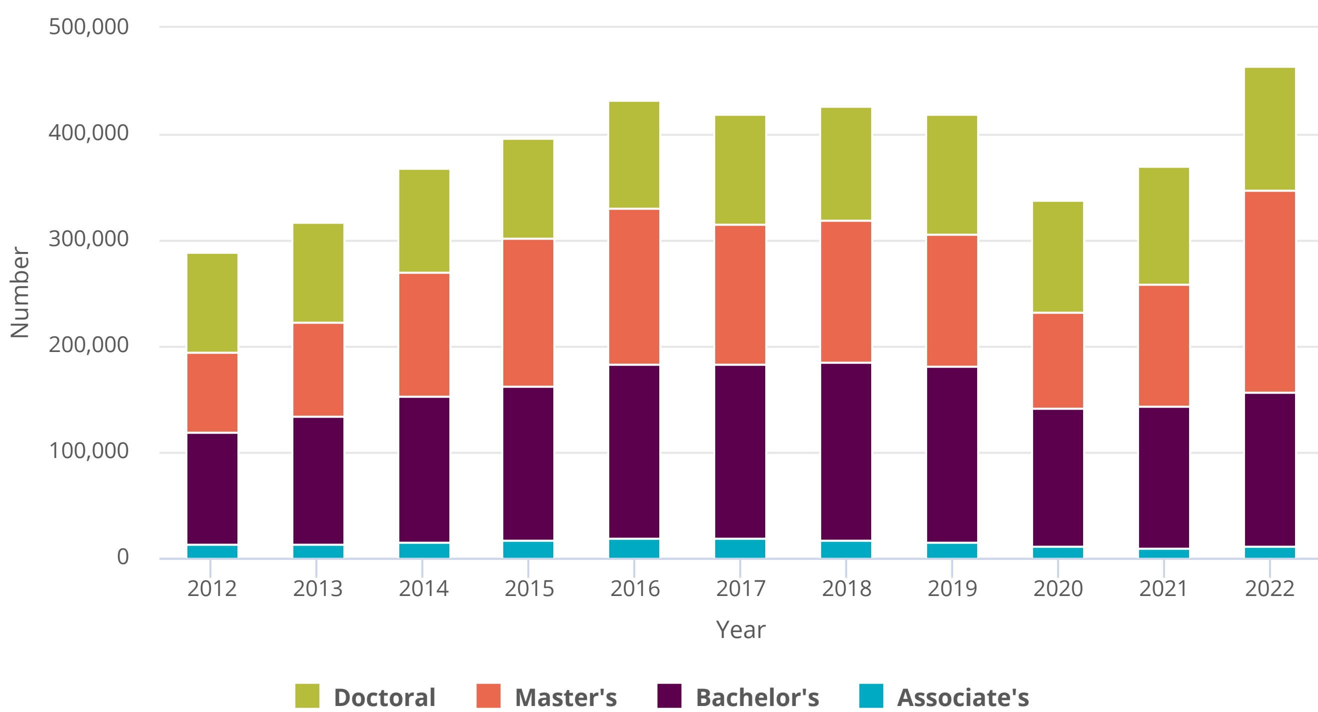
Source(s): Educational statistics of OECD; NBS and MOE (China); MOE (India). *Indicators 2024: Higher Education*

The United States is the most popular destination for internationally mobile students, hosting 15% of all international students worldwide in 2020. Students on temporary visas studying in the United States earn a small proportion of S&E undergraduate degrees but a much higher share of S&E graduate degrees. In 2021, temporary visa holders earned 3% of S&E associate's degrees, 7% of S&E bachelor's degrees, 34% of S&E master's degrees, and 35% of S&E doctoral degrees. Between 2012 and 2021, the shares of S&E degrees earned by temporary visa holders increased for all degree levels, although most substantially at the master's level.

Among postsecondary degree recipients, those on temporary visas are more likely than U.S. citizens and permanent residents to earn their degree in S&E fields, especially at advanced degree levels. In 2021, 57% of master's degrees awarded to temporary visa holders were in S&E fields, compared with 19% for U.S. citizens and permanent residents. Among doctoral degree recipients, the vast majority (83%) of temporary visa holders earned degrees in S&E fields, compared with 59% of U.S. citizens and permanent residents. The overall high representation of temporary visa holders among S&E advanced degree recipients varies greatly by S&E field. In 2021, temporary visa holders earned 7% of doctoral degrees in psychology. In contrast, they earned more than half of doctoral degrees in computer and information sciences (59%), engineering (60%), and mathematics and statistics (54%), all S&E fields that the National Science Board has linked to critical and emerging technologies crucial for national security and economic prosperity (NSB 2022).

The number of international students on temporary visas who travel to the United States to earn postsecondary degrees in S&E fields has increased substantially since the first year of the COVID-19 pandemic in 2020, up by 37% (almost 130,000 students) from fall 2020 to fall 2022 (Figure 6).[8] International S&E master's enrollment more than doubled from 2020 to 2022, pushing total international S&E graduate enrollment to nearly 310,000 in 2022, the highest level in the past decade. This increase has been driven by rapid growth in enrollment of S&E master's students from India, who are concentrated in computer sciences and engineering. Enrollment of S&E graduate students from China, the most common country of origin at the doctoral level, has also increased since 2020, but not to the extent as enrollment of students from India.

Figure 6. International S&E students on temporary visas enrolled in U.S. higher education institutions, by level of enrollment: 2012–22



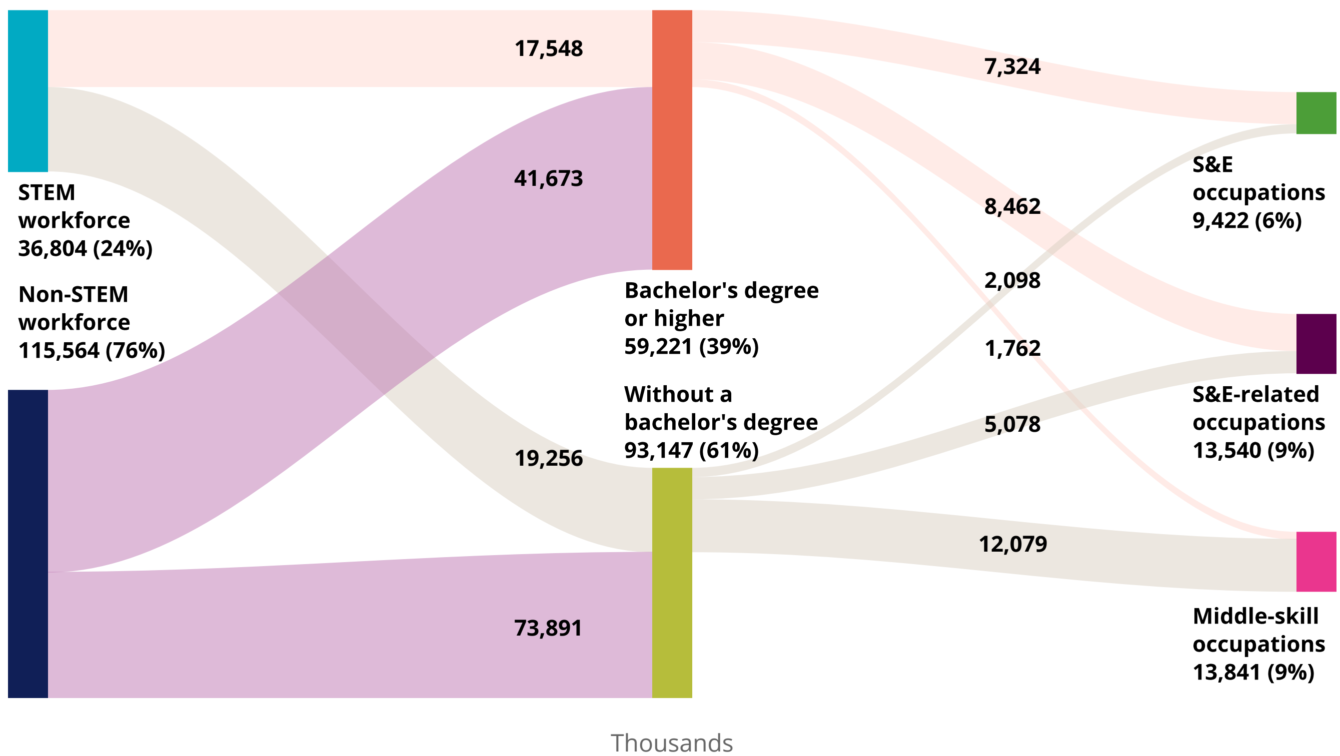
Note(s): Numbers are rounded to the nearest 10.

Source(s): NCSES, special tabulations (2022) of the SEVIS database, DHS, ICE. *Indicators 2024: Higher Education*

The STEM Labor Market and the Economy

The U.S. STEM workforce comprised 36.8 million people in diverse occupations that require STEM knowledge and expertise in 2021, constituting 24% of the total U.S. workforce (Figure 7).[9] The STEM workforce encompasses all workers who use STEM skills in their jobs, regardless of degree level. It includes 17.5 million workers with at least a bachelor's degree and 19.3 million workers without a bachelor's degree. The latter subgroup is defined as the skilled technical workforce (STW).

Figure 7. U.S. workforce, by STEM occupation group and education level: 2021



Note(s): STEM is science, technology, engineering, and mathematics. Numbers are rounded to the nearest thousand. Percent values shown are the shares of the total workforce.

Source(s): Census Bureau, ACS, 2021. *Indicators 2024: Labor Force*

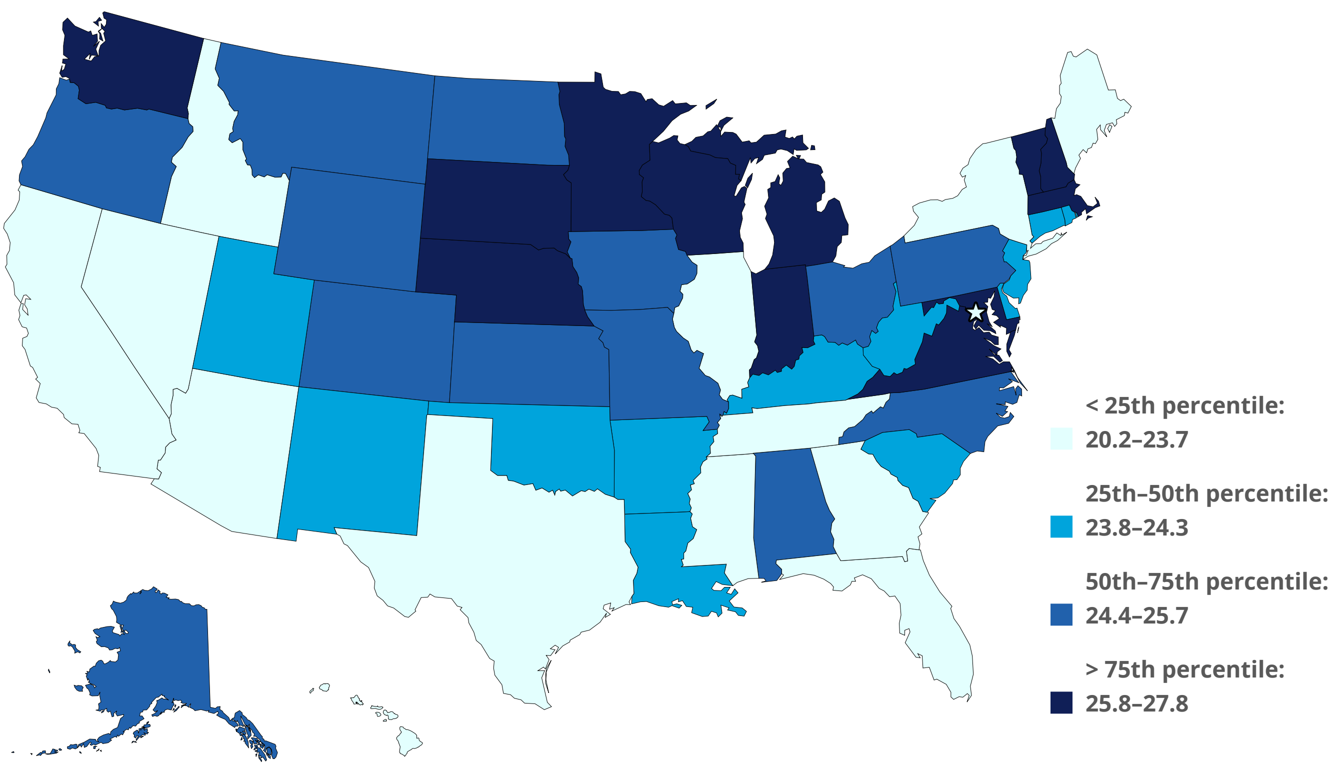
The STEM workforce includes S&E occupations and S&E-related occupations, as well as middle-skill occupations that require STEM skills but typically do not require a bachelor's degree for entry (see Glossary section for definitions of S&E, S&E-related, and middle-skill occupations). Of the 9.4 million workers in S&E occupations, 7.3 million (78%) hold at least a bachelor's degree (Figure 7). Most (62%) of the 13.5 million workers in S&E-related occupations also hold at least a bachelor's degree. In contrast, of the 13.8 million workers in middle-skill occupations, only 1.8 million (13%) have at least a bachelor's degree.

Over the past decade, the STEM workforce grew both in number and in the percentage of the total workforce.[10] Between 2011 and 2021, STEM workers increased from 22% to 24% of the U.S. workforce. By educational attainment, the STEM workforce with a bachelor's degree or higher increased more (growth of 5.7 million workers) than the STW (growth of 1.4 million workers). The expansion of the STEM workforce during this period was also unequally distributed among the different types of STEM occupations. From 2011 to 2021, the number of workers in S&E occupations increased by 62% (3.6 million), whereas S&E-related occupations increased by 26% (2.8 million) and middle-skill occupations increased by 6% (0.8 million).

Workers in STEM occupations have higher employment rates and higher median earnings than their non-STEM counterparts. During the economic downturn associated with the coronavirus pandemic, STEM workers experienced a smaller decrease in their employment rate than non-STEM workers between 2019 and 2021. By 2021, the employment rate of the STEM labor force remained higher than that of the non-STEM labor force (86% versus 79%). STEM workers also earned a higher median annual salary than non-STEM workers in 2021 ($69,000 versus $50,000).

The prevalence of STEM workers throughout the United States is uneven. In 2021, the national share of workers employed in STEM occupations was 24%, with STEM employment shares at the state level ranging from 20% to 28% (Figure 8). States with the highest shares (top quartile) of STEM workers with a bachelor's degree or higher were primarily located on the West Coast and in the Northeast corridor from the Washington, DC, area to New England. States in the top quartile of shares of the STW (STEM workers without a bachelor's degree or higher) employment were mostly in the South and Midwest.[11]

Figure 8. Employment in the STEM workforce, by state: 2021



Note(s): STEM is science, technology, engineering, and mathematics. Quartiles are based on point estimates and do not account for sampling variability.

Source(s): Census Bureau, ACS, 2021. *Indicators 2024: Labor Force*

Demographic Composition of the STEM Workforce

Women made up 35% of the STEM workforce in 2021, less than their share of the employed U.S. population (47%).[12] Women made up 44% of STEM workers with bachelor's degrees or higher and about a quarter of the STW (26%). With respect to type of STEM occupations, women accounted for a minority of workers in S&E occupations (27%) and in middle-skill occupations (10%) but a majority of workers in S&E-related occupations (65%).

Racial and ethnic representation also varies in the STEM workforce and within types of STEM occupations. Black or African American, Hispanic or Latino, and American Indian or Alaska Native individuals collectively accounted for 23% of the STEM workforce in 2021, compared with 30% of the total U.S. workforce (Table 1). Each of these groups was underrepresented in the STEM workforce relative to their share of the total U.S. workforce and had the lowest levels of representation in S&E occupations in particular. For example, in 2021, Black or African American individuals made up 11% of all workers, 8% of

STEM workers, and 7% of workers in S&E occupations. In contrast, Asian individuals accounted for 18% of S&E workers, almost triple their share of the total workforce. Despite the underrepresentation of Hispanic or Latino workers in the overall STEM workforce, they accounted for a higher share of middle-skill STEM workers (22%) than their share of the total workforce (18%).

Table 1. Distribution of select racial and ethnic groups in the workforce, by occupational group: 2021
(Percent)

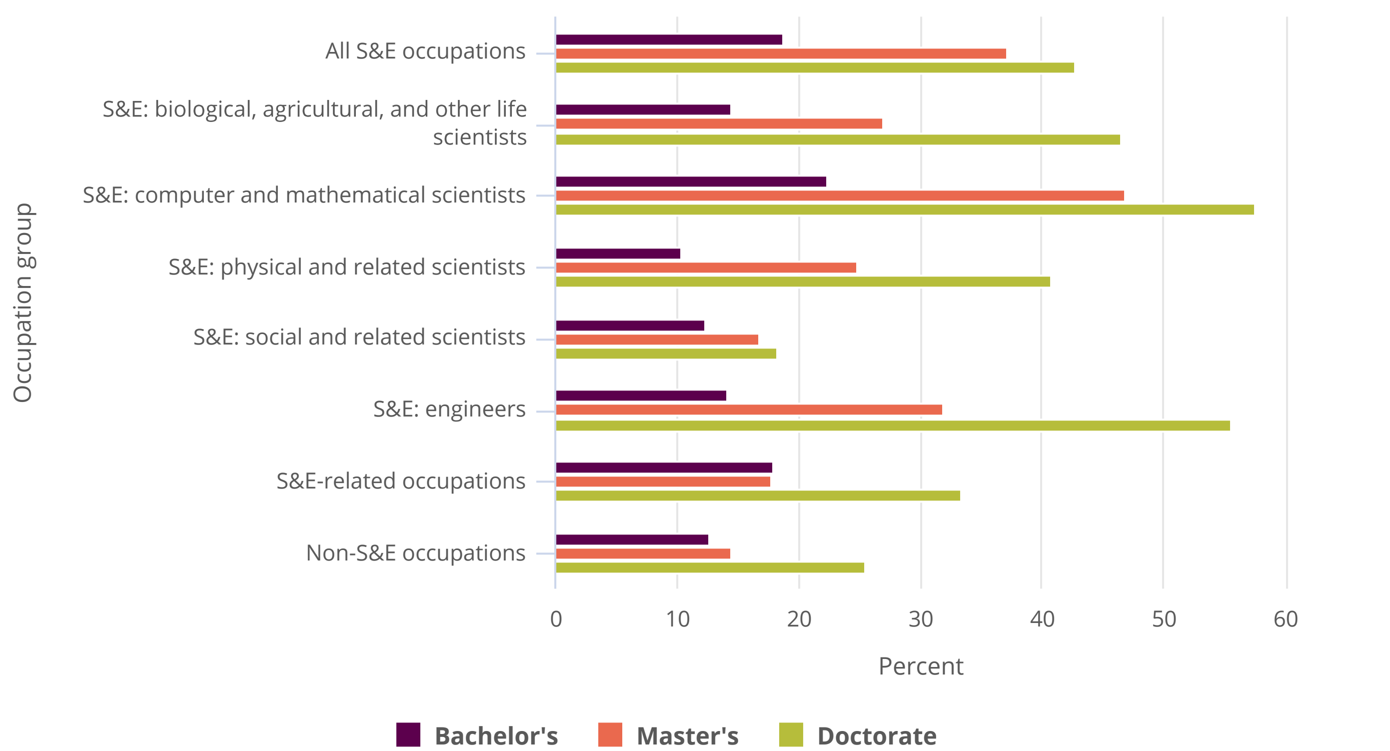
Occupation group	White	Hispanic or Latino	Black or African American	Asian	American Indian or Alaska Native	Some other race or more than one race
All workers	59.8	18.2	11.0	6.3	0.4	4.3
STEM	62.9	14.8	8.2	9.5	0.3	4.3
S&E	60.9	9.5	6.8	18.0	0.2	4.6
S&E-related	65.3	10.6	9.6	9.9	0.3	4.3
Middle-skill	62.0	22.5	7.7	3.4	0.5	4.0
Non-STEM	58.8	19.3	11.9	5.2	0.4	4.4

Note(s): STEM is science, technology, engineering, and mathematics. Hispanic or Latino may be any race; race categories exclude Hispanic origin.

Source(s): Census Bureau, ACS, 2021. *Indicators 2024: Labor Force*

In 2021, foreign-born workers (regardless of citizenship status) accounted for 19% of the STEM workforce. Foreign-born workers accounted for 19% of workers in S&E occupations at the bachelor's degree level, 37% at the master's degree level, and 43% at the doctorate level (Figure 9). More than half of doctorate-level computer and mathematical scientists and engineers—occupations associated with critical and emerging technologies by the National Science Board (NSB 2022)—working in the United States were born outside the country. Including workers of all education levels, India and China were the leading birthplaces of foreign-born S&E workers in the United States, accounting for 29% and 12%, respectively, of all foreign-born S&E workers.

Figure 9. Foreign-born share of workers with a bachelor's degree or higher, by highest degree level and occupation group: 2021



Source(s): NCSES, NSCG, 2021. *Indicators 2024: Labor Force*

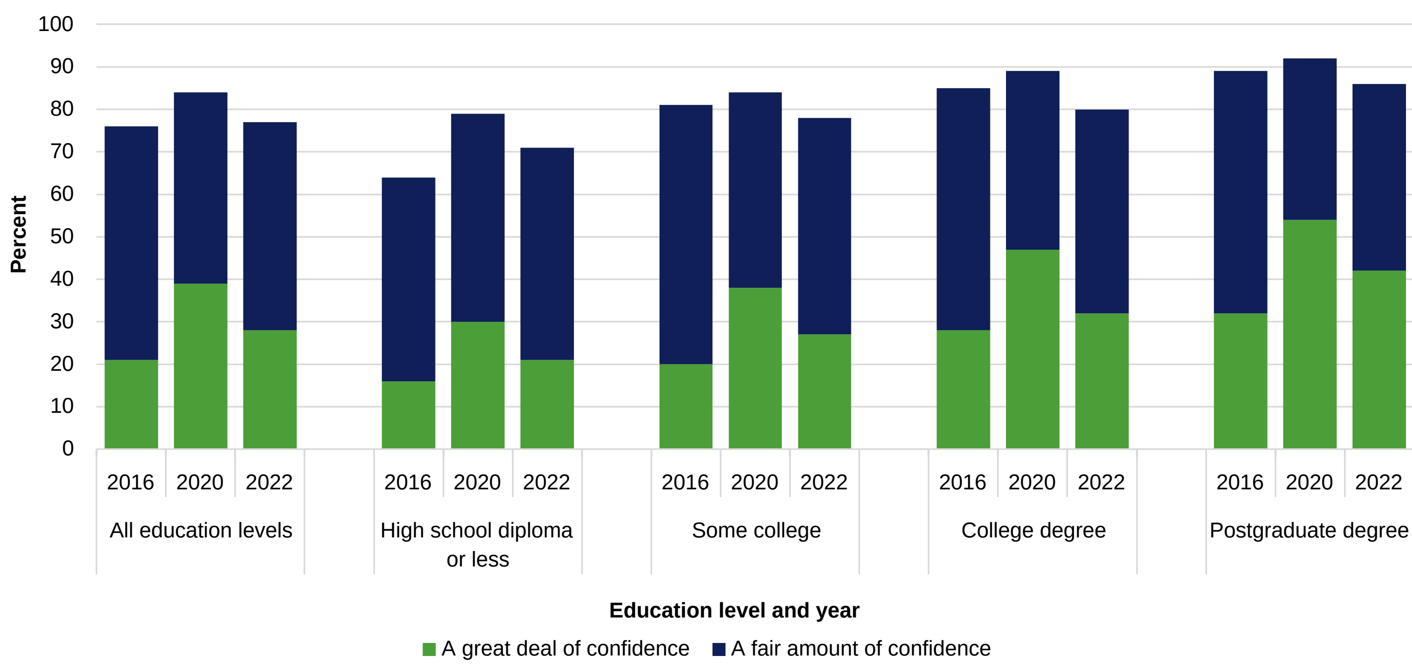
U.S.-trained S&E doctorate recipients who were on temporary visas at the time of graduation are a vital source of STEM workers for the U.S. economy. From 2018 to 2021, temporary visa holders—most commonly from China or India—accounted for 37% of U.S. S&E research doctorate recipients, and over 70% of these S&E doctorate recipients stated that they intend to live in the United States in the year after graduation. NCSES surveys of S&E doctorate recipients 5 years and 10 years after receiving their doctorates show that a majority of those who were on temporary visas at the time of graduation remained in the United States for significant amounts of time. When S&E doctorate recipients were surveyed in 2021 across all countries of citizenship and degree fields, the 5-year stay rate for those who were on temporary visas at graduation was 71% and the 10-year stay rate was 65%.

Stay rates varied by doctoral field of degree as well as by country of citizenship at degree award. The 10-year stay rate for engineering, the most common S&E doctoral field of temporary visa holders, was 72%. In contrast, the 10-year stay rate for degree holders in social sciences, a less common doctoral field for temporary visa holders, was 41%, the only field with a 10-year stay rate below 50%. S&E doctorate recipients with Chinese citizenship at graduation had higher than average 5-year and 10-year stay rates (88% and 81%, respectively).

Americans' Perceptions about Scientists

Americans' degree of trust in scientists has remained high for decades, although it varies by level of education and has fluctuated in recent years.[13] In 2022, 77% of adults in the United States expressed either "a great deal" or "a fair amount" of confidence in scientists to act in the best interests of the public (Figure 10).[14] Looking at just the response of "a great deal," 21% of adults overall indicated this level of confidence in 2016; this share increased to 39% in 2020 (after the onset of the COVID-19 pandemic) but then decreased to 28% in 2022.

Figure 10. Respondents expressing confidence in scientists to act in the best interests of the public, by education level: 2016, 2020, and 2022



Note(s): Data collected in May–June 2016, November 2020, and September 2022. Percentages do not add to 100% because not all responses are shown.

Source(s): Pew Research Center, American Trends Panel (2016, 2020, 2022). *Indicators 2024: Public Perceptions*

Adults with higher levels of education typically express the greatest degree of trust in scientists, and those with the lowest level of education express the least trust. For example, in 2022, 42% of adults with postgraduate degrees expressed “a great deal” of confidence in scientists to act in the best interests of the public (**Figure 10**). This share was higher than the share of adults with a college degree (32%) and those with some college (27%) who expressed the same degree of confidence, and it was double the share of adults with a high school diploma or less (21%).[15]

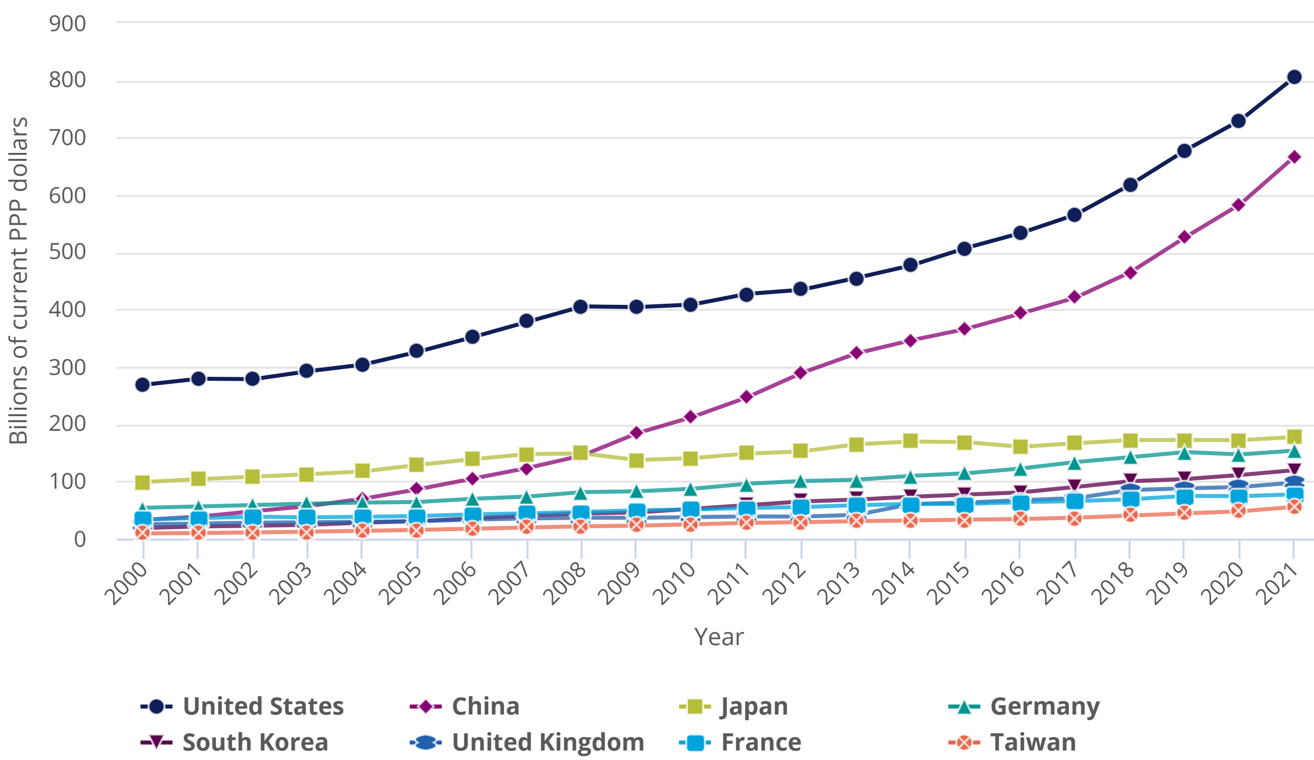
Discovery: U.S. and Global R&D

The global competitiveness of the United States in STI is driven not only by the country's development of a workforce equipped to perform technologically advanced activities but also by its investments in R&D. R&D—creative and systematic work undertaken to increase knowledge and devise new applications for knowledge—fosters scientific and technological breakthroughs and leads to the development of new and improved processes, services, and products. STI competitiveness encourages a strengthened market and workforce, prompting improvements to national living standards, economic sectors, and infrastructure.

Global R&D

The United States is the top performer of R&D, with $806 billion in gross domestic expenditures on R&D in 2021, according to statistics from the Organisation for Economic Co-operation and Development (OECD) (Figure 11).[16] The other top R&D-performing economies are located in East and Southeast Asia and in Europe. China, the second-highest R&D performer, had $668 billion in R&D expenditures in 2021. The United States and China each have much greater R&D expenditures than the remaining top R&D performers, which include Japan ($177 billion), Germany ($154 billion), and South Korea ($120 billion).

Figure 11. Gross domestic expenditures on R&D, by selected country or economy: 2000–21



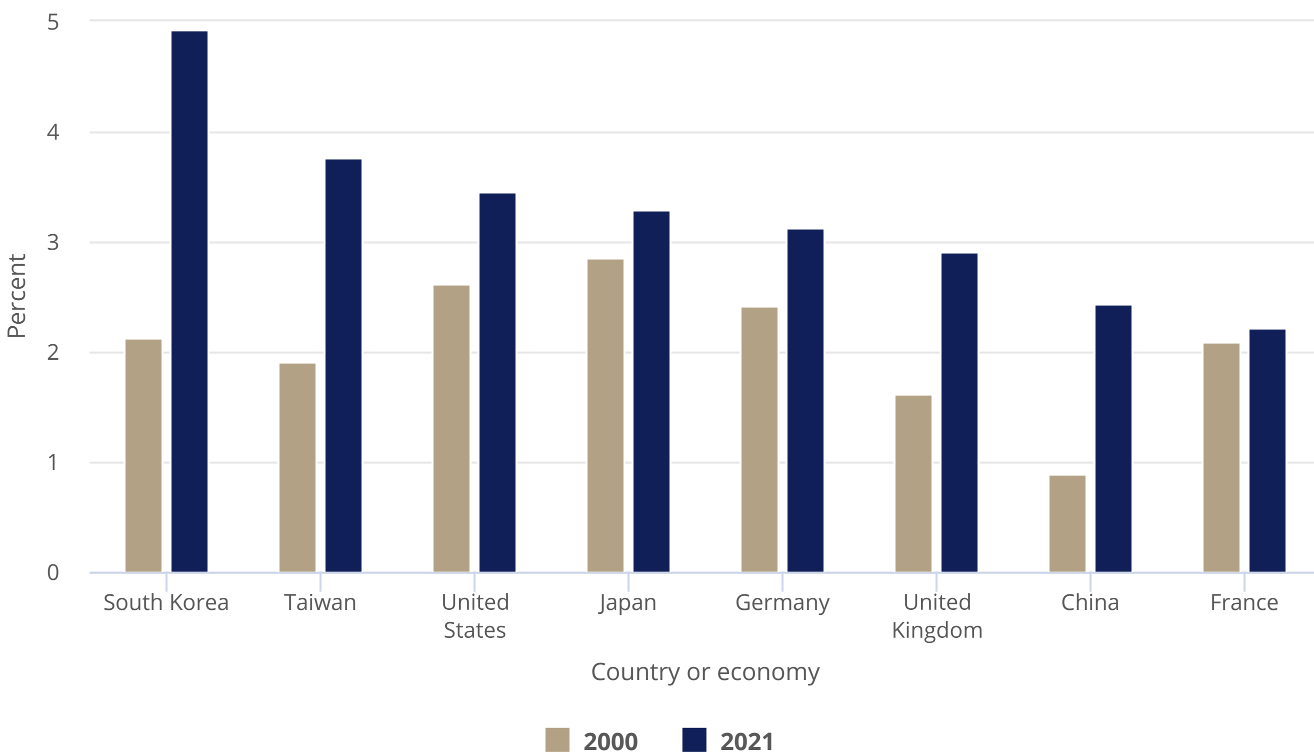
Note(s): PPP is purchasing power parity. Data are for the top eight R&D-performing countries or economies.

Source(s): OECD, MSTI, September 2023 release. *Indicators 2024: R&D*

In recent years, growth in R&D expenditures has varied considerably among the top R&D performers. According to OECD statistics, gross domestic expenditures on R&D began increasing rapidly in the mid-2000s in China, which surpassed Japan in 2009 and the combined R&D expenditures of the European Union (EU-27) countries in 2013 (see Glossary section for definition of EU-27). From 2011 to 2021, U.S. R&D expenditures increased by 89%, greater growth than France (44%) and Germany (60%) but less growth than South Korea and Taiwan, which both doubled R&D expenditures. Japan experienced the slowest rate of growth among the top R&D-performing countries, with R&D expenditures increasing by 20% from 2011 to 2021.

The major R&D-performing countries vary in their R&D-to-gross domestic product (GDP) ratios, known as *R&D intensities* (see Glossary section for definition). The United States, which has the highest level of R&D expenditures, had an R&D intensity of 3.5% in 2021 (Figure 12). However, several smaller economies with lower total R&D expenditures than the United States have higher R&D intensities, such as South Korea (4.9%) and Taiwan (3.8%). Although R&D intensities of all the major R&D performers increased from 2000 to 2021, they increased to different extents over this period. The United States increased R&D intensity from 2.6% in 2000 to 3.5% in 2021, surpassing Japan, which exhibited comparatively slower growth in R&D intensity. In 2000, South Korea and Taiwan both had lower R&D intensities than the United States. However, after experiencing the greatest percentage point increases in R&D intensity among the top R&D performers, South Korea and Taiwan had the highest R&D intensities by 2021.

Figure 12. R&D intensity, by selected country or economy: 2000 and 2021



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

Source(s): OECD, MSTI, September 2023 release. *Indicators 2024: R&D*

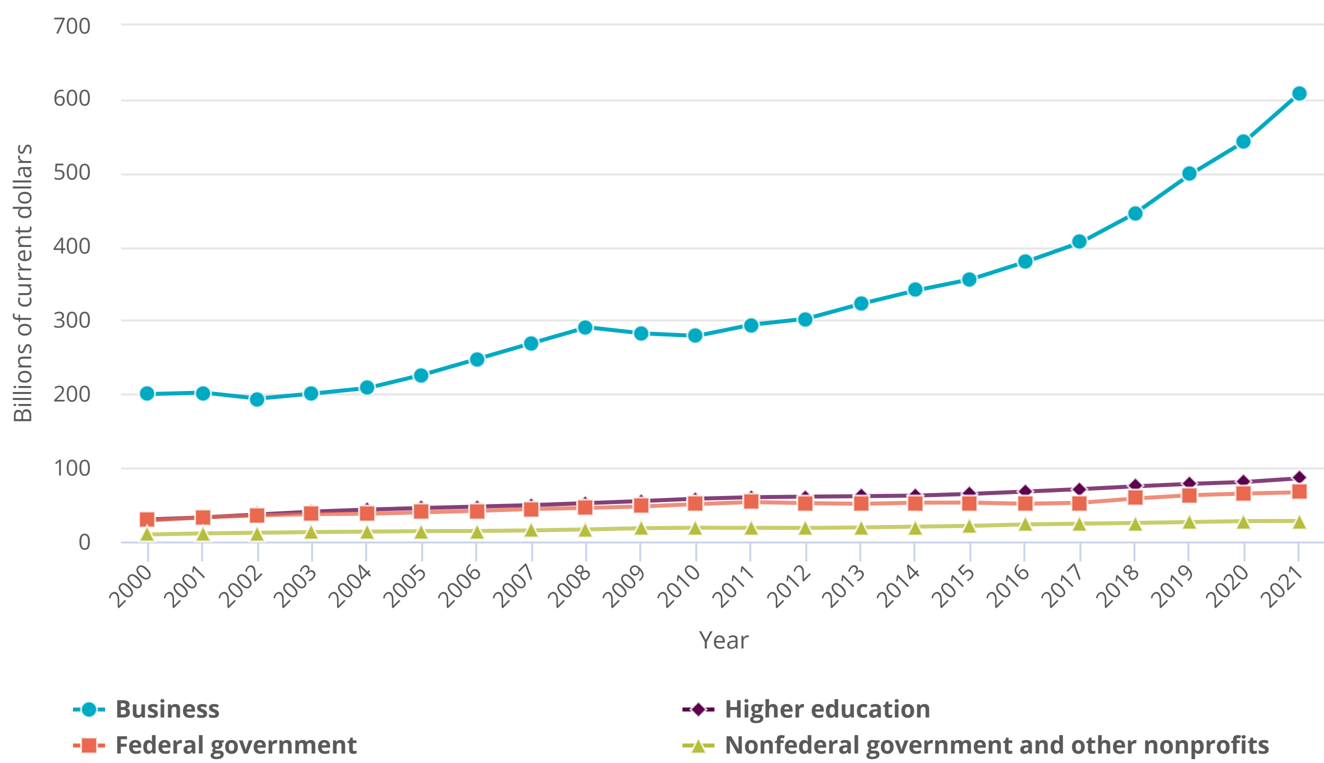
Countries allocate different shares of their R&D expenditures across three types of R&D: basic research, applied research, and experimental development (see Glossary section for definitions). In 2021, the United States spent 15% ($119 billion) of its total R&D expenditures on basic research, 18% ($146 billion) on applied research, and 67% ($540 billion) on experimental development. South Korea and Japan were similar to the United States in their distributions of R&D expenditures across the three types of R&D. Compared with the United States, Taiwan dedicated a lower share of its R&D expenditures to basic research (7%), and France dedicated a higher share (23%); however, in absolute terms, the United States spent far more on basic research than any other economy.

The business sector is the largest funder of R&D in the top R&D-performing countries, with lower shares funded by government, higher education, and private nonprofit institutions. In each of the leading R&D performers in East and Southeast Asia—China, Japan, South Korea, and Taiwan—the domestic business sector accounted for at least 75% of R&D funding in 2021. The domestic business share of R&D funding is lower but still a substantial majority in the United States (68%); among the top R&D performers in Europe (Germany, United Kingdom, France), the business share of R&D funding is closer to 60%.

U.S. R&D 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 nonacademic, nonprofit organizations—also perform and fund domestic R&D.[17] R&D performed in the United States totaled $717 billion in 2020 and, according to preliminary data, $789 billion in 2021.[18] The business sector was the main driver of R&D performance. R&D performed by businesses accounted for 87% of increased R&D from 2011 to 2021 (Figure 13).[19]

Figure 13. U.S. R&D expenditures, by performing sector: 2000–21

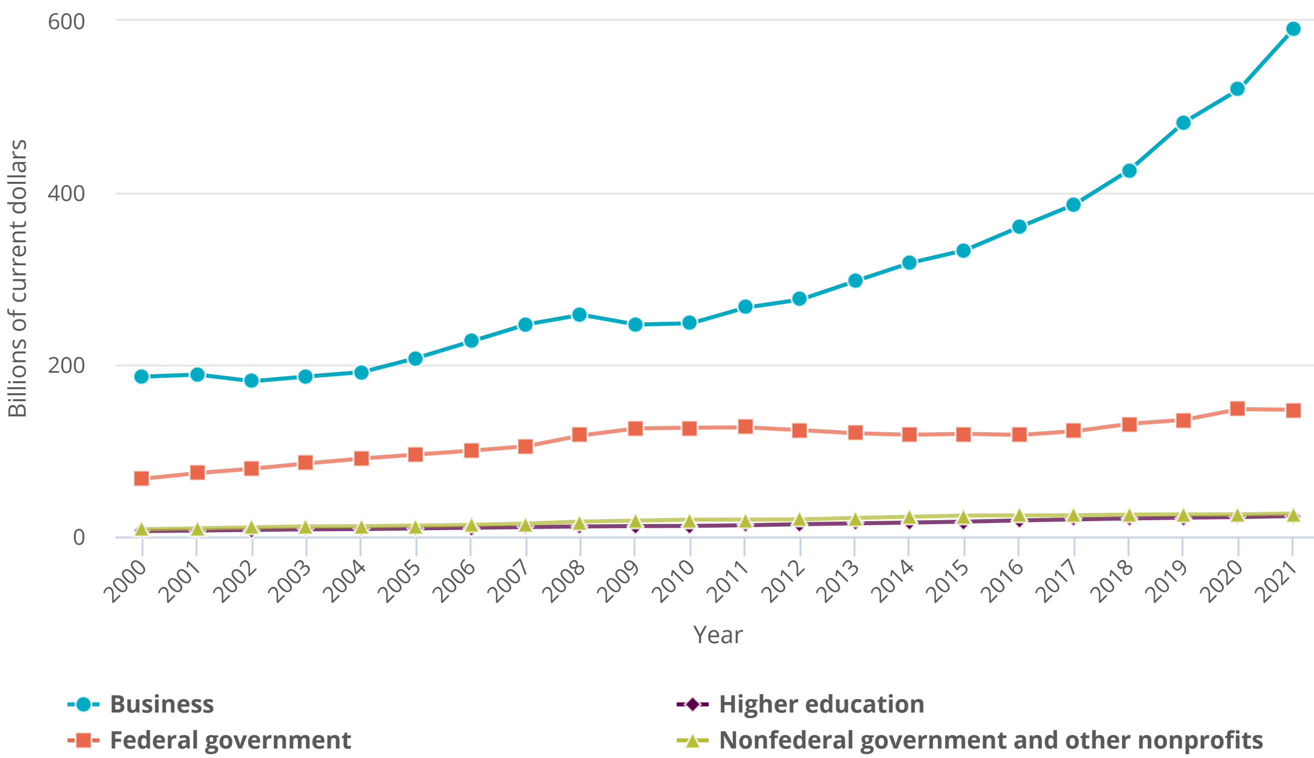


Note(s): Some data for 2021 are preliminary and may be revised later.

Source(s): NCSES, National Patterns of R&D Resources (2021–22 edition). *Indicators 2024: R&D*

The business sector funds (or pays for) most of the R&D performed in the United States, accounting for 75% of U.S. R&D funding in 2021, followed by the federal government, which funded 19% of R&D (Figure 14).[20] Nearly all (99%) of the business sector's R&D funding supports R&D performance within the business sector. In contrast, the federal government supports R&D performed by all sectors. In 2021, the federal government funded 52% of the R&D performed by the higher education sector, 43% by nonprofits, and 4% by businesses. Because a substantial share of federal R&D funding is directed toward R&D performed by other sectors, especially academic institutions, the federal government *performs* less R&D than the higher education sector but *funds* over six times more R&D than the higher education sector.

Figure 14. U.S. R&D expenditures, by source of funds: 2000–21

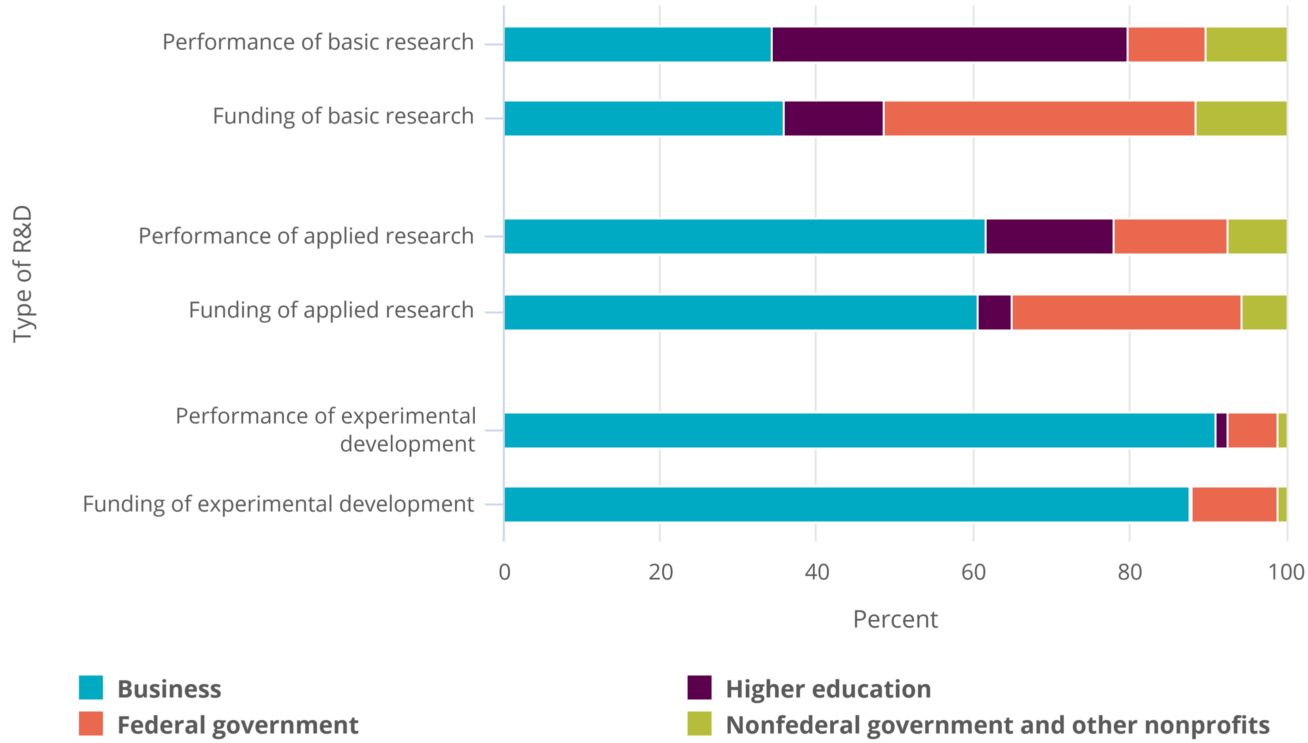


Note(s): Some data for 2021 are preliminary and may be revised later.

Source(s): NCSES, National Patterns of R&D Resources (2021–22 edition). *Indicators 2024: R&D*

The majority of U.S. R&D performance is in experimental development (67%) and applied research (18%), and the business sector is the most active in both of these types of R&D. With its focus on new and improved goods, services, and processes, the business sector performs 91% of experimental development and 62% of applied research performed in the United States (Figure 15). Several industries—chemicals manufacturing (including pharmaceuticals and medicine); computer and electronic products; transportation equipment; professional, scientific, and technical services; and information services—account for the vast majority of R&D performed by the business sector. The higher education sector is the largest performer of basic research (46%), and the federal government performs low shares of all types of R&D.

Figure 15. U.S. R&D performance and funding, by type of R&D and sector: 2021



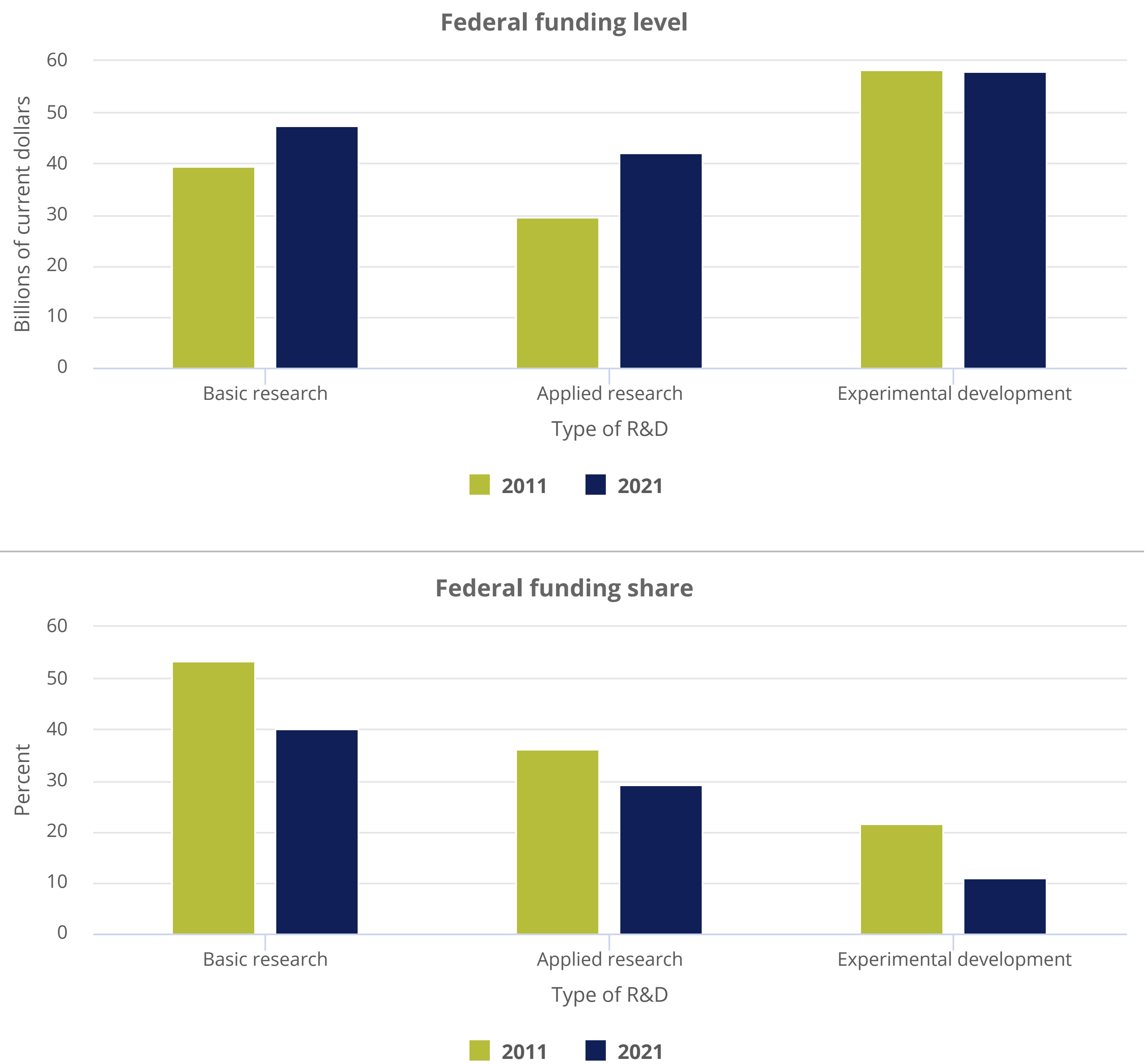
Note(s): Some data for 2021 are preliminary and may be revised later.

Source(s): NCSES, National Patterns of R&D Resources (2021–22 edition). *Indicators 2024: R&D*

Federal funding of R&D increased from $127 billion in 2011 to $148 billion in 2021, but the share of total R&D funded by the federal government declined from 30% to 19%. This decline in the federal share of R&D funding occurred across all types of R&D (Figure 16). The federal government funded a majority of basic research performed in the United States from the early 1950s to the early 2010s. Although it is still the largest funder of basic research (40% in 2021), the federal government's share of basic research funding is now only slightly higher than the share funded by the business sector, which increased from 20% in 2011 to 36% in 2021.

Higher education institutions, which are the most significant performers of basic research, rely heavily on federal support for R&D. Federal funding of R&D performed by the higher education sector increased in dollar amount from 2011 to 2021—from $35.7 billion to $44.7 billion—but the proportion of higher education R&D funded by the federal government declined from 59% to 52% over the same period. In contrast, the proportion of higher education R&D funded by higher education institutions themselves increased from 22% to 27%. The remainder of R&D performed by the higher education sector in 2021 was funded by nonprofit organizations (9%), businesses (6%), and nonfederal governments (5%).

Figure 16. U.S. R&D performance funded by the federal government of each type of R&D: 2011 and 2021



Note(s): Some data for 2021 are preliminary and may be revised later.

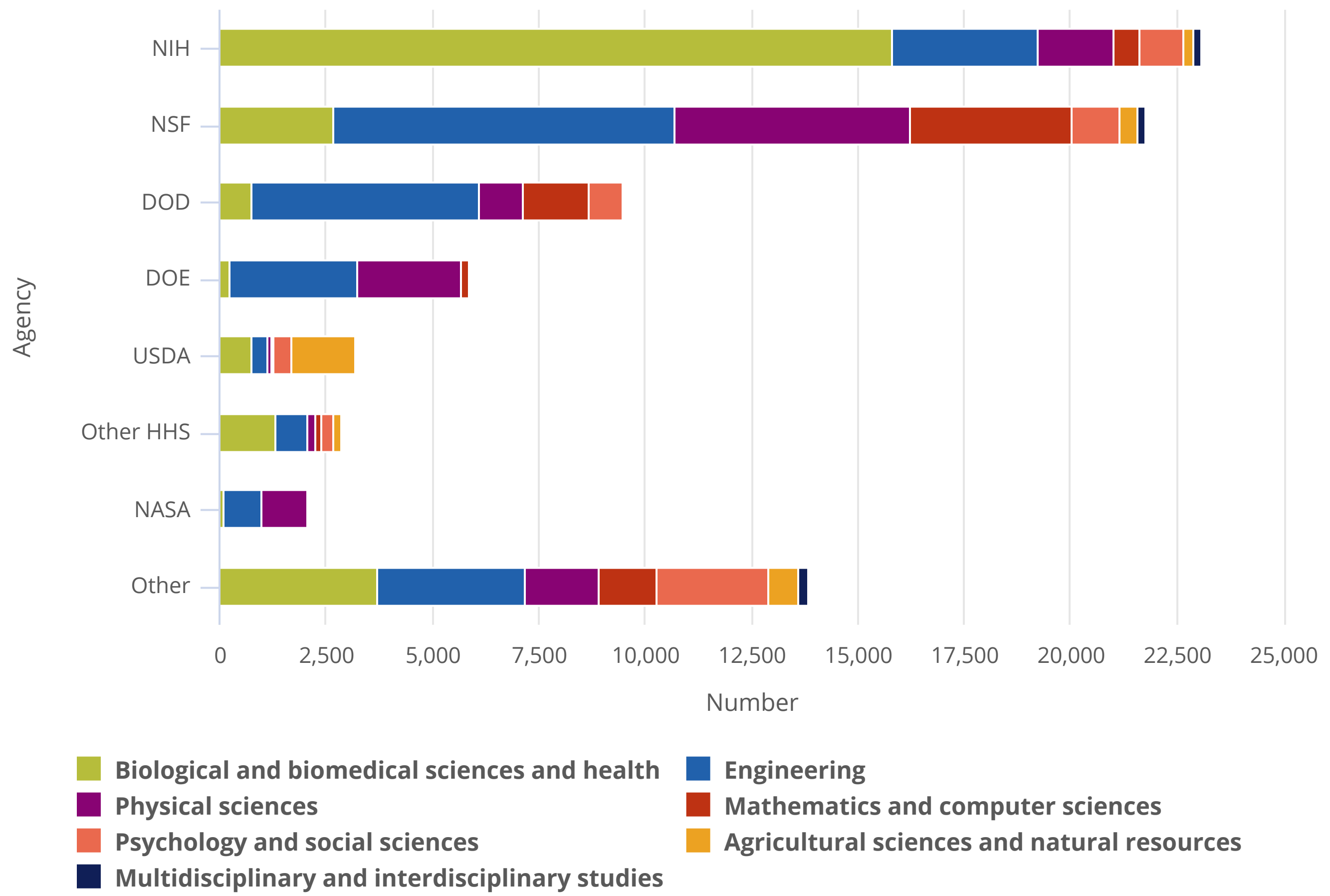
Source(s): NCSES, National Patterns of R&D Resources (2021–22 edition). *Indicators 2024: R&D*

Federal Agency Funding of R&D and S&E Graduate Students

In 2021, a large majority of the federal government's R&D budget was obligated to the Department of Health and Human Services (HHS) (40%), the parent agency of the National Institutes of Health (NIH), and to the Department of Defense (DOD) (37%).[21] Most of the remaining federal R&D budget was allocated to the Department of Energy (DOE) (7%), the National Aeronautics and Space Administration (NASA) (6%), and the National Science Foundation (NSF) (4%). DOD directs the bulk of its R&D budget toward experimental development (86% in 2021). In comparison, DOE and NASA are more evenly distributed between basic research, applied research, and experimental development. Supplemental COVID-19 pandemic-related stimulus funding has vastly increased the share of HHS R&D obligations directed toward experimental development (44%), which accounted for very little of total HHS R&D in the years prior to the pandemic. NSF focuses on basic research, which accounted for 86% of its R&D obligations in 2021.

The federal government supported 15% of full-time S&E graduate students (mostly doctoral degree students) in 2021, a decline from the most recent high of 21% in 2004.[22] The federal government supports a higher proportion of S&E doctoral degree students than S&E master's degree students (26% versus 5%), consistent across all fields of S&E. Among federal agencies, NIH and NSF support the greatest number of S&E graduate students (Figure 17). In 2021, NIH supported about 23,000 students and NSF supported almost 22,000 students, collectively 54% of the almost 83,000 federally supported graduate students. NSF supports substantial numbers of students across a range of S&E fields, whereas other agencies are more specialized in their financial support. In 2021, 68% of full-time S&E graduate students supported by NIH were studying biological and biomedical sciences and health, 56% of those funded by DOD were in engineering, and 91% of those funded by DOE were in engineering or physical sciences.[23]

Figure 17. Full-time graduate students in S&E primarily supported by the federal government, by degree field and agency: 2021



Note(s): DOD is Department of Defense. DOE is Department of Energy. HHS is Department of Health and Human Services, excluding NIH. NASA is National Aeronautics and Space Administration. NIH is National Institutes of Health. NSF is National Science Foundation. USDA is Department of Agriculture. S&E includes health fields. Physical sciences includes geosciences, atmospheric sciences, and ocean sciences. Agricultural sciences includes veterinary sciences; natural resources includes conservation. Mathematics includes statistics; computer sciences includes information sciences.

Source(s): NCSES, GSS, 2021. *Indicators 2024: Academic R&D*

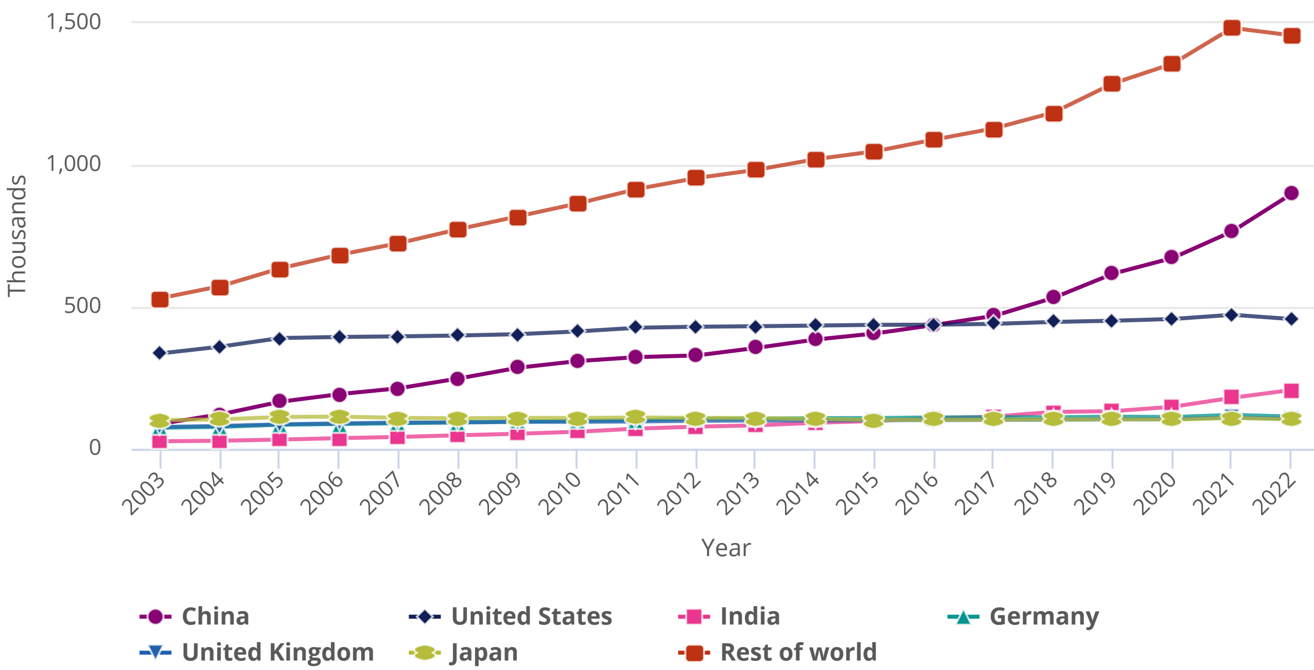
Translation: U.S. and Global Science, Technology, and Innovation Capabilities

Investment in R&D and in a workforce equipped to perform technologically advanced activities enables scientific discovery, which supports the development of STI capabilities, including capabilities in critical and emerging technologies (see sidebar **Critical and Emerging Technologies**). In turn, STI capabilities result in scientific publications, patent activity, and knowledge- and technology-intensive (KTI) industry output. The United States is the world leader with respect to many STI capabilities and outputs—especially KTI services—although overall invention and innovation output continues a long-term shift toward other regions of the globe, including China and India.

Research Publications

Publication of research in peer-reviewed literature is an important mechanism for disseminating new S&E knowledge, which supports the development of innovations and the vitality of KTI industries.[24] Globally, six countries combined produced more than 50% of the worldwide peer-reviewed S&E publications in 2022: China (27%), the United States (14%), India (6%), Germany (3%), the United Kingdom (3%), and Japan (3%) (Figure 18). The United States was the top producer of S&E articles until 2016, after which China has been the leading producer. From 2003 to 2022, annual S&E publications increased by roughly a third (36%) in the United States, whereas they increased approximately 10-fold in China and 8-fold in India. Japan, the second-highest producer of S&E articles in 2003, experienced little change in publications output, falling to the sixth spot by 2020.

Figure 18. S&E articles, by selected region, country, or economy: 2003–22



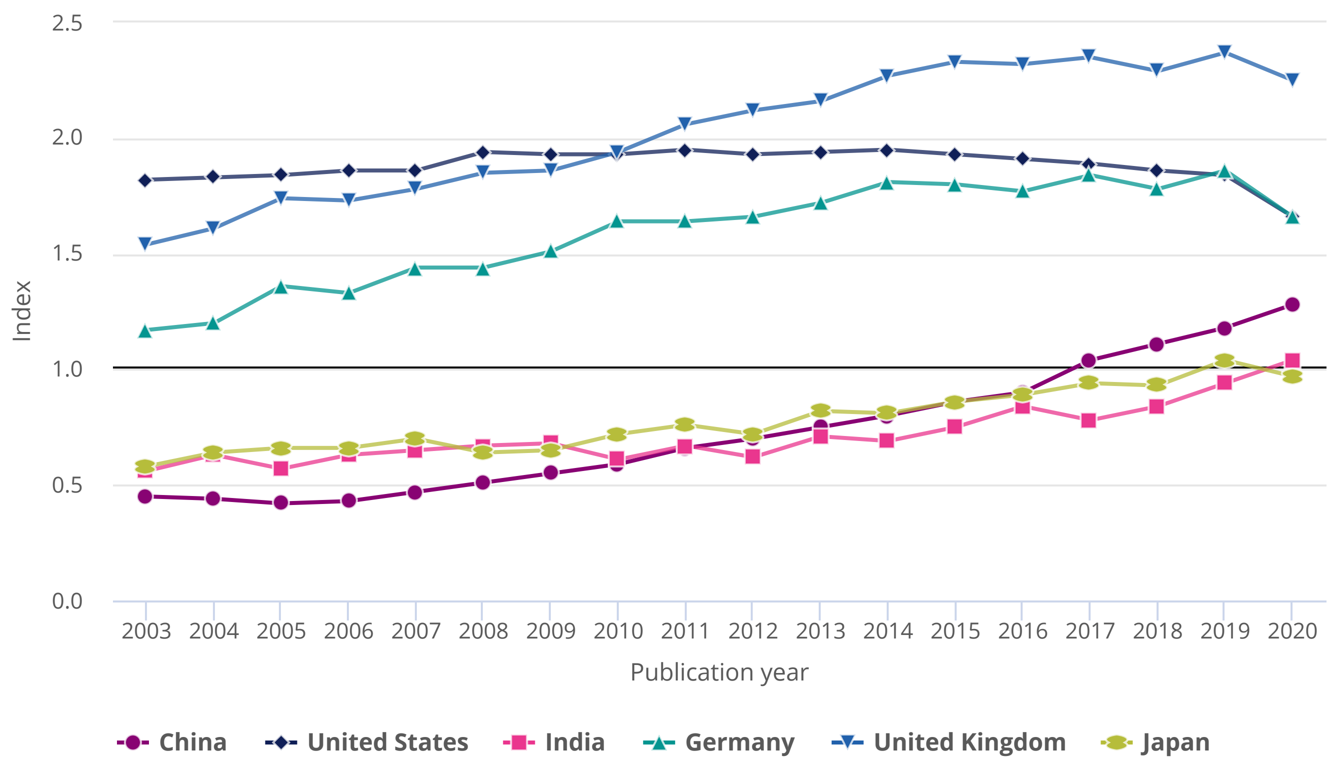
Note(s): Articles are fractionally counted and classified by publication year and assigned to a region, country, or economy by author's institutional address.

Source(s): NCSES, special tabulations (2023) by Science-Metrix of Elsevier's Scopus abstract and citation database. *Indicators 2024: Publications Output*

The distribution of publications by field and by region, country, or economy is one indicator of research priorities and capabilities. In the United States, the United Kingdom, Germany, and Japan, the largest proportion of journal articles published in 2022 was in the field of health sciences. In China, the largest proportion was in engineering. In India, the largest proportion was in computer and information sciences.

S&E publications authored by researchers in the United States are highly impactful, as measured by the level of citations they receive. From 2003 to 2019, the highly cited article (HCA) index for the United States was stable at between 1.8 and 1.9, although it declined to 1.7 in 2020 (Figure 19) (see Glossary section for definition of HCA). Because the baseline value for this index is 1.0, this means that the United States contributed nearly twice as many HCAs relative to its share of total publications. As of 2020, Germany had an HCA score similar to the United States (1.7), and the United Kingdom had the highest HCA score (2.2) out of the top producers of S&E articles. China and India have increased their HCA scores simultaneously with their volume of scientific publishing, which indicates that their publication growth has been especially high among HCAs. China's HCA score increased from well below baseline in 2003 (0.5) to 1.3 in 2020.

Figure 19. Highly cited article index, by selected country: 2003–20

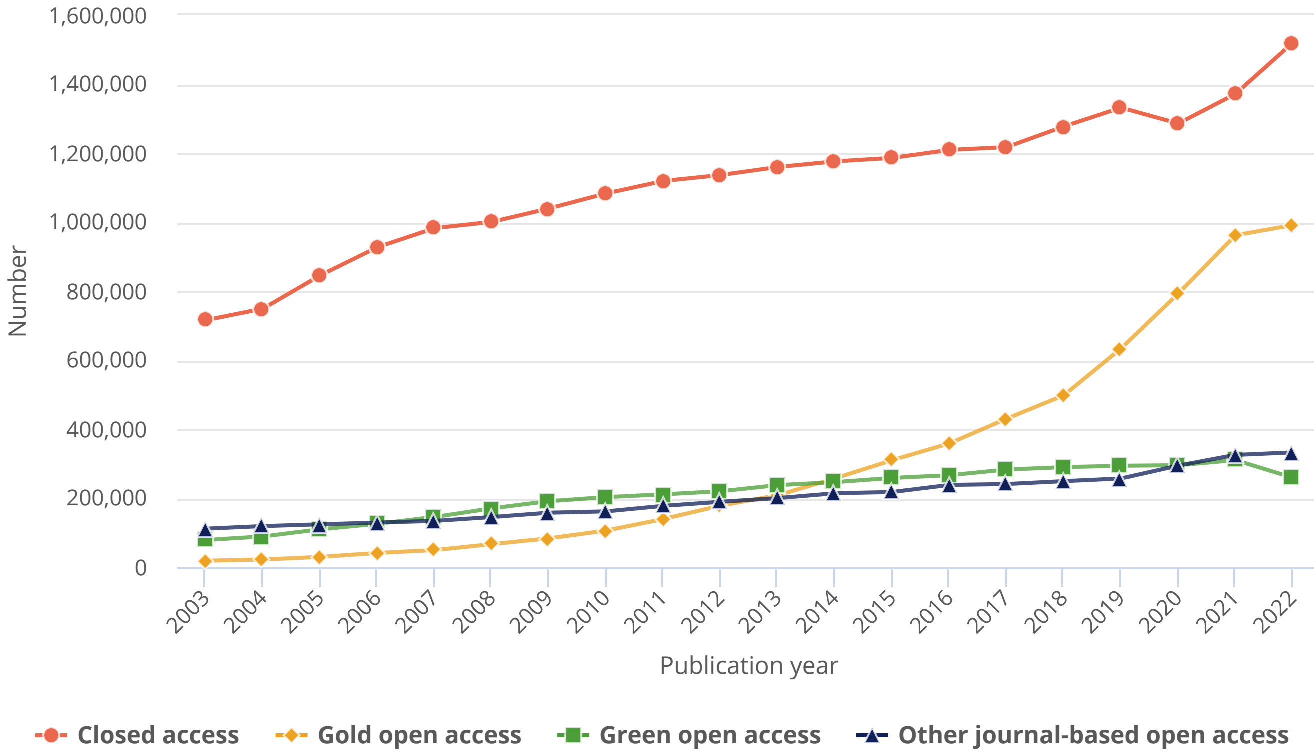


Note(s): The highly cited article index is a country's share of the top 1% most-cited S&E publications divided by the country's share of all S&E publications. The index is calculated on whole counts of publications.

Source(s): NCSES, special tabulations (2023) by Science-Metrix of Elsevier's Scopus abstract and citation database. *Indicators 2024: Publications Output*

Open-access (OA) publications provide free access to peer-reviewed scientific literature without requiring user fees or journal subscriptions. Scientists, institutions, and funders have offered support for increased publication in OA venues through both open encouragement and requirements that funded research outputs be freely available (Brainard and Kaiser 2022). Between 2003 and 2022, the number of S&E articles published through each type of OA journal experienced far greater percentage-based growth than articles published in traditional closed-access journals (see Glossary section for definitions of four commonly used OA publication types) (Figure 20). Gold OA articles (which are articles published in fully OA journals as a matter of journal policy) increased over 50-fold, from 19,000 articles published in 2003 to 992,000 articles in 2022. As a result of this rapid growth, Gold OA articles expanded from 2% of all S&E articles in 2003 to 32% in 2022.

Figure 20. S&E articles, by publication access type: 2003–22



Note(s): OA is open access. Articles refer to publications from a selection of conference proceedings and peer-reviewed journals in S&E fields from Scopus. Open-access types are mutually exclusive. Gold OA denotes articles published in journals that are entirely OA as a matter of journal policy. Green OA denotes articles that are self-archived by authors in OA repositories.

Source(s): NCSES, special tabulations (2023) by Science-Metrix of Elsevier's Scopus abstract and citation database. *Indicators 2024: Publications Output*

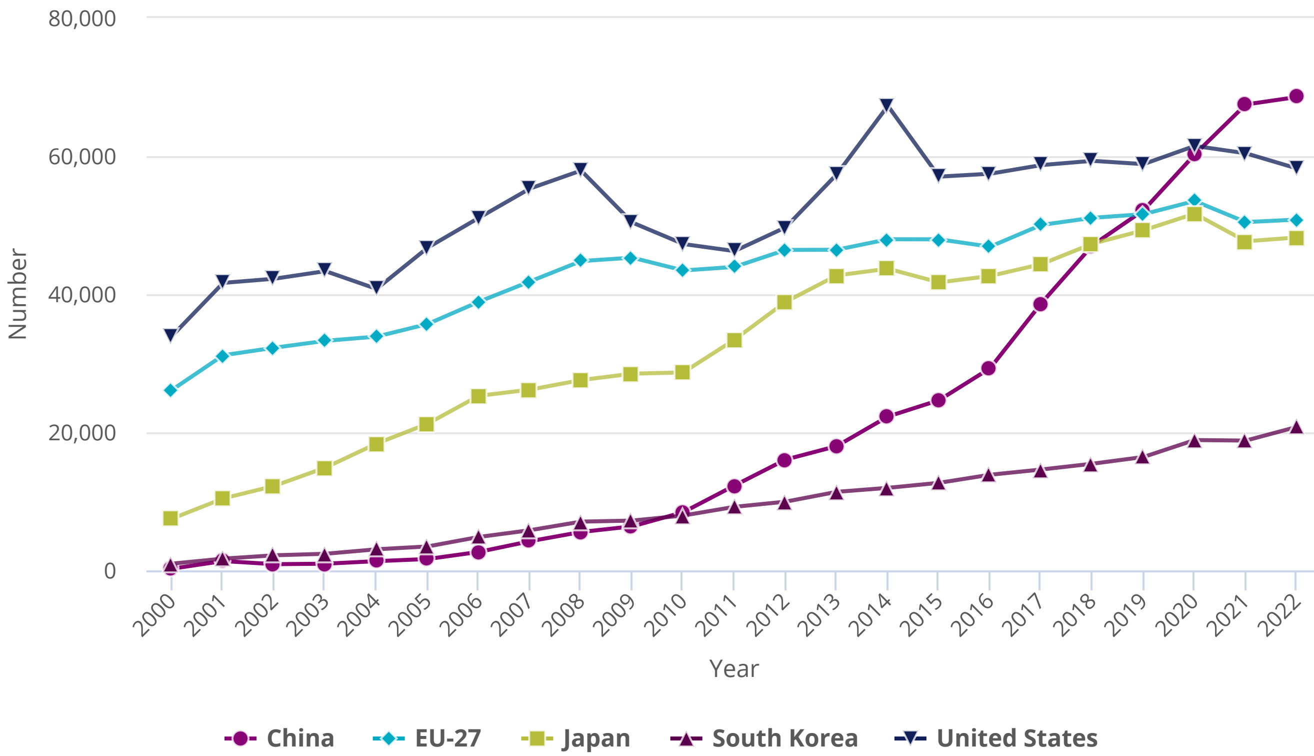
Whereas most (77%) S&E articles in 2003 were published in closed-access journals, just under half (49%) were published in closed-access journals in 2022. This expansion of OA publishing may represent a shift toward both a more open paradigm for the dissemination of research and a change in the structure of academic publishing, as many types of OA articles often require article processing fees from authors rather than fees from readers.

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).[25] Patents are one way that governments support invention by providing legal mechanisms for intellectual property protection. Patent documents provide detailed information that is widely used to understand invention activity.

International patent applications filed under the Patent Cooperation Treaty (see Glossary section for definition of Patent Cooperation Treaty application) represent inventors' interests in protecting their ideas internationally. Global patenting activity is at the highest levels in China (69,000 international patent applications in 2022), the United States (58,000), the EU-27 (51,000), and Japan (48,000) (Figure 21). The number of international patent applications from inventors based in China increased rapidly in the 2010s, resulting in a significant shift in the balance of patenting worldwide. Although the United States had more than twice as many international patent applications as China in 2015, the two countries had similar application numbers in 2020, with China surpassing the United States for the first time in 2021.

Figure 21. Patent Cooperation Treaty applications, by selected region, country, or economy: 2000–22



Note(s): EU-27 is European Union. Countries are allocated using the receiving office for each Patent Cooperation Treaty application, which is based on the location of the inventors.

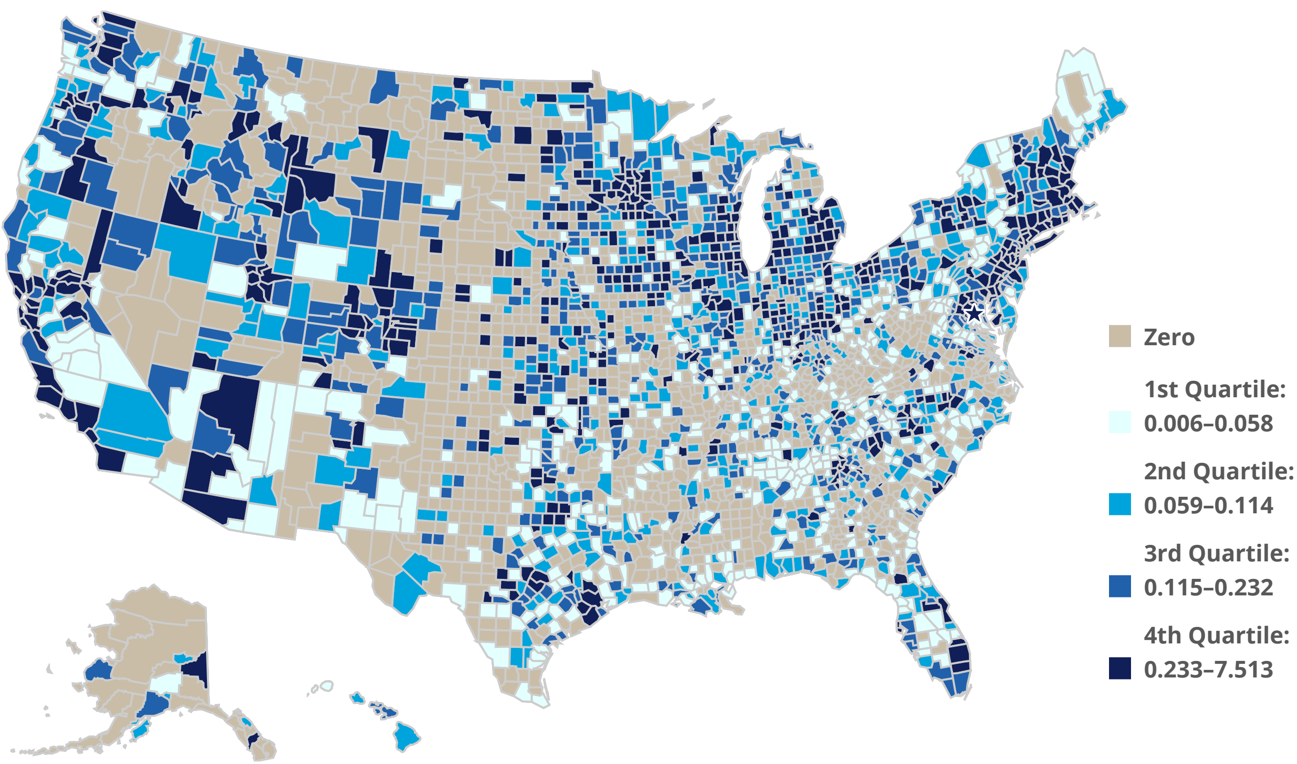
Source(s): NCSES, special tabulations (2023) by 1790 Analytics of European Patent Bibliographic Data (EBD). *Indicators 2024: Innovation*

Across all countries, the largest share of international patent applications in 2022 was in the technology category of electrical engineering (37%), followed by chemistry (22%), instruments (17%), and mechanical engineering (16%), with other fields accounting for the remaining 7%. Patent applications in the field of electrical engineering—which includes semiconductors, computer technology, and digital communication—experienced the fastest growth, increasing more than fivefold from 19,000 in 2000 to 98,000 in 2022. Inventors from the United States were responsible for the largest share of international patent applications in chemistry and in instruments, accounting for 27% of the world total in each field in 2022. Patent applications from China were more focused in electrical engineering, where China-based inventors accounted for 37% of total international patent applications in this field. Inventors from the EU-27 accounted for the largest share (31%) of international patent applications in mechanical engineering.

Patents issued by the Patent and Trademark Office (USPTO) focus on inventions, both foreign and domestic, that are granted exclusive use rights in the U.S. market. Utility patents granted by the USPTO have increased both to domestic inventors and to inventors residing in other countries (see **Glossary** section for definitions of USPTO patents and utility patents).[26] Of the 325,000 USPTO utility patents granted in 2022, a total of 142,000 (44%) were granted to U.S. inventors. Foreign inventors' share of USPTO patents increased from 52% in 2012 to 56% in 2022, reflecting the long-term trend of increased internationalization of U.S. patents. Inventors from Japan (46,000) and the EU-27 (40,000) accounted for the largest shares of foreign USPTO patent grantees in 2022, although patents granted to inventors from China (28,000) have been increasing at a faster rate than either Japan or the EU-27.

Patenting activity is unevenly distributed across the United States and is highest in regions that also have strong concentrations of STEM workers and KTI industries. Patenting intensity is defined here as the number of utility patents granted to patent inventors in a county relative to its population. Counties with the highest patenting intensity are generally located in the Northeast, the West Coast, and in parts of the Great Lakes region, Texas, and the Rocky Mountains (Figure 22). In 2022, Santa Clara County in California's Silicon Valley region had the highest patenting intensity. Three of the country's top five counties in patenting intensity were in the San Jose-San Francisco-Oakland combined statistical area. Patents were granted to inventors in 64% of U.S. counties in 2022.

Figure 22. USPTO utility patents granted to inventors per 1,000 residents, by U.S. county: 2022

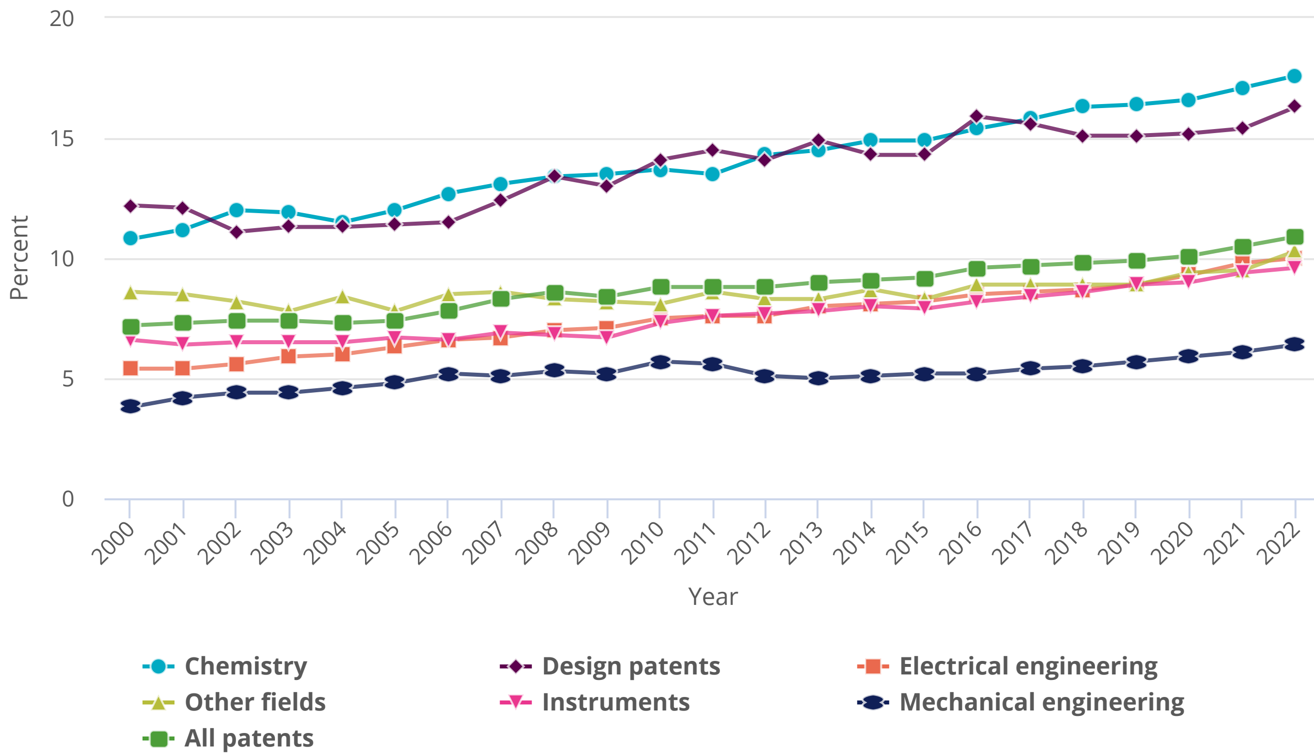


Note(s): USPTO is Patent and Trademark Office. USPTO patents are allocated according to the address for each inventor listed on a patent.

Source(s): NCSES; Science-Metrix; PatentsView, USPTO; Census Bureau, U.S. population data, 2022. *Indicators 2024: Innovation*

U.S. patenting rates are also uneven with respect to inventor demographic characteristics. Over the past two decades, the share of inventors who are women has increased, but women still account for a disproportionately low share of inventors (Figure 23).[27] In 2022, 11% of all USPTO patents were granted to inventors identified as women, an increase from 7% in 2000. Women accounted for comparatively higher shares of inventors on design patents (16%) and chemistry patents (18%) in 2022 and for lower shares on mechanical engineering patents (6%).

Figure 23. Inventors with female names on granted USPTO patents, by technology area and issue year: 2000–22



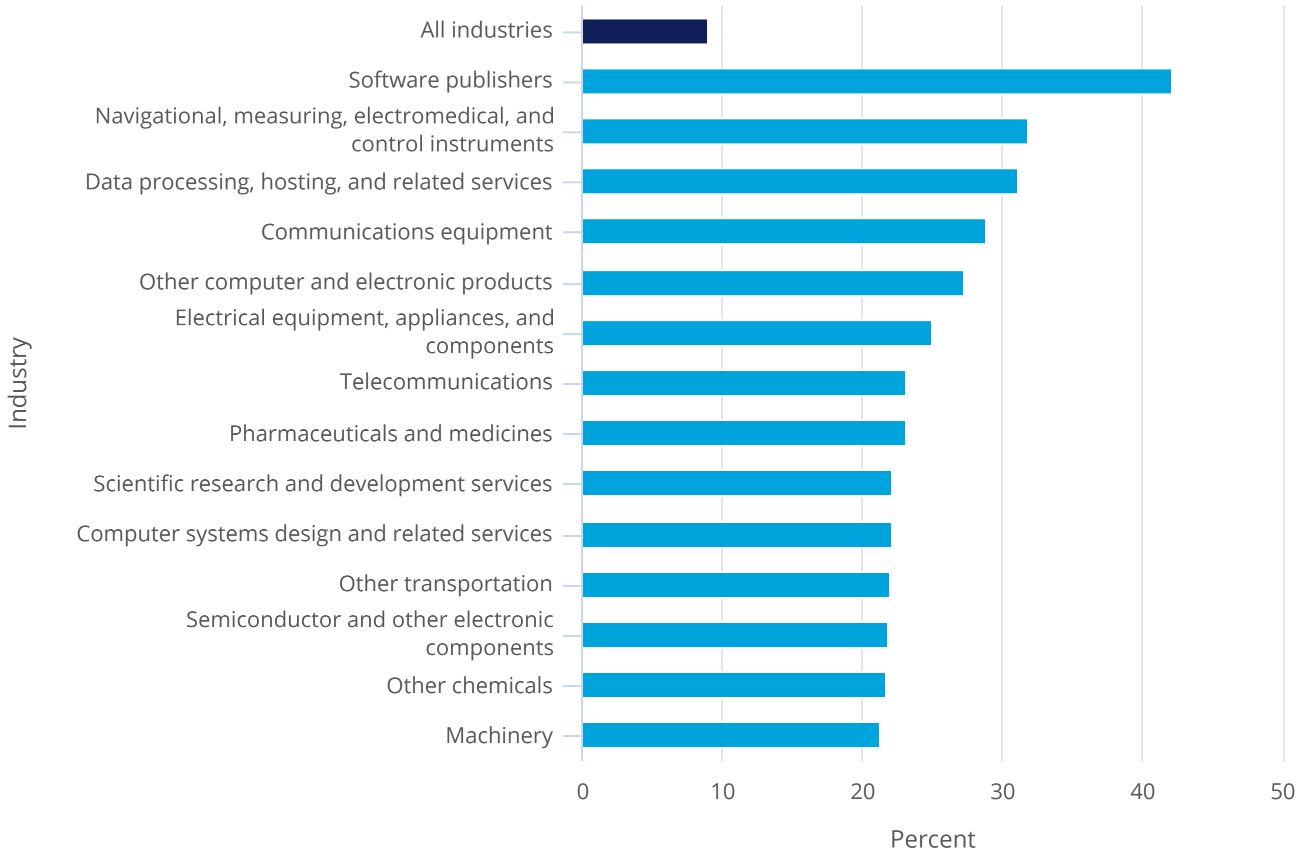
Note(s): USPTO is Patent and Trademark Office. The analysis of patenting by gender is based on patents granted by the USPTO. Fractional counting of inventors is used, with the credit for each patent divided equally between the inventors.

Source(s): NCSES, special tabulations (2023) by 1790 Analytics of USPTO Bulk Data Storage System. *Indicators 2024: Innovation*

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 2021, U.S. universities executed about 8,800 new technology licenses or options; 17% of these licenses and options were executed with startup companies, and 61% were executed with small companies (those with fewer than 500 employees). New university-associated startups increased from nearly 400 in 2000 to over 1,000 in 2021.

Invention is the creation of something new and useful, and innovation is its implementation. An average of 9% of U.S. businesses, including 42% of software publishers, introduced a new product during the 3-year period from 2018 to 2020 (Figure 24). Many of the industries with the highest innovation rates invest heavily in R&D, including computer and electronics manufacturing and information technology (IT)–intensive services.

Figure 24. U.S. companies reporting product innovation, by selected industry: 2018–20



Note(s): Industry classification is based on dominant establishment payroll. Statistics are representative of companies located in the United States. Product innovations may be goods or services. Values are the share of firms reporting a product innovation in the 3-year period from 2018 to 2020. Other computer and electronic products excludes communications equipment, semiconductors, and instruments. Other transportation excludes automobiles and aerospace. Other chemicals excludes agricultural chemicals, pharmaceuticals, and cleaning chemicals.

Source(s): NCSES, ABS, 2020. *Indicators 2024: Innovation*

Venture capital plays a substantial role in the innovation process through investment in startups with high growth potential and early stage firms. Total venture capital investment has increased over the past decade, although it declined by 28% in 2022 following a surge of investment in 2021. In 2022, firms in the United States received 46% ($248 billion) of global venture capital investment, firms in Europe received 20% ($107 billion), and those in China received 16% ($88 billion). Venture capital investment in the United States increased fivefold from 2013 to 2022, which was nonetheless slower than the global average rate of venture capital investment growth; as a result, the U.S. share of venture capital decreased from 66% in 2013 to 46% in 2022. Investment in China peaked at 39% of the world total in 2016—just slightly behind the United States that year—but has since declined substantially as a share of global venture capital investment.

SIDEBAR

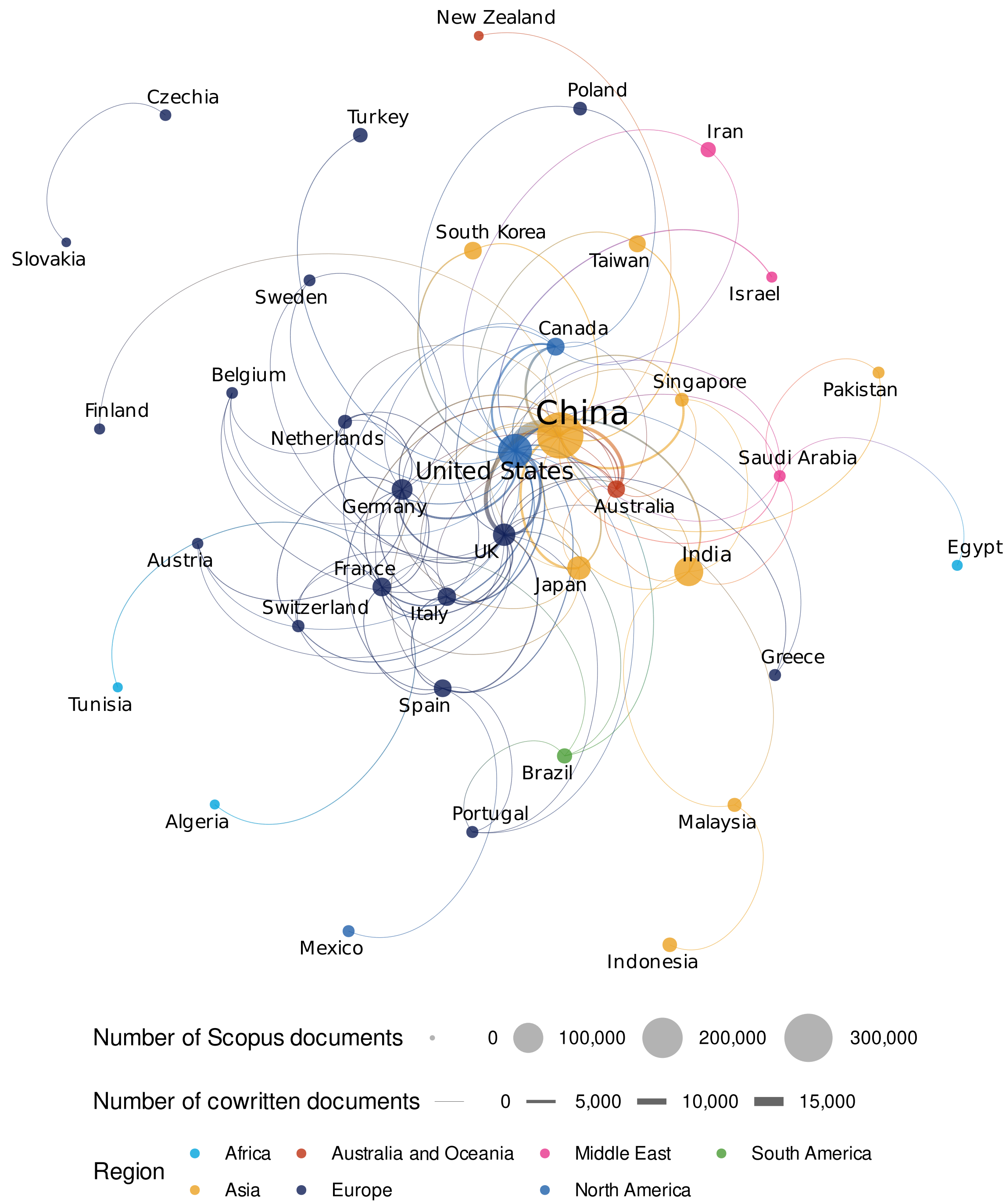
Critical and Emerging Technologies

The National Science and Technology Council (NSTC) has formulated a list of critical and emerging technologies, which it identifies as a "subset of advanced technologies that are potentially significant to U.S. national security" (NSTC 2022). This sidebar provides select international comparisons of science, technology, and innovation capabilities in two technologies identified as critical and emerging by the NSTC: artificial intelligence (AI) and semiconductors.

China and the United States are the two largest contributors to AI research, both in terms of their national publications output and extent of international coauthorship (Figure A). From 2003 to 2022, researchers from China authored 274,000 AI-related articles (measured on a whole-count basis), and researchers from the United States authored 134,000 articles. Collaborative research between the United States and China resulted in the largest number of coauthored articles of any country pair (14,000); furthermore, all of the 10 largest coauthorship country pairs include either the United States or China. India and Japan each produced more total AI-related publications than the United Kingdom, but the United Kingdom coauthored more AI-related publications with both the United States and China than either India or Japan.

International comparisons of AI-related patenting indicate the extent to which inventors across the world are developing intellectual property of potential commercial value that relies on AI, including AI capabilities developed via published AI research. After a period of slow growth in the early 21st century, AI patenting has expanded rapidly in the past several years—most prominently in China. The leading countries for international patents granted in AI are China (40,000 in 2022), the United States (9,000), South Korea (5,000), and Japan (3,000). From 2000 to 2016, U.S. inventors were granted the most international AI patents but were surpassed by Chinese inventors in 2017. In terms of functional applications, AI patents by Chinese inventors have specialized in computer vision, whereas U.S. inventors have received a comparatively large proportion of patents in knowledge representation.

Figure A. AI collaboration network, by country: 2003–22

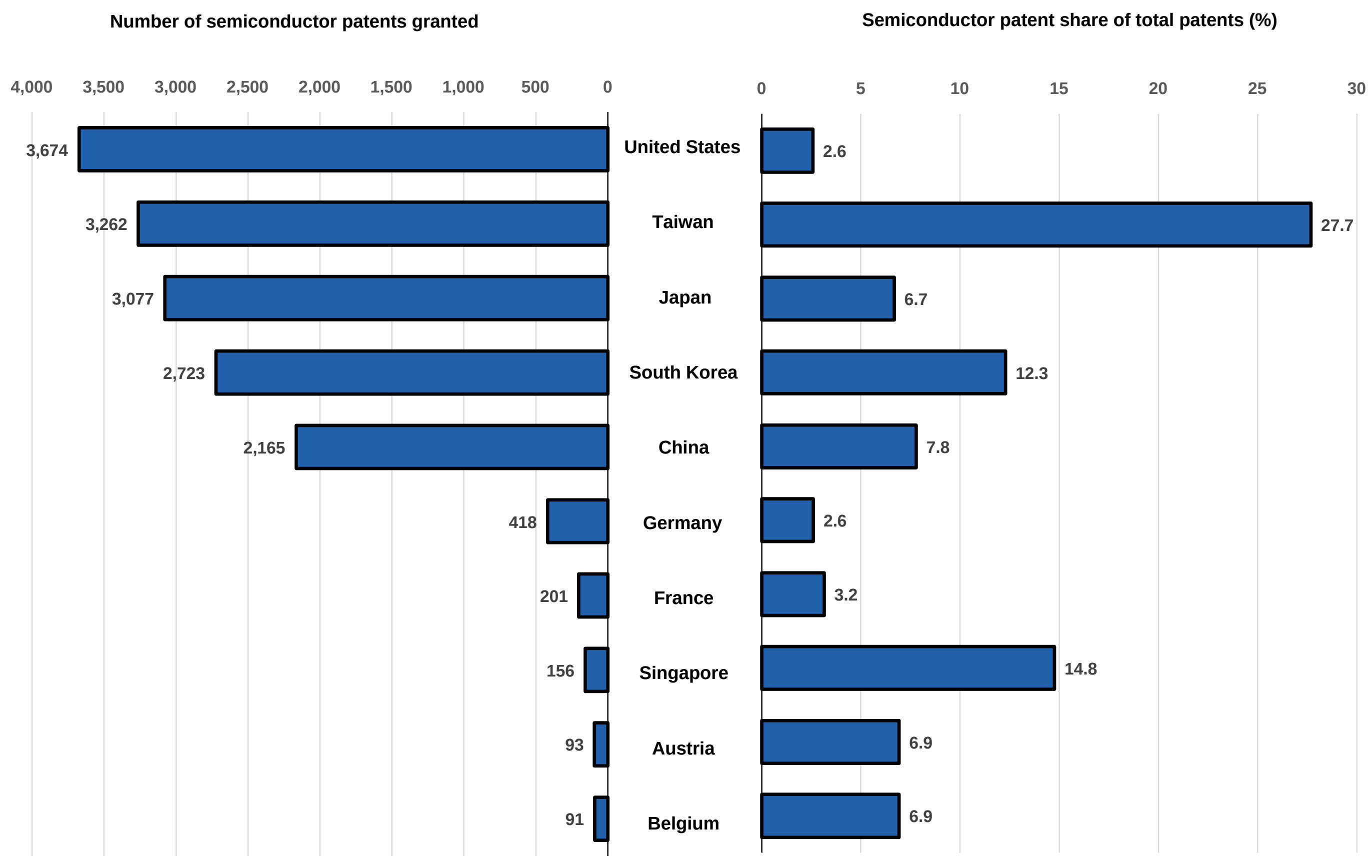


Note(s): AI is artificial intelligence. UK is United Kingdom. Network diagram shows the number of cowritten articles by all pairs of countries within the top 60 producers of AI-related research based on whole counting for those pairs that cowrote 400 articles or more. AI article counts refer to publications from a selection of conference proceedings and peer-reviewed journals in S&E fields from Scopus that were classified as AI in the All-Science Journal Classification. 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. The size of the nodes is proportional to the total number of AI-related articles written by each country. The width of the links between nodes is proportional to the quantity of articles both countries have cowritten. Positioning of nodes is defined using the Kamada-Kawai algorithm.

Source(s): NCSES, special tabulations (2023) by Science-Metrix of Elsevier's Scopus abstract and citation database. *Indicators 2024: Publications Output*

Patent and Trademark Office (USPTO) utility patents granted in semiconductors show how inventors from both the United States and abroad are seeking commercial protection for their inventions in this critical technology in the U.S. market. Approximately 3,700 USPTO semiconductor patents, 22% of the total, were granted to U.S.-based inventors in 2022, with the remainder of semiconductor patents issued to foreign inventors (Figure B). The most common foreign inventor locations for USPTO semiconductor patents—Taiwan, Japan, South Korea, and China—collectively accounted for 68% of all USPTO patents granted in this technology category. These locations also had considerably higher shares of their total USPTO patents granted in semiconductors than did inventors from the United States. Taiwan, the most common foreign inventor location, had 28% of its USPTO patents granted in semiconductors in 2022, one of the largest shares of any country or economy. Several European countries were also among the top foreign inventor locations, although semiconductors generally accounted for small shares of the total USPTO patents granted to these countries.

Figure B. USPTO utility patents granted in semiconductors, by country or economy: 2022



Note(s): USPTO is Patent and Trademark Office. USPTO patents are fractionally allocated among countries or economies based on the proportion of residences of all named inventors.

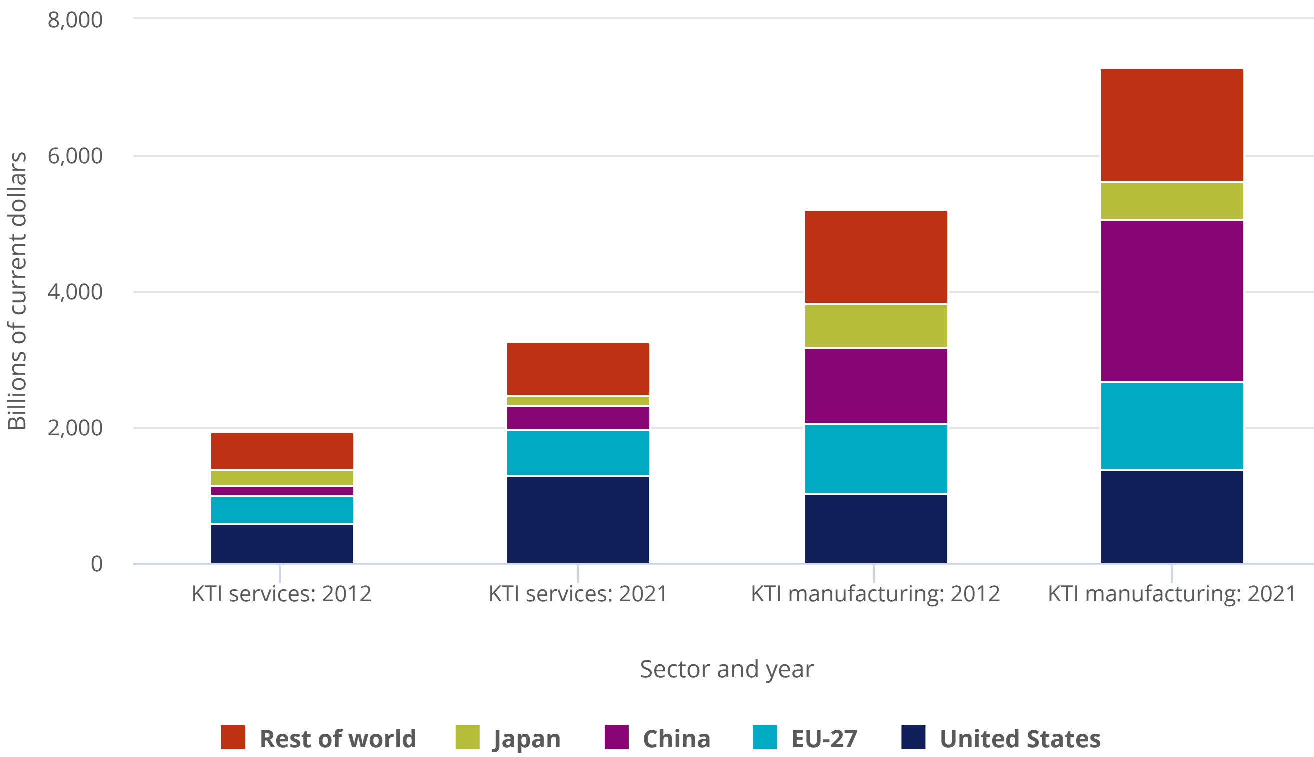
Source(s): NCSES, special tabulations (2023) by Science-Metrix of USPTO PatentsView. *Indicators 2024: Innovation*

Knowledge- and Technology-Intensive Industry Output

Production and trade by KTI industries—12 industries with high or medium-high R&D intensities (see Glossary section for definition of KTI industries)—indicate the translation of S&E capabilities into the marketplace.[28] The nine KTI manufacturing industries are pharmaceuticals; chemicals and chemical products (excluding pharmaceuticals); computer, electronic, and optical products (including semiconductors); electrical equipment; motor vehicles, trailers, and semi-trailers; air and spacecraft and related machinery; railroad, military vehicles, and other transport equipment; other machinery and equipment; and medical and dental instruments.[29] The three KTI services industries are IT and other information services, scientific R&D services, and software publishing.

In 2021, the global value-added output of KTI industries (see Glossary section for definition of value-added output) was $10.6 trillion, including $3.3 trillion in KTI services and $7.3 trillion in KTI manufacturing (Figure 25).[30] From 2012 to 2021, global value-added output increased by 68% for KTI services and by 41% for KTI manufacturing.

Figure 25. Value-added output of KTI industries, by selected region, county, or economy and by sector: 2012 and 2021



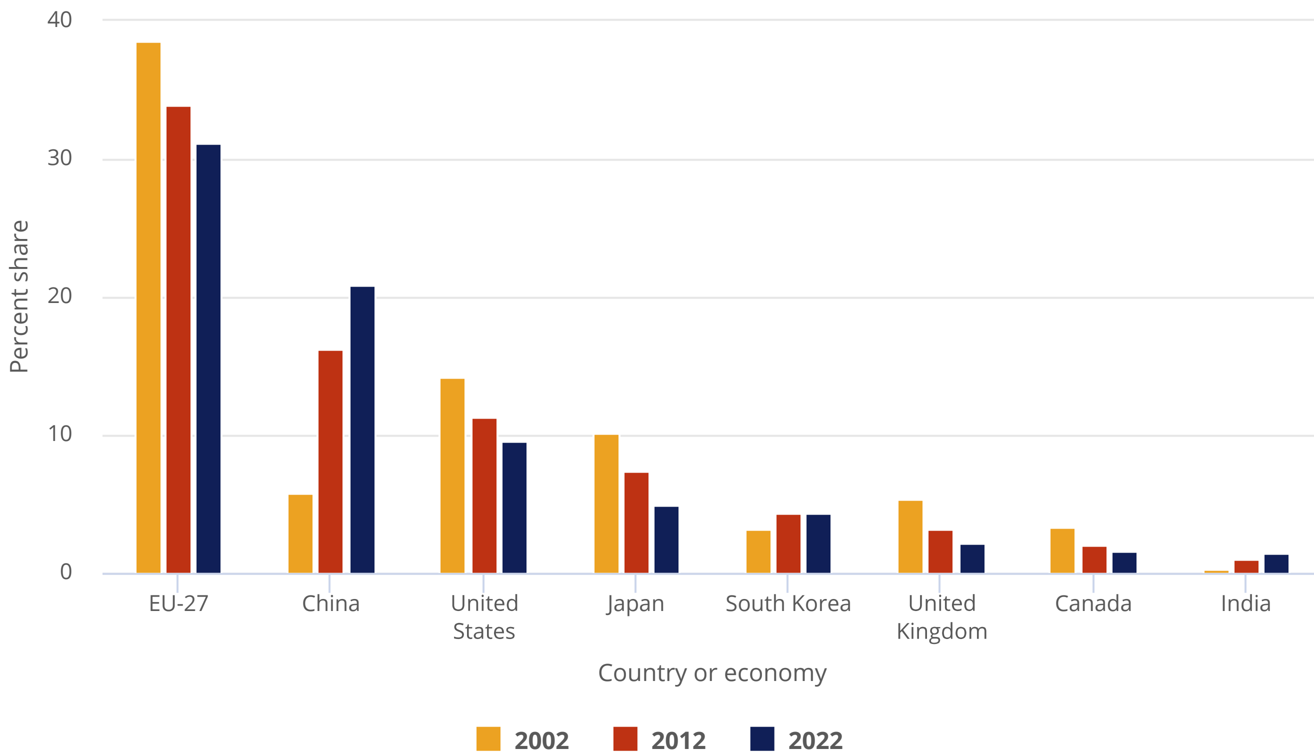
Note(s): EU-27 is European Union. KTI is knowledge and technology intensive.

Source(s): S&P Global IHS Markit, special tabulations (2023) of the Comparative Industry Service Database. *Indicators 2024: Industry Activities*

The United States is the largest provider of KTI services, with $1.3 trillion in value-added output in 2021. U.S. KTI services output more than doubled from 2012 to 2021, increasing the U.S. share of global KTI services from 30% in 2012 to 39% in 2021, nearly twice the EU-27's share (21%) of global KTI services in 2021. Although the value-added output of U.S. KTI manufacturing increased from 2012 to 2021, the U.S. share of global KTI manufacturing was 19% in 2021, little changed from 20% in 2012. At the same time, China more than doubled its KTI manufacturing output, increasing its global share from 22% ($1.1 trillion) to 33% ($2.4 trillion). Although the United States has lower total KTI manufacturing value-added output than China—and roughly the same as the EU-27—it is the largest producer of two KTI manufacturing industries: air and spacecraft as well as medical and dental instruments.

Exports are an indicator of a country's competitiveness in the world market. Global gross exports of KTI manufacturing industries were $11.4 trillion in 2022; this total represents a 6.5% increase from 2021. In 2022, countries with the highest share of global KTI manufacturing exports were China (21%), the United States (9%), and Germany (9%), although the combined share of EU-27 countries (including Germany) was highest at 31%. Global shares of KTI manufacturing exports for the EU-27 and United States declined slightly from 2002 to 2022, whereas China's share of the global total more than tripled (Figure 26). Over the same period, the share of China's total manufacturing exports that were in KTI industries increased from 47% to 64%, surpassing the share for the EU-27 (60%) and matching the share for the United States (64%).

Figure 26. Share of global KTI manufacturing exports, by selected country or economy: 2002, 2012, and 2022

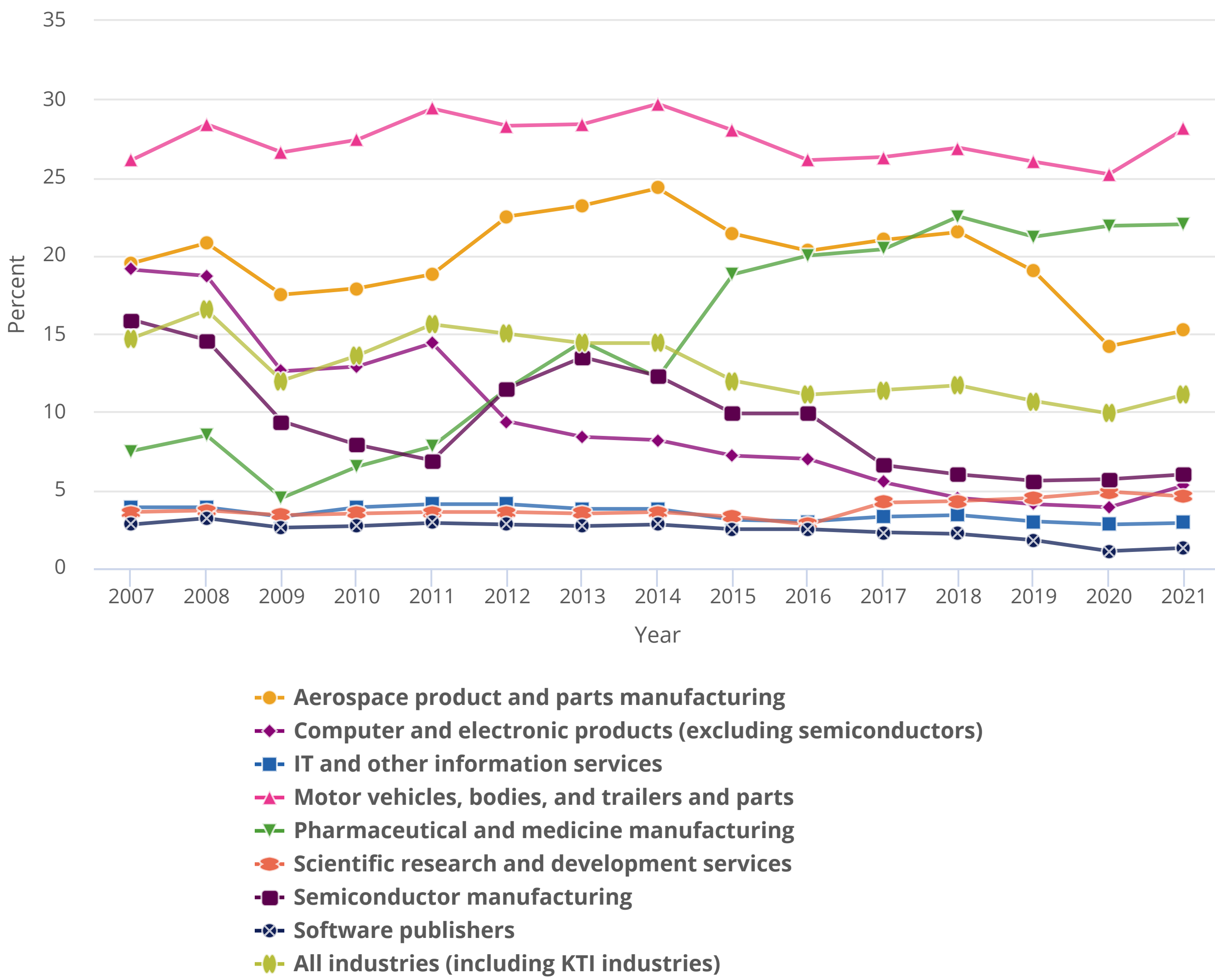


Note(s): EU-27 is European Union. KTI is knowledge and technology intensive. KTI manufacturing exports include exports from the following industries: chemicals and chemical products; pharmaceuticals; computer, electronic, and optical products; electrical equipment; machinery and equipment not elsewhere classified; motor vehicles, trailers, and semi-trailers; air and spacecraft and related machinery; weapons and ammunition; and other transport equipment (the latter comprises railway locomotives and rolling stock manufacturing and transport equipment not elsewhere classified and military equipment manufacturing).

Source(s): S&P Global IHS Markit, special tabulations (2023) of the Comparative Industry Service Database. *Indicators 2024: Industry Activities*

Because not all of the value of gross exports is generated in the exporting country, an important indicator of globalization and supply chains is the imported content of exports. This indicator captures the value of imported inputs embodied in exports. Compared with the average imported content share for all U.S. gross exports (11% in 2021), U.S. KTI manufacturing industries such as aerospace (15%), motor vehicles (28%), and pharmaceuticals (22%) have a relatively high share of foreign value added. In contrast, KTI services—software publishers (1%), IT services (3%), and scientific R&D services (5%)—have much lower shares of foreign value added (Figure 27). Imported content shares of U.S. exports by the semiconductor manufacturing industry (6%) and by the rest of the computer and electronic product manufacturing industry (5%) have been in the single digits since 2017 and 2012, respectively.

Figure 27. Imported content share of U.S. gross exports, by exporting industry: 2007–21



Note(s): IT is information technology. KTI is knowledge and technology intensive. Industry data are based on the North American Industry Classification System.

Source(s): BEA, Trade in Value Added Data. *Indicators 2024: Industry Activities*

Conclusion

U.S. global competitiveness in STI is supported through the nation's investment and capabilities in STEM talent, R&D-driven discovery, and translation of knowledge into the economy and society through innovation. The data presented in this report show the evolving nature of the position of the United States in the global S&E landscape. The COVID-19 pandemic resulted in short-term disruptions to S&E education and research and led to substantial declines in the mathematics performance of American elementary and secondary mathematics students; otherwise, global levels of research and innovation have continued to increase. With respect to long-term trends, aggregate levels of S&E resources and activity have shifted toward East and Southeast Asia—in particular, China. The United States is the leading source of health sciences publications and patenting in chemistry and instruments, whereas China is the top producer of S&E doctoral degrees, total S&E publications, and international patents. The United States performs more total R&D than any other country and is by far the largest performer of basic research. However, the U.S. R&D system—and by extension, the nation's competitiveness—relies heavily on foreign-born scientists and engineers, especially at the doctorate level. Rather than predominating across all elements of STI, the United States is distinguished by the strength of U.S. universities as destinations for international students, its highly cited and collaborative S&E research, and its global leadership in KTI services.

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

European Union (EU-27): Twenty-seven member nations: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden.

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 as "long first degrees" within level 7 (master's degree or equivalent) 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: Consists of all federal, state, and local governments, except those that provide higher education services, and all nonmarket, 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: 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 that are administered by, tertiary education institutions (OECD 2015).

Highly cited article (HCA): An HCA ratio provides an indication of scientific impact (Waltman, van Eck, and Wouters 2013). The HCA ratio for a region, country, or economy is calculated as the share of all articles published in a given year by authors with institutional addresses within that region, country, or economy that fall within the top 1% by citation count of all articles published that year, measured for each research field. The HCA ratio is indexed to 1.00, so a region, country, or economy whose authors produce highly cited articles at the expected (i.e., global average) rate has an HCA ratio of 1.00—that is, 1% of the region's, country's, or economy's articles are among the top 1% of the world's HCAs. A region, country, or economy with an HCA ratio greater than 1.00 is producing a disproportionately high level of articles with exceptional scientific impact, whereas a region, country, or economy whose authors produce relatively fewer influential articles will have an HCA ratio below 1.00.

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 2018* (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 (USPTO 2023).

Knowledge- and technology-intensive (KTI) industries: Industries classified by the Organisation for Economic Co-operation and Development as high R&D intensive and medium-high R&D intensive industries based on R&D intensity (see *R&D intensity*).

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.

Open access (OA): OA refers to peer-reviewed publications that are accessible online to any reader without requiring a journal subscription or other fees from readers (Piwowar et al. 2018). Several commonly defined types of OA have been adopted for the purposes of this analysis. *Gold OA* denotes articles published in journals that are entirely OA as a matter of journal policy. *Hybrid OA* refers to articles appearing in closed-access journals where the authors have paid a fee to make the article OA. *Bronze OA* denotes articles in closed-access journals that become OA after an embargo period of closed access or articles that appear available as OA despite lacking the license information to guarantee OA in the long term. *Green OA* denotes articles that are self-archived by authors in OA repositories, which are often maintained and administered by universities or other institutions.

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 2023). Patent Cooperation Treaty applications include Patent and Trademark Office (USPTO) patent applications (see *USPTO patent*).

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

Patent and Trademark Office (USPTO) patent: As defined by the USPTO, 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. Available at https://www.uspto.gov/learning-and-resources/glossary. Accessed 1 August 2023. USPTO applications are included in Patent Treaty Cooperation applications (see *Patent Cooperation Treaty applications*).

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 2023). 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-gross domestic product (GDP) 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 (OECD 2015).

Science and engineering (S&E) fields: Degrees awarded in the following fields: agricultural sciences and natural resources; biological and biomedical sciences; computer and information sciences; engineering; geosciences, atmospheric sciences, and ocean sciences; mathematics and statistics; multidisciplinary and interdisciplinary sciences; physical sciences; psychology; and social sciences. At the doctoral level only, health sciences are also included in S&E fields of study because at this level these fields are more likely to be research oriented rather than practitioner oriented.

Science and engineering (S&E) occupations: Occupations in the following five major categories: (1) computer and mathematical scientists; (2) biological, agricultural, and environmental life scientists; (3) physical scientists; (4) social scientists; and (5) engineers.

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

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

Skilled technical workforce (STW): Workers in STEM occupations (S&E, S&E-related, and middle-skill occupations) who do not have an educational attainment of a bachelor's degree or higher.

Utility patent: Intellectual property protection for a potentially useful, previously unknown, and nonobvious invention.

Value-added output: A measure of industry production that is the amount contributed by the country, industry, or other entity to the value of the good or service. It excludes the country's, industry's, or other entity's 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

BEA: Bureau of Economic Analysis

DHS: Department of Homeland Security

DOD: Department of Defense

DOE: Department of Energy

EBD: European Patent Bibliographic Data

EU-27: European Union

GDP: gross domestic product

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

HCA: highly cited article

HHS: Department of Health and Human Services

ICE: Immigration and Customs Enforcement

IPEDS: Integrated Postsecondary Education Data System

IT: information technology

KTI: knowledge and technology intensive

MOE (China): Ministry of Education (China)

MOE (India): Ministry of Education (India)

MSTI: Main Science and Technology Indicators

NAEP: National Assessment of Educational Progress

NASA: National Aeronautics and Space Administration

NBS (China): National Bureau of Statistics (China)

NCES: National Center for Education Statistics

NCSES: National Center for Science and Engineering Statistics

NIH: National Institutes of Health

NSB: National Science Board

NSCG: National Survey of College Graduates

NSF: National Science Foundation

NSTC: National Science and Technology Council

OA: open access

OECD: Organisation for Economic Co-operation and Development

PPP: purchasing power parity

R&D: research and (experimental) development

S&E: science and engineering

SEVIS: Student and Exchange Visitor Information System

STEM: science, technology, engineering, and mathematics

STI: science, technology, and innovation

STW: skilled technical workforce

TIMSS: Trends in International Mathematics and Science Study

UK: United Kingdom

USDA: Department of Agriculture

USPTO: Patent and Trademark Office

WIPO: World Intellectual Property Organization

References

Brainard J, Kaiser J. 2022. U.S. to Require Free Access to Papers on All Research It Funds. *Science* 377(6610):1026–27. Available at https://doi.org/10.1126/science.ade6577. Accessed 17 April 2023.

Bureau of Economic Analysis (BEA). 2023. *Global Value Chains.* Available at https://www.bea.gov/data/special-topics/global-value-chains. Accessed 31 July 2023.

Census Bureau. 2022a. American Community Survey (ACS) Public Use Microdata. Available at https://www.census.gov/programs-surveys/acs/microdata.html. Accessed 27 December 2022.

Census Bureau. 2022b. Annual Estimates of the Resident Population by Sex, Age, Race, and Hispanic Origin for the United States: April 1, 2020 to July 1, 2021 (NC-EST2021-ASR6H). Available at https://www.census.gov/data/tables/time-series/demo/popest/2020s-national-detail.html. Accessed 1 October 2022.

Ministry of Education, Government of India (MOE [India]). *All India Survey on Higher Education* (various years). Available at https://aishe.gov.in/aishe/gotoAisheReports. Accessed 15 December 2023.

Ministry of Education, People's Republic of China (MOE [China]). Available at http://en.moe.gov.cn/. Accessed 1 October 2022.

Mullis IVS, Martin MO, Foy P, Kelly DL, Fishbein B. 2020. *TIMSS 2019 International Results in Mathematics and Science*. Boston, MA: Boston College, TIMSS and PIRLS International Study Center. Available at https://timssandpirls.bc.edu/timss2019/international-results/. Accessed 7 March 2023.

National Bureau of Statistics of China (NBS [China]). *China Statistical Yearbook* (various years). Available at https://www.stats.gov.cn/english/Statisticaldata/yearbook/. Accessed 15 December 2023.

National Center for Education Statistics (NCES). *Integrated Postsecondary Education Data System (IPEDS), Completions Survey: 2012–21.* Available at https://nces.ed.gov/ipeds/use-the-data. Accessed 1 November 2022.

National Center for Science and Engineering Statistics (NCSES). 2022a. *Doctorate Recipients from U.S. Universities: 2021*. NSF 23-300. Alexandria, VA. Available at https://ncses.nsf.gov/pubs/nsf23300/.

National Center for Science and Engineering Statistics (NCSES). 2022b. Special tabulations of the 2000–22 main National Assessment of Educational Progress (NAEP) mathematics assessments, National Center for Education Statistics (NCES). Alexandria, VA: National Science Foundation.

National Center for Science and Engineering Statistics (NCSES). 2022c. Special tabulations of 2022 Student and Exchange Visitor System (SEVIS) database, Department of Homeland Security, Immigration and Customs Enforcement (DHS, ICE). Alexandria, VA: National Science Foundation.

National Center for Science and Engineering Statistics (NCSES). 2023a. *2021 Annual Business Survey: Data Year 2020 (ABS 2020)*. Alexandria, VA: National Science Foundation. Available at https://ncses.nsf.gov/surveys/annual-business-survey/2021.

National Center for Science and Engineering Statistics (NCSES). 2023b. *Federal Funds for Research and Development: Fiscal Years 2021–22.* NSF 24-309. Alexandria, VA: National Science Foundation. Available at https://ncses.nsf.gov/surveys/federal-funds-research-development/2021-2022/.

National Center for Science and Engineering Statistics (NCSES). 2023c. *National Survey of College Graduates, 2021 (NSCG 2021)*. Alexandria, VA: National Science Foundation. Available at https://www.nsf.gov/statistics/srvygrads/.

National Center for Science and Engineering Statistics (NCSES). 2023d. Special tabulations by 1790 Analytics of European Patent Bibliographic Data (EBD). Alexandria, VA: National Science Foundation.

National Center for Science and Engineering Statistics (NCSES). 2023e. Special tabulations by 1790 Analytics of USPTO Bulk Data Storage System. Alexandria, VA: National Science Foundation.

National Center for Science and Engineering Statistics (NCSES). 2023f. Special tabulations by Science-Metrix of Elsevier's Scopus abstract and citation database. Alexandria, VA: National Science Foundation.

National Center for Science and Engineering Statistics (NCSES). 2023g. Special tabulations by Science-Metrix of USPTO PatentsView. Alexandria, VA: National Science Foundation.

National Center for Science and Engineering Statistics (NCSES). 2023h. Special tabulations of the 2020 and 2023 National Assessment of Educational Progress (NAEP) long-term trend mathematics assessments, National Center for Education Statistics (NCES). Alexandria, VA: National Science Foundation.

National Center for Science and Engineering Statistics (NCSES). 2023i. *Survey of Graduate Students and Postdoctorates in Science and Engineering, 2021 (GSS 2021).* Alexandria, VA: National Science Foundation. Available at https://ncses.nsf.gov/surveys/graduate-students-postdoctorates-s-e/2021.

National Center for Science and Engineering Statistics (NCSES). 2024. *National Patterns of R&D Resources (annual series).* Alexandria, VA: National Science Foundation. Available at https://ncses.nsf.gov/data-collections/national-patterns/.

National Science and Technology Council (NSTC). 2022. *Critical and Emerging Technologies List Update.* Washington, DC: Executive Office of the President of the United States. Available at https://www.whitehouse.gov/wp-content/uploads/2022/02/02-2022-Critical-and-Emerging-Technologies-List-Update.pdf. Accessed 24 July 2023.

National Science Board (NSB), National Science Foundation. 2022. *International STEM Talent Is Crucial for a Robust U.S. Economy*. NSB-2022-16. Alexandria, VA. Available at https://www.nsf.gov/nsb/sei/one-pagers/NSB-International-STEM-Talent-2022.pdf.

National Science Board (NSB), National Science Foundation. 2023a. Academic Research and Development. *Science and Engineering Indicators 2024* (*Indicators 2024*). NSB-2023-26. Alexandria, VA. Available at https://ncses.nsf.gov/pubs/nsb202326.

National Science Board (NSB), National Science Foundation. 2023b. Elementary and Secondary STEM Education. *Science and Engineering Indicators 2024* (*Indicators 2024*). NSB-2023-31. Alexandria, VA. Available at https://ncses.nsf.gov/pubs/nsb202331/.

National Science Board (NSB), National Science Foundation. 2023c. Higher Education in Science and Engineering. *Science and Engineering Indicators 2024* (*Indicators 2024*). NSB-2023-32. Alexandria, VA. Available at https://ncses.nsf.gov/pubs/nsb202332/.

National Science Board (NSB), National Science Foundation. 2023d. Publications Output: U.S. Trends and International Comparisons. *Science and Engineering Indicators 2024* (*Indicators 2024*). NSB-2023-33. Alexandria, VA. Available at https://ncses.nsf.gov/pubs/nsb202333/.

National Science Board (NSB), National Science Foundation. 2024a. Invention, Knowledge Transfer, and Innovation. *Science and Engineering Indicators 2024* (*Indicators 2024*). NSB-2024-1. Alexandria, VA. Available at https://ncses.nsf.gov/pubs/nsb20241/.

National Science Board (NSB), National Science Foundation. 2024b. Production and Trade of Knowledge- and Technology-Intensive Industries. *Science and Engineering Indicators 2024* (*Indicators 2024*). NSB-2024-7. Alexandria, VA. Available at https://ncses.nsf.gov/pubs/nsb20247/.

National Science Board (NSB), National Science Foundation. 2024c. Research and Development: U.S. Trends and International Comparisons. *Science and Engineering Indicators 2024* (*Indicators 2024*). NSB-2024-6. Alexandria, VA. Available at https://ncses.nsf.gov/pubs/nsb20246/.

National Science Board (NSB), National Science Foundation. 2024d. Science and Technology: Public Perceptions, Awareness and Information Sources. *Science and Engineering Indicators 2024* (*Indicators 2024*). NSB-2024-4. Alexandria, VA. Available at https://ncses.nsf.gov/pubs/nsb20244/.

National Science Board (NSB), National Science Foundation. 2024e. The STEM Labor Force: Scientists, Engineers, and Skilled Technical Workers. *Science and Engineering Indicators 2024* (*Indicators 2024*). NSB-2024-5. Alexandria, VA. Available at https://ncses.nsf.gov/pubs/nsb20245/.

Organisation for Economic Co-operation and Development (OECD). 2015. *Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development,* The Measurement of Scientific, Technological and Innovation Activities. Paris: OECD Publishing.

Organisation for Economic Co-operation and Development (OECD). 2022. Education at a Glance Database. Available at https://stats.oecd.org/. Accessed 12 October 2022.

Organisation for Economic Co-operation and Development (OECD). 2023. Main Science and Technology Indicators (MSTI) September 2023 release. Available at https://www.oecd.org/science/msti.htm. Accessed 2 October 2023.

Organisation for Economic Co-operation and Development, Eurostat (OECD, Eurostat). 2018. *Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation.* 4th ed. The Measurement of Scientific, Technological and Innovation Activities. Paris: OECD Publishing, Luxembourg: Eurostat.

Patent and Trademark Office (USPTO). 2023. *2104 Requirements of 35 U.S.C. 101* [R-10.2019]. Available at https://www.uspto.gov/web/offices/pac/mpep/s2104.html. Accessed 1 August 2023.

Pew Research Center. 2016, 2020, 2022. American Trends Panel, Wave 17 (May–June 2016); Wave 79 (November 2020); Wave 114 (September 2022). Available at https://www.pewresearch.org/our-methods/u-s-surveys/the-american-trends-panel/.

Piwowar H, Priem J, Larivière V, Alperin JP, Matthias L, Norlander B, Farley A, West J, Haustein S. 2018. The State of OA: A Large-Scale Analysis of the Prevalence and Impact of Open Access Articles. *PeerJ* 6:e4375. Available at https://doi.org/10.7717/peerj.4375. Accessed 27 July 2023.

S&P Global IHS Markit. 2023. Special tabulations of the Comparative Industry Service Database.

World Bank. 2023. *International Comparison Program.* Available at https://www.worldbank.org/en/programs/icp. Accessed 1 August 2023.

World Intellectual Property Organization (WIPO). 2023. *WIPO: Patent Cooperation Treaty*. Available at https://www.wipo.int/pct/en/. Accessed 1 August 2023.

Notes

1 The section "**Elementary and Secondary Mathematics and Science**" draws on data and sources in the *Indicators 2024* report "[2024] Elementary and Secondary STEM Education."

2 All comparisons of TIMSS and National Assessment of Educational Progress (NAEP) scores in this section of the report are statistically significant at the 0.10 level of significance.

3 Average scores declined from 2019 to 2022 by a statistically significant amount for all racial and ethnic groups shown except for American Indians or Alaska Natives and Native Hawaiians or Other Pacific Islanders.

4 The section "**S&E Higher Education in the United States**" draws on data and sources in the *Indicators 2024* report "[2024] Higher Education in Science and Engineering." The Higher Education report also provides further breakouts by sex and race or ethnicity.

5 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 20–34 years old on 1 July 2021. Degree totals may differ from those cited elsewhere in the report; degrees awarded to people of unknown or other race were excluded, as were degree earners on temporary visas.

6 The section "**International S&E Higher Education and Student Mobility**" draws on data and sources in the *Indicators 2024* report "[2024] Higher Education in Science and Engineering."

7 For **Figure 5**, to facilitate international comparison, data for the United States are those reported to the Organisation for Economic Co-operation and Development, which vary slightly from the NCSES classification of fields presented in other sections of the report.

8 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 approved for optional practical training. Undergraduate level includes associate's and bachelor's degrees; graduate level includes master's and doctoral degrees.

9 The section "**The STEM Labor Market and the Economy**" draws on data and sources in the *Indicators 2024* report "[2024] The STEM Labor Force: Scientists, Engineers, and Skilled Technical Workers."

10 All comparative statements on STEM workforce, foreign-born S&E workers with at least a bachelor's degree, and stay rates of S&E research doctorate recipients on temporary visas that are based on sample surveys are statistically significant at the 0.10 level of significance.

11 Because STEM employment measures are based on estimates, not all states in the top quartile on these measures are statistically significantly different from all states not ranking in the top quartile. For more information on the geographical distribution of the STEM workforce by education level, see the *Indicators 2024* report "[2024] The STEM Labor Force: Scientists, Engineers, and Skilled Technical Workers."

12 The section "**Demographic Composition of the STEM Workforce**" draws on data and sources in the *Indicators 2024* report "The STEM Labor Force: Scientists, Engineers, and Skilled Technical Workers."

13 The section "**Americans' Perceptions about Scientists**" draws on data and sources in the *Indicators 2024* report "[2024] Science and Technology: Public Perceptions, Awareness, and Information Sources."

14 For **Figure 10**, responses are to the following: *How much confidence, if any, do you have in [scientists] to act in the best interests of the public?*

15 In this section, *some college* includes individuals with some college credit or an associate's degree, *college degree* includes bachelor's degree holders, and *postgraduate* includes individuals with a master's degree, advanced professional degree, or doctoral degree.

16 International comparisons of R&D expenditures are measured in current dollars, adjusted for purchasing power parity (PPP; see **Glossary** section for definition).

17 The section "**U.S. R&D Performance and Funding Trends**" draws on data and sources in the *Indicators 2024* report "[2024] 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 because estimates in this section may be subject to revision.

18 Data for the United States in this section and its accompanying figures reflect NCSES standards for domestic reporting of U.S. total R&D. This results in marginal differences from the data on gross expenditures on R&D that NCSES provides to OECD for international comparisons. Unless otherwise stated, all measurements of U.S. R&D performance in this report are in current dollars, unadjusted for inflation; inflation-adjusted amounts (constant dollars) will be provided in the *Indicators 2024* report "[2024] Research and Development: U.S. Trends and International Comparisons."

19 *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).

20 The business sector's share of U.S. R&D funding reported here (75%) includes funding from both domestic and foreign businesses (foreign parent companies, foreign subsidiaries, and unaffiliated foreign companies). It is higher than the share reported in the prior section (68%), which includes only R&D funded by domestic businesses per OECD standards for internationally comparable R&D statistics.

21 Federal R&D obligations data for 2021 include the additional funding provided by supplemental COVID-19 pandemic-related appropriations. For more information, see data and sources in the *Indicators 2024* report "[2024] Research and Development: U.S. Trends and International Comparisons."

22 For more information, see data and sources in the *Indicators 2024* report "[2024] Academic Research and Development."

23 Including geosciences, atmospheric sciences, and ocean sciences.

24 The section "**Research Publications**" draws on data and sources in the *Indicators 2024* report "[2024] Publications Output: U.S. Trends and International Comparisons."

25 The section "**Invention and Innovation**" draws on data and sources in the *Indicators 2024* report "[2024] Invention, Knowledge Transfer, and Innovation."

26 For the data presented in this paragraph, USPTO patents are fractionally allocated among regions, countries, or economies based on the proportion of residences of all named inventors.

27 For discussion of the methodology used to determine the gender of inventors, see the *Indicators 2024* report "[2024] Invention, Knowledge Transfer, and Innovation": Technical Appendix.

28 The section "**Knowledge- and Technology-Intensive Industry Output**" draws on data and sources in the *Indicators 2024* report "[2024] Production and Trade of Knowledge- and Technology-Intensive Industries."

29 Data on goods trade in this report include an additional industry, weapons manufacturing.

30 All measurements of KTI industries in this section are provided in current dollars, unadjusted for inflation.

Acknowledgments and Citation

Acknowledgments

The National Science Board extends its appreciation to the staff of the National Center for Science and Engineering Statistics (NCSES) within the National Science Foundation and to the many others, too numerous to list individually, who contributed to the preparation and review of this report.

This report was produced under the leadership of Emilda B. Rivers, Director, NCSES; Christina Freyman, Deputy Director, NCSES; and John Finamore, Chief Statistician, NCSES.

The report benefited from extensive contributions from NCSES staff and contractors. All persons acknowledged are from NCSES unless otherwise specified. The content was developed by Clara Boothby (ORISE), Amy Burke (formerly NCSES), Steven Deitz, Christina Freyman, and Alex Rhodes. Jaqui Falkenheim, Robin Henke (RTI International), Francisco Moris, Carol Robbins, Susan Rotermund (RTI International), Benjamin Schneider, Brian Southwell (RTI International), and Danielle Taylor provided subject-matter expertise. Darius Singpurwalla provided advice on statistical issues. Christine Hamel and Tanya Gore conducted editorial and composition review.

August Gering, RTI International, provided editorial assistance. Angela Haskell (Windsor Group) provided administrative support. Staff at Penobscot Bay Media, LLC (PenBay Media), created the report website. The following agencies reviewed this report:

Bureau of Economic Analysis

Bureau of Labor Statistics

Census Bureau

Defense Advanced Research Projects Agency

Department of Education

National Aeronautics and Space Administration

National Institutes of Health

Office of Management and Budget

Office of Science and Technology Policy

State Department

U.S. Geological Survey

The Board is especially grateful to the Committee on National Science and Engineering Policy for overseeing preparation of the volume and to the National Science Board Office, under the direction of John Veysey, which provided vital coordination throughout the project. Elizabeth Jeffers led the outreach and dissemination efforts. Amanda Vernon served as National Science Board Office Liaison to the committee. May Aydin, Steven Deitz, and Anne Emig were the Executive Secretaries.

Cover Image Credit

Researchers have developed a method where they imprint tiny patterned grooves onto swellable sheets, such as flat pasta dough or silicone rubber, and watch it "morph" into spirals, tubes, twists, and flowers. The method could lead to more effective food packaging by reducing packing space during transport and storage and reducing landfill waste. This work is led by the Morphing Matter Lab at Carnegie Mellon University, in collaboration with Syracuse University. (Research supported by National Science Foundation grants CMMI 1847149 and IIS 2017008.)

Credit: Lining Yao, Morphing Matter Lab, Carnegie Mellon University

Recommended Citation

National Science Board, National Science Foundation. 2024. *Science and Engineering Indicators 2024: The State of U.S. Science and Engineering*. NSB-2024-3. Alexandria, VA. Available at https://ncses.nsf.gov/pubs/nsb20243.

Contact Us

To report an issue with the website, please e-mail ncsesweb@nsf.gov. For questions about the National Science Foundation (NSF), visit the NSF help page at https://nsf.gov/help/. To see more from the National Science Board, visit http://nsf.gov/nsb/.

Report Authors

Steven Deitz
Science Analyst
National Center for Science and Engineering Statistics
sdeitz@nsf.gov

Christina Freyman
Deputy Division Director
National Center for Science and Engineering Statistics
cfreyman@nsf.gov

NCSES

National Center for Science and Engineering Statistics
Directorate for Social, Behavioral and Economic Sciences
National Science Foundation
2415 Eisenhower Avenue, Suite W14200
Alexandria, VA 22314
Tel: (703) 292-8780
FIRS: (800) 877-8339
TDD: (800) 281-8749
ncsesweb@nsf.gov

https://ncses.nsf.gov/indicators

NSB-2024-3