NATIONAL SCIENCE BOARD
SCIENCE & ENGINEERING INDICATORS 2024

Innovation

# Invention, Knowledge Transfer, and Innovation

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This publication is part of the 2024 edition of the *Science and Engineering Indicators* (*Indicators*) suite of reports. *Indicators* is prepared under the guidance of the National Science Board by the National Science Foundation's National Center for Science and Engineering Statistics. The *Indicators* suite consists of a summary report called *The State of U.S. Science and Engineering*, more-detailed thematic reports with supporting data, and a data tool that provides state-level indicators.

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## Executive Summary

Key takeaways:

- U.S. patenting and trademark activities are concentrated in certain areas of the country, with the highest rates on the East Coast and West Coast, around the Great Lakes, and in parts of the Southwest.
- Internationally, China and the United States are granted the highest numbers of artificial intelligence (AI) utility patents, with China's AI patents primarily granted in machine learning.
- Consistent with the overall increase of international collaboration in peer-reviewed literature, the largest increase in collaboration for U.S. business-authored publications is with international authors.
- Among patents on technologies for climate change mitigation and adaptation issued by the Patent and Trademark Office (USPTO), those for climate change mitigation in energy generation, transmission, and distribution account for the highest number granted to inventors in each of the five most active countries or regions.
- About 190,000 USPTO utility patents were granted in 2022 in technology areas that correspond to CHIPS and Science Act technologies, almost half of which were granted to U.S. inventors.
- As an indicator of knowledge flow, biological and biomedical sciences publications and health sciences publications are by far the most cited by patent documents.
- The number of university licenses and license options granted to private sector entities has increased 50% in the last decade.
- Peer-reviewed publications from authors at the Department of Health and Human Services received more citations in patent documents than any other federal agency over the period from 2013 to 2022.
- At the federal agency level, the National Aeronautics and Space Administration (NASA) and the Department of Energy (DOE) report the highest numbers of invention disclosures in each year from 2011 through 2020, an indicator of invention prior to patenting.
- In 2009, only DOE, the Department of Commerce, and NASA used open-source platforms to share software with other users; by 2023, 26 federal departments and agencies did so.
- Venture capital investment dropped globally in 2022 after reaching record levels in 2021.
- The incidence of product innovation in the United States decreased between 2017 and 2020, driven by decreases in smaller companies with service sector innovation.

## Introduction

Governments, academia, and business all contribute to the activities that comprise the innovation process. Through intellectual property protection measures, successful business research and development (R&D) incorporates new knowledge into new products and processes while attempting to prevent useful new knowledge from spreading to rivals (Arora, Belenzon, and Sheer 2017). In contrast, many government, academic, and nonprofit institutions create new knowledge with the intention of sharing it widely to support innovation—for example, through publications, data sets, and technology transfer agreements. New knowledge created by R&D activities across all sectors takes different forms, including scientific literature meant to be published and private knowledge meant to be kept secret. Both forms may contribute to inventions or innovations.

The distinction between invention and innovation is an important one; implementation of new ideas as products or processes with real-world applications is what separates inventions from innovations. In this report, an *invention* is defined as any new and useful process, machine, manufacture, or composition of matter, including any new and useful improvement thereof (USPTO 2020). By contrast, an *innovation* is "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)" (OECD/Eurostat 2018). The activities along the way constitute innovation activities.

This report starts with invention, ends with innovation, and situates knowledge transfer activities in between. Where applicable, this report also addresses critical and emerging technologies using current and relevant typologies. For example, the National Science and Technology Council (NSTC 2022) includes advanced manufacturing, biotechnologies, and artificial intelligence (AI) as current examples of critical and emerging technologies, among other priorities. This report provides tabulations of international AI patents and of Patent and Trademark Office (USPTO) patents granted based on two different typographies: environmental sustainability technology areas, and technology areas named in the CHIPS and Science Act of 2022.

The geography of innovation is addressed in this report through county-level data on patenting and trademarking for the United States, as well as regional breakdowns where possible, such as with venture capital data. These units of geography are imperfect: for economic processes, metropolitan areas may be preferred; for political processes, congressional districts may be preferred. While resource and space limitations have guided this choice in this thematic report, machine-readable patent and trademark data sets provided with this report allow users to combine county-level data for their own purposes.

Similarly, the central role of the business sector in innovation activity has shaped the available data, and most indicators of innovation address the private sector. Notwithstanding the availability of data, however, a diverse set of actors who span the economic sectors of the economy contributes to the creation of innovative output, including universities, government agencies, and individuals. Not every topic that matters has relevant high-quality data available for this report.

The innovation indicators in this report include both direct, survey-based measures of innovation output from the businesses and also indirect innovation indicators connected to venture investment and trademarks. Self-reported company data on the introduction of new or significantly improved products are reported based on a joint National Center for Science and Engineering Statistics (NCSES) and Census Bureau survey that now contains three consecutive years of data.

Access to financing is an essential component of the translation of new knowledge into innovations. Venture capital is a particularly important indicator of innovation because venture investors tend to invest in companies whose products, they believe, have a significant likelihood of achieving market success. Venture capital–backed firms that become publicly traded are more likely to have recorded R&D expenditures compared to publicly traded firms that were not originally

venture backed (Lerner and Nanda 2020). In this regard, data on U.S. and global venture capital investment trends, provided by PitchBook, can be viewed as leading indicators of the innovative output expected from startups and from early investments to create innovations. The data sources for the indicators used in this report are shown in **Table INV-1** and rely on both administrative data and survey data and on public as well as private data sources.

**Table INV-1**

**Indicators of invention, knowledge transfer, and innovation used in this thematic report and their sources**

(Indicator and source)

| Section | Indicator | Source |
|---|---|---|
| Invention Indicators: Protecting Useful Ideas | Number of USPTO utility patents granted to U.S. owners, by type of grantee | USPTO |
| | Number of world patent applications | WIPO |
| | Number of USPTO utility patents granted, by selected region, country, or economy | USPTO |
| | Number of USPTO patents granted to inventors in selected countries, by field of technology | USPTO |
| | Number of USPTO utility patents, by U.S. county | USPTO |
| | Proportion of patent applications by country with at least one woman applicant | WIPO |
| | International patents granted in artificial intelligence | EPO |
| Knowledge Transfer: Making Information Available | Number of coauthored business sector publications with other academic, government, and foreign institutions | USPTO<br>Elsevier Scopus |
| | Total number of U.S. establishment startups | Census Bureau |
| | Total number of startups launched annually based on university technology | AUTM |
| | Number of technology transfer activities supported by federal laboratories, by selected agency | NIST |
| | Number of peer-reviewed publications by federal authors | Elsevier Scopus |
| | Number of patents issued to federal inventors | USPTO |
| | Number of open-source projects sponsored by federal agencies | GSA<br>Code.gov |
| | Number of federally sponsored public science projects on CitizenScience.gov, by agency | GSA<br>CitizenScience.gov |
| Innovation: Introducing New Products and Processes | SBIR and STTR program funding awards | Small Business Administration |
| | Venture capital investments | PitchBook |
| | U.S. companies introducing product innovation | NCSES<br>Census Bureau |
| | Number of U.S.-registered USPTO trademarks, by business sector | USPTO |

EPO = European Patent Office; GSA = General Services Administration; NCSES = National Center for Science and Engineering Statistics; NIST = National Institute of Standards and Technology; SBIR = Small Business Innovation Research; STTR = Small Business Technology Transfer; USPTO = Patent and Trademark Office; WIPO = World Intellectual Property Organization.

**Source(s):**
NCSES; RTI International; 1790 Analytics; SRI International; Science-Metrix

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# Invention Indicators: Protecting Useful Ideas

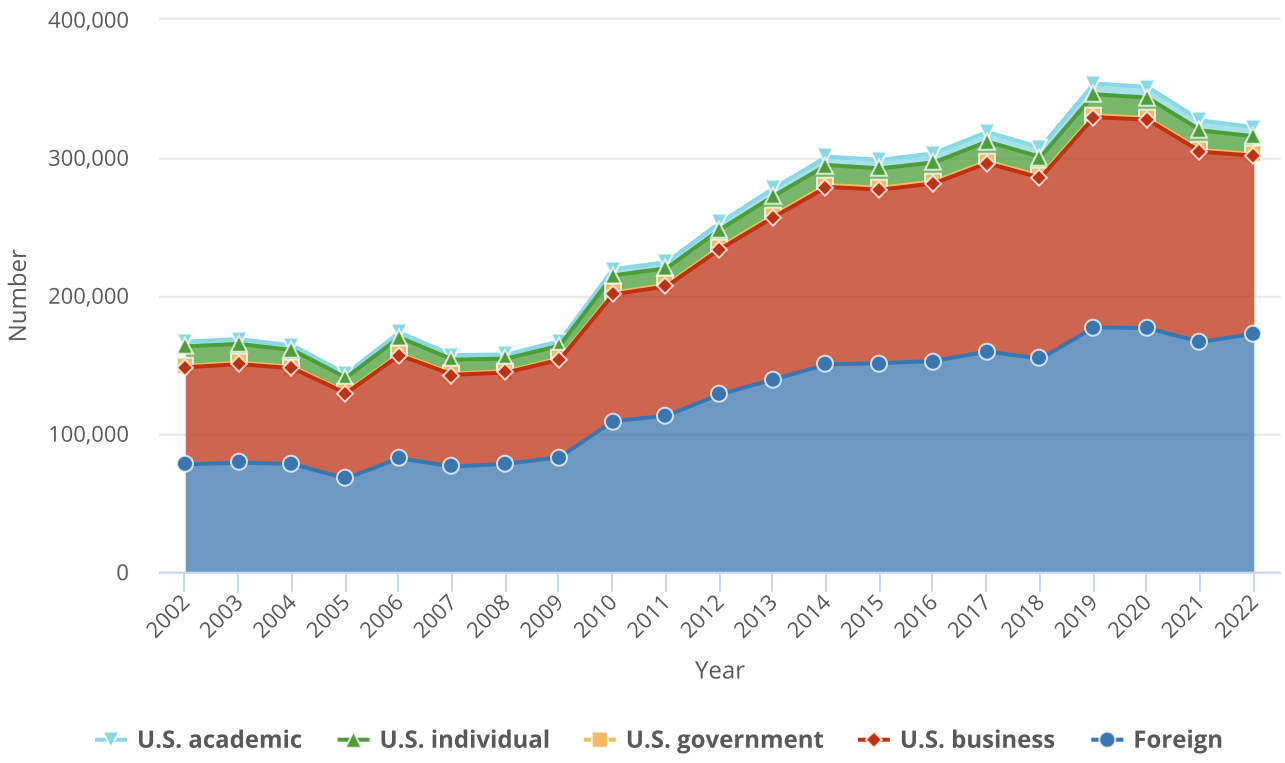
## Contributors to U.S. Patent Activity

USPTO patent records provide industry, technology areas, and geographical inventor information for all patents registered in the United States, including patents granted to individuals and foreign entities. Most patent topics in this report cover only inventions protected by utility patents. Design patents are included in this report in the coverage of patenting by gender; plant patents were last covered in *Science and Engineering Indicators 2020* (see *Indicators 2020* report "[2020] Invention, Knowledge Transfer, and Innovation"). More information on the patent data used in this report is available in the **Technical Appendix** provided with this report, and detailed methodological information is provided in Science-Metrix (2024).

The USPTO awarded 325,000 utility patents in 2022, of which 152,000 (47%) were assigned to domestic owners (Table SINV-1). Obtaining and defending a patent incurs significant costs; among U.S. *assignees* (the U.S. entities to whom inventors assign the rights of ownership), private owners—which are primarily businesses—receive by far the most patents (86%), while individual filers and those in academia and government account for much smaller shares (**Figure INV-1**). In the wake of the global pandemic, the total number of USPTO utility patents awarded annually to U.S. owners has declined since 2019, when 179,000 were granted. Patents assigned to U.S. businesses declined 15% between 2019 and 2022, in contrast to a general upward trend from 2000 to 2019 (Table SINV-1).

**Figure INV-1**

**USPTO utility patents granted to owners, by nationality and U.S. sector: 2002–22**




USPTO = Patent and Trademark Office.

**Note(s):**
Patents are allocated according to patent ownership information. Patents are credited on a fractional-count basis (i.e., for patents with collaborating institutions, each institution receives fractional credit on the basis of the proportion of inventors from participating institutions). Unclassified patents are not shown. See Table SINV-1 and the Technical Appendix for additional detail.

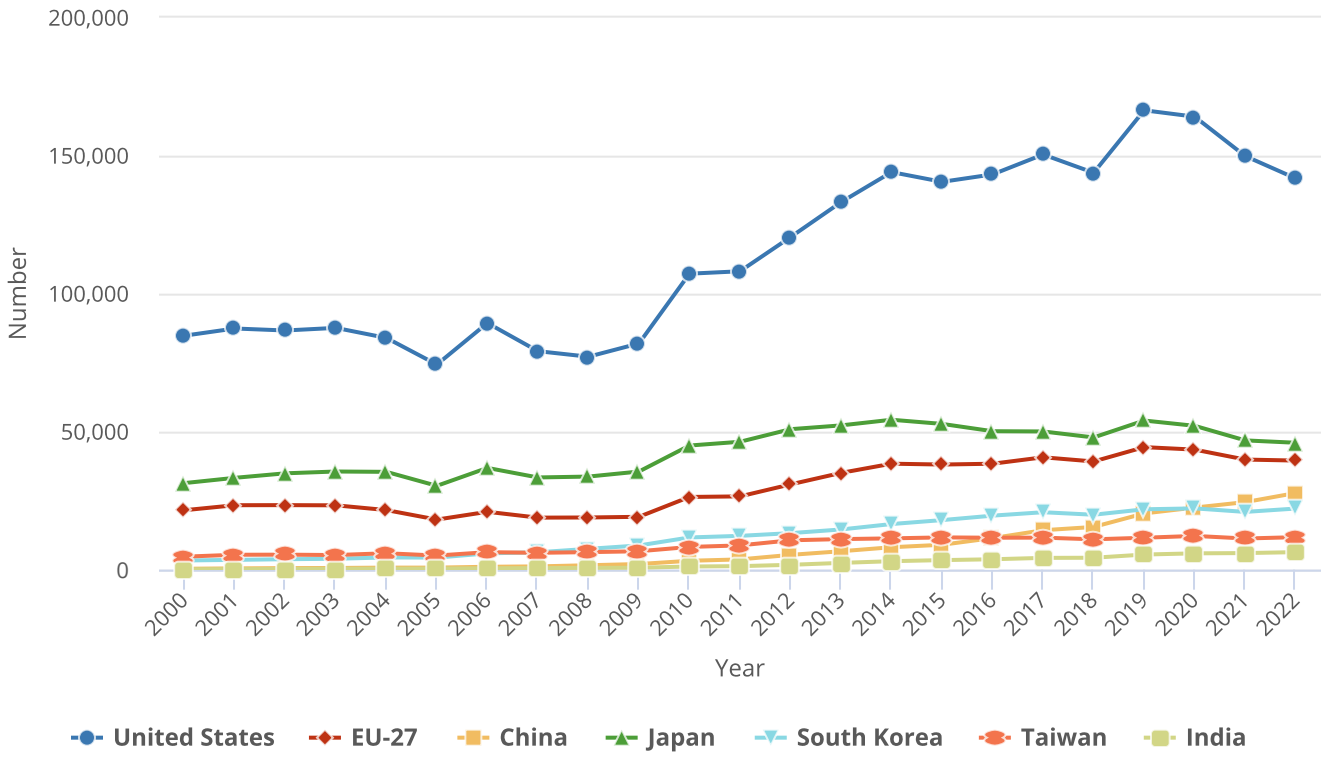
**Source(s):**
National Center for Science and Engineering Statistics; Science-Metrix; PatentsView, USPTO, accessed June 2023.

*Science and Engineering Indicators*

As commercial activities increasingly cross international borders, rising rates of foreign patenting reflect the desire of foreign firms to seek patent protection in multiple international jurisdictions (Fink, Khan, and Zhou 2015). Foreign owners were assigned rights to 53% of USPTO utility patents in 2022, an increase from 44% in 2000 (Table SINV-1). In contrast with ownership information, the addresses of inventors provide information about where inventors reside. The European Union (EU-27) and Japan continue to account for the largest numbers of foreign inventors (**Figure INV-2**). In 2020, the number of patents granted to inventors from China exceeded the number of patents granted to inventors from South Korea for the first time ever. Inventors with addresses in China received about 28,000 patents in 2022 (**Figure INV-2**). According to a USPTO report, the growth in USPTO patents granted to China is driven by nonmarket factors as well as by traditional market factors. The report identifies nonmarket factors such as university and government subsidies for patenting that can exceed the cost of filing the patent. These subsidies are often higher for patents granted in foreign jurisdictions (USPTO 2021).

**Figure INV-2**

**USPTO utility patents granted to inventors, by selected region, country, or economy: 2000–22**




EU-27 = European Union; USPTO = Patent and Trademark Office.

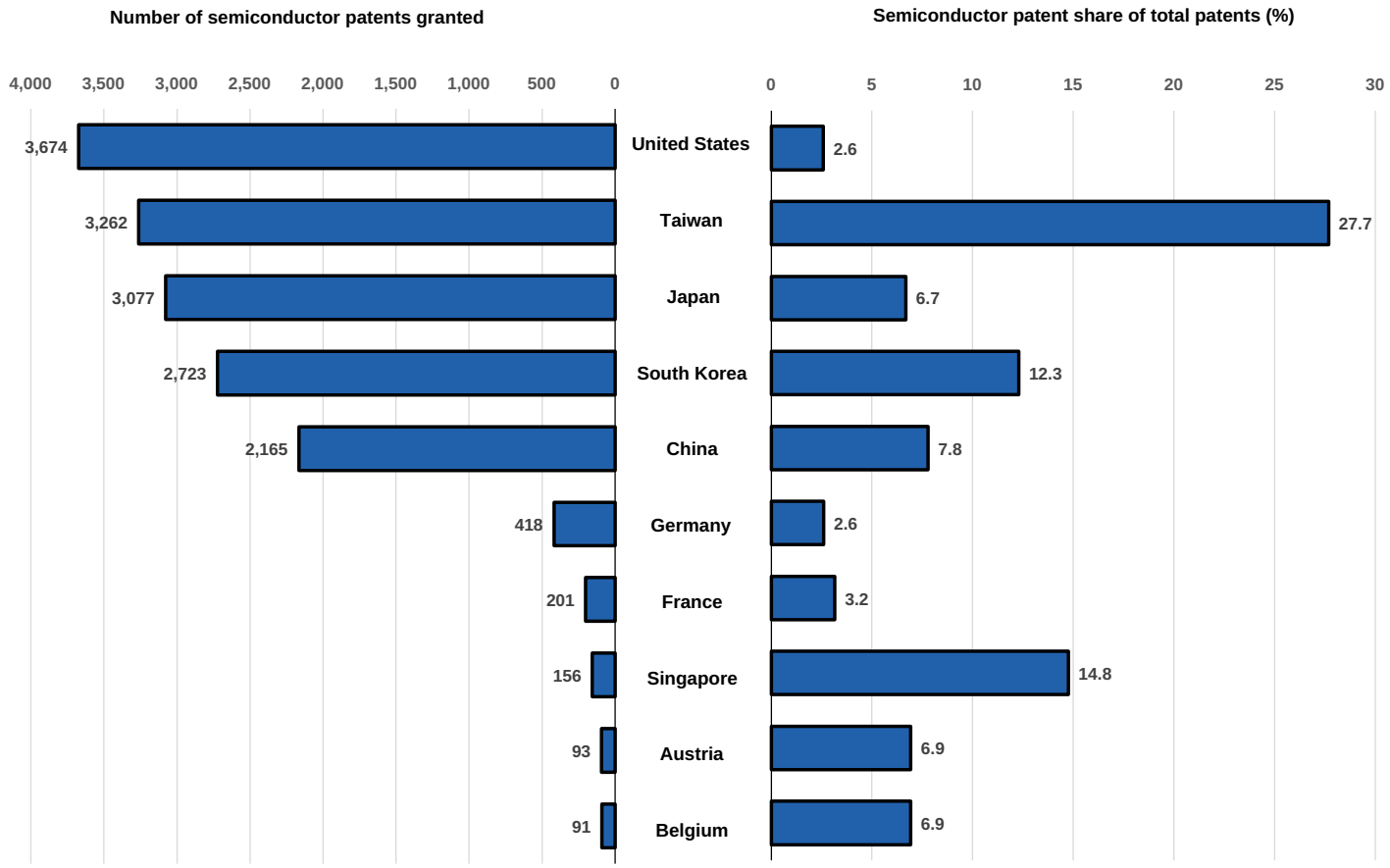
**Note(s):**
Patents are allocated according to patent inventorship information. Patents are fractionally allocated among regions, countries, or economies based on the proportion of residences of all named inventors. China includes Hong Kong. The United States includes Puerto Rico and all other U.S. territories. See Table SINV-4 for additional countries.

**Source(s):**
National Center for Science and Engineering Statistics; Science-Metrix; PatentsView, USPTO, accessed June 2023.

USPTO utility patents granted in semiconductors make up 5% of total 2022 patents. Inventors who were resident in the United States received the largest number of USPTO patents in semiconductors, which is identified as a critical or emerging category (NSTC 2022) (**Figure INV-3**). In addition to inventors from the United States, the highest numbers of USPTO utility patents in semiconductors were issued to inventors from Taiwan, Japan, South Korea, and China. Semiconductor utility patents make up more than a quarter of the USPTO patents received by inventors from Taiwan (**Figure INV-3**). A public-use file contains data on USPTO patents granted by five broad technology areas and tabulated in Table SINV-4 through Table SINV-9 (File USPTO patents, by county and technical field).

**Figure INV-3**

**USPTO utility patents granted in semiconductors, by selected country or economy: 2022**




USPTO = Patent and Trademark Office.

**Note(s):**
Patents are allocated according to patent inventorship information. Patents are fractionally allocated among regions, countries, or economies based on the proportion of residences of all named inventors. China includes Hong Kong. The United States includes Puerto Rico and all other U.S. territories. See Table SINV-10 for additional regions, countries, and economies.

**Source(s):**
National Center for Science and Engineering Statistics; Science-Metrix; PatentsView, USPTO, accessed September 2023.

As presented above, these data provide rich geographic and technological detail; however, patent data represent just a portion of all the ways that economically valuable ideas and inventions are protected by their owners. Nondisclosure agreements, trade secrets, trademarks, and copyrights are used by U.S. businesses in addition to utility and design patents (Shackelford and Kindlon 2021).

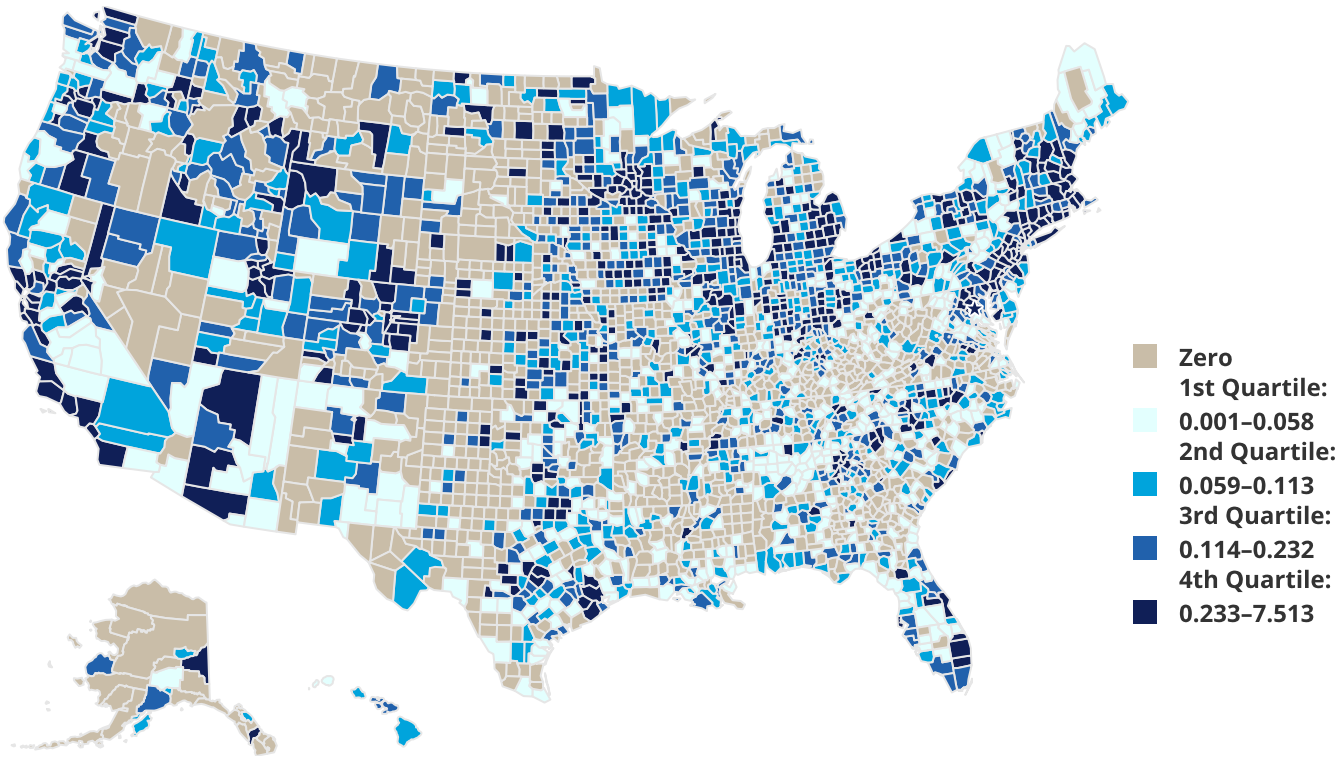
## The Geography of U.S. Patenting

Invention is a market-driven activity and tends to take place where skilled human capital and other inputs are relatively abundant. As new knowledge spreads, it produces localized growth benefits or spillovers that drive additional growth (Grossman and Helpman 1991). States that have relatively high proportions of workers with a bachelor's degree or higher in science, technology, engineering, and mathematics (STEM) are located primarily on the East Coast and West Coast of the United States and in the U.S. Midwest (see *Indicators 2022* report "[2022] The STEM Labor Force of Today: Scientists, Engineers, and Skilled Technical Workers"). As skilled labor and other inputs accumulate, a location's initial advantages grow over time relative to other locations, leading to different growth rates and economic outcomes. Because patent documents include the addresses of both the inventor and the patent owner, patent data provide an indicator of the location of inventive activity.

County-level patenting intensity is measured in this thematic report by the location of the inventor of utility patents granted per 1,000 population. Counties with high patenting intensity are concentrated in the United States along the coasts and in parts of the Great Lakes region, Texas, and the Rocky Mountains (**Figure INV-4**). This geographic distribution corresponds to indicators of knowledge- and technology-intensive (KTI) industries, in which California is the single largest producer of KTI industry output, followed by Texas, Washington, and New York (see *Indicators 2022* report "[2022] Production and Trade of Knowledge- and Technology-Intensive Industries"). 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. The top three counties in 2022 for patenting intensity are Santa Clara in California, followed by Fairfax City in Virginia and San Mateo County in California (**Figure INV-4**).

**Figure INV-4**

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




USPTO = Patent and Trademark Office.

**Note(s):**
USPTO patents are allocated to counties according to the address for each inventor listed on a patent. U.S. addresses were geocoded to 3,143 U.S. counties according to U.S. states, U.S. cities, and ZIP Codes appearing in these addresses. Because of the absence of ZIP Codes for most U.S. addresses in the patent data, coassignment to multiple U.S. counties occurred for addresses accounting for about 14% of all U.S. patent counts, mostly in populous cities encompassing multiple counties. Further manual disambiguation was performed based on information available to assign some of the ambiguous addresses to a single county. When more than one county remained for an address on a patent, the fraction of the patent associated to this address was split equally across all the counties. See File USPTO patents, by county and technical field and the Technical Appendix for additional detail.

**Source(s):**
National Center for Science and Engineering Statistics; Science-Metrix; PatentsView, USPTO, accessed June 2023. Population data from the Census Bureau, https://www2.census.gov/programs-surveys/popest/tables/2020-2022/counties/totals/co-est2022-pop.xlsx, accessed June 2023.

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The county patenting data files released with this report provide additional detail by technology area, showing, for example, the high rate of transportation technology patenting in Oakland and Wayne Counties in Michigan (File USPTO patents, by region, country, economy, and technical field). In 2022, 64% of all counties had at least one patent granted to inventors in that county.[1] Beyond geography, the technological detail in the patent documents makes it possible for new insights into environmental management and mitigation. The sidebar **Patenting That Addresses Environmental Sustainability** provides country and U.S. state data on the patents granted and geographic specialization in these technologies. A supplemental workbook released with this report provides annual country-, state-, and county-level data for 1998–2022 (File USPTO environmental and critical technology patent data).

SIDEBAR

## Patenting That Addresses Environmental Sustainability

Patenting that addresses climate change through mitigation and adaptation is of increasing interest internationally, and renewable energy generation is identified as a critical or emerging technology (NSTC 2022). Based on an analysis of Patent and Trademark Office (USPTO) utility patents, the foreign locations where inventors have the highest numbers of patents that address environmental sustainability through climate change mitigation and adaptation are the European Union (EU-27), China, Japan, and South Korea. Climate change mitigation in energy generation, transmission, or distribution has the highest numbers of USPTO patents granted.

The following analysis of utility patents that address this topic is based on a set of classification codes developed by the United Nations and the European Patent Office. This classification system for patent documents identifies climate change mitigation technologies (CCMT), climate change adaptation technologies (CCAT), and environmental management technologies that explicitly and cleanly correspond to existing patent classification systems that are used by USPTO and the World Intellectual Property Organization (Veefkind et al. 2012; Haščič and Migotto 2015). In 2022, more than 32,000 USPTO utility patents were granted in these environmental technologies, a threefold increase since 2000 (Table SINV-A). These 10 technologies are classified as follows:

- Environmental management
- CCMT in energy generation, transmission, or distribution
- CCMT in capture, storage, sequestration, or disposal of greenhouse gases
- CCMT in transportation
- CCMT in buildings
- CCMT in wastewater treatment or waste management
- CCMT in the production and processing of goods
- CCMT in information and communications technologies
- CCAT
- Sustainable ocean economy

Climate change mitigation in energy generation, transmission, or distribution have the highest numbers of USPTO patents granted in each of the five most active countries or regions, with a global total of about 7,900 USPTO patents granted in 2022 (**Table INV-A**). The classification used for this analysis includes patenting related to a sustainable ocean economy: 280 such USPTO utility patents were granted in 2022. Additionally, almost 700 patents within these 10 categories address sustainable technologies for agriculture and forestry (**Table INV-A**).

**Table INV-A**

**USPTO patents granted to selected regions or countries in environmental sustainability technologies: 2022**

(Number)

| Technology area | World | China | EU-27 | Japan | South Korea | United States |
|---|---|---|---|---|---|---|
| Environmental management | 5,288 | 295 | 873 | 890 | 268 | 2,321 |
| CCMT in energy generation, transmission, or distribution | 7,943 | 757 | 1,103 | 1,622 | 1,154 | 2,544 |
| CCMT in capture, storage, sequestration, or disposal of greenhouse gases | 199 | 7 | 25 | 25 | 11 | 98 |
| CCMT in transportation | 5,170 | 172 | 983 | 1,105 | 353 | 2,035 |
| CCMT in buildings | 2,317 | 258 | 341 | 325 | 156 | 996 |
| CCMT in wastewater treatment or waste management | 557 | 42 | 88 | 51 | 17 | 262 |
| CCMT in the production or processing of goods | 3,975 | 306 | 635 | 710 | 286 | 1,542 |
| CCMT in information and communication | 3,428 | 447 | 260 | 304 | 410 | 1,532 |
| CCAT | 2,974 | 140 | 364 | 198 | 87 | 1,722 |
| Sustainable ocean economy | 280 | 18 | 45 | 19 | 15 | 131 |
| Addendum | | | | | | |
| CCAT in agriculture, forestry, livestock, or agroalimentary production | 442 | 36 | 38 | 20 | 14 | 262 |
| CCMT in agriculture, livestock, or agroalimentary industries | 245 | 24 | 31 | 7 | 11 | 134 |

CCAT = climate change adaptation technology; CCMT = climate change mitigation technology; EU-27 = European Union; USPTO = Patent and Trademark Office.

**Note(s):**
USPTO patents are allocated according to patent inventorship information. USPTO patents are fractionally allocated among regions, countries, or economies based on the proportion of residences of all named inventors. Patents are classified under the World Intellectual Property Organization (WIPO) classification of patents, which classifies International Patent Classification (IPC) codes under 35 technical fields. IPC reformed codes take into account changes that were made to the WIPO classification in 2006 under the eighth version of the classification and were used to prepare these data. However, because PatentsView only provides the original IPC codes as they appeared on patents and not the IPC reformed codes, current Cooperative Patent Classification codes on patents were converted back to the most recent IPC classification to prepare these statistics. Fractional counts of patents were assigned to each technological field on patents to assign the proper weight of a patent to the corresponding technological fields under the classification. Beginning in 2020, the United Kingdom was no longer a member of the EU. China includes Hong Kong. See File USPTO environmental and critical technology patent data.

**Source(s):**
National Center for Science and Engineering Statistics; Science-Metrix; USPTO data hosted by Reed Tech (LexisNexis), accessed June 2023.

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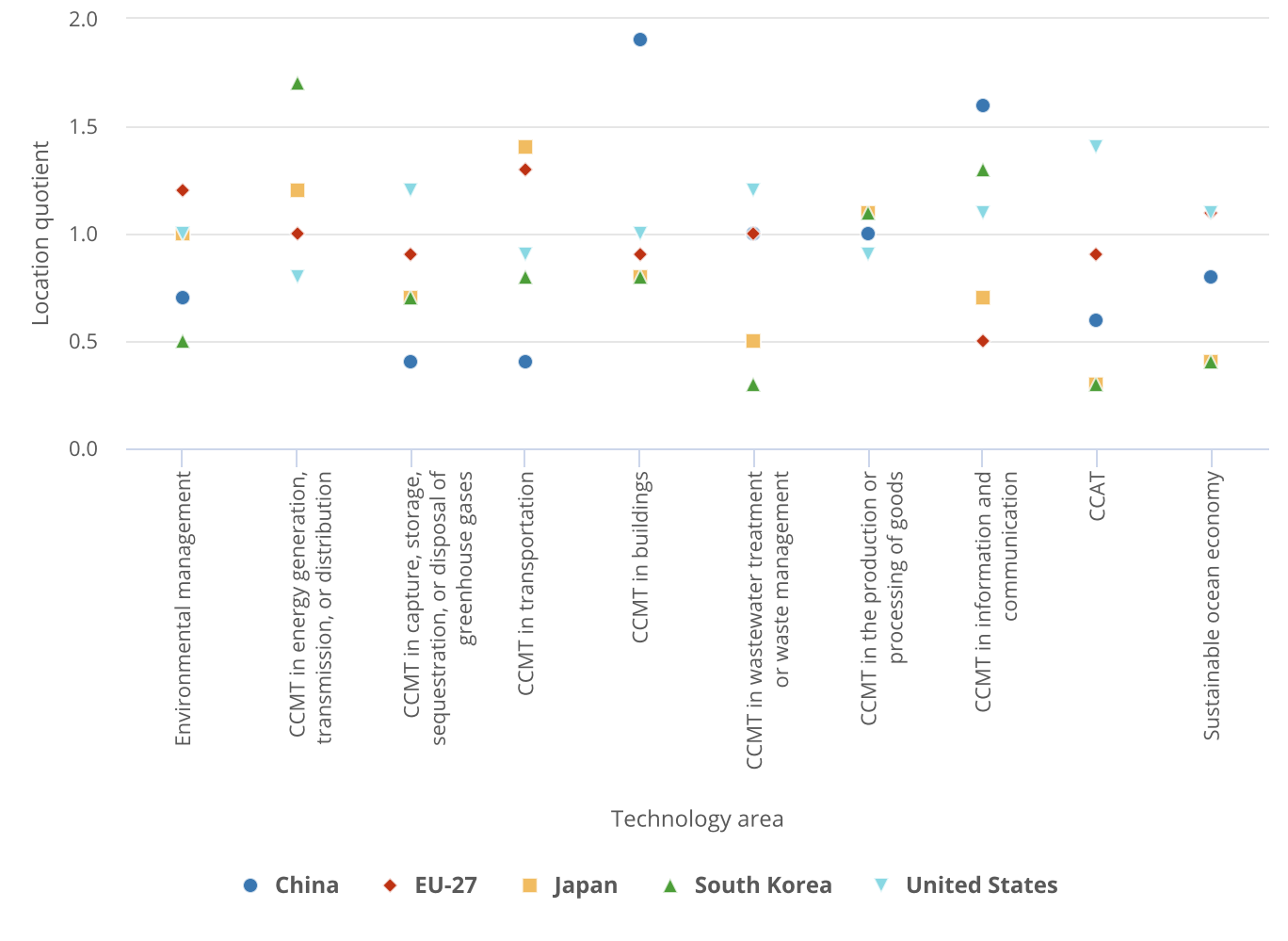
Along with the number of patents granted, location quotients (LQs) are a useful analytical tool for providing insight into the technological specialization by region, country, or economy relative to overall size. The LQs here compare activity in specific technology categories to overall global or national patents in environmental technologies.* For example, while the presentation shown in **Table INV-A** shows higher levels of patenting in energy generation, transmission, or distribution relative to other sustainable technologies, LQs show specialization. For example, an LQ of 1.5 implies that the location has 50% more activity in a given technology than would be expected based on volume alone. Inventors from China are more specialized in CCMT related to buildings (1.9) than would be expected, while the EU-27 (1.3) is more highly specialized in CCMT in transportation, as is Japan (1.4). As shown by LQs closer to 1.0, the United States is more balanced than other locations in its overall concentration of its patenting by technology area (**Figure INV-A**).

Figure INV-A

**Specialization of patents among technology areas for the top 5 regions or countries in environmental sustainability technology: 2011–22**




CCAT = climate change adaptation technology; CCMT = climate change mitigation technology; EU-27 = European Union.

**Note(s):**
Patent and Trademark Office (USPTO) patents are allocated according to patent inventorship information. USPTO patents are fractionally allocated among regions, countries, or economies based on the proportion of residences of all named inventors. Patents are classified under the World Intellectual Property Organization (WIPO) classification of patents, which classifies International Patent Classification (IPC) codes under 35 technical fields. IPC reformed codes take into account changes that were made to the WIPO classification in 2006 under the eighth version of the classification and were used to prepare these data. However, because PatentsView only provides the original IPC codes as they appeared on patents and not the IPC reformed codes, current Cooperative Patent Classification codes on patents were converted back to the most recent IPC classification to prepare these statistics. Fractional counts of patents were assigned to each technological field on patents to assign the proper weight of a patent to the corresponding technological fields under the classification. Beginning in 2020, the United Kingdom was no longer a member of the EU. China includes Hong Kong. United States includes Puerto Rico and all other U.S. territories.

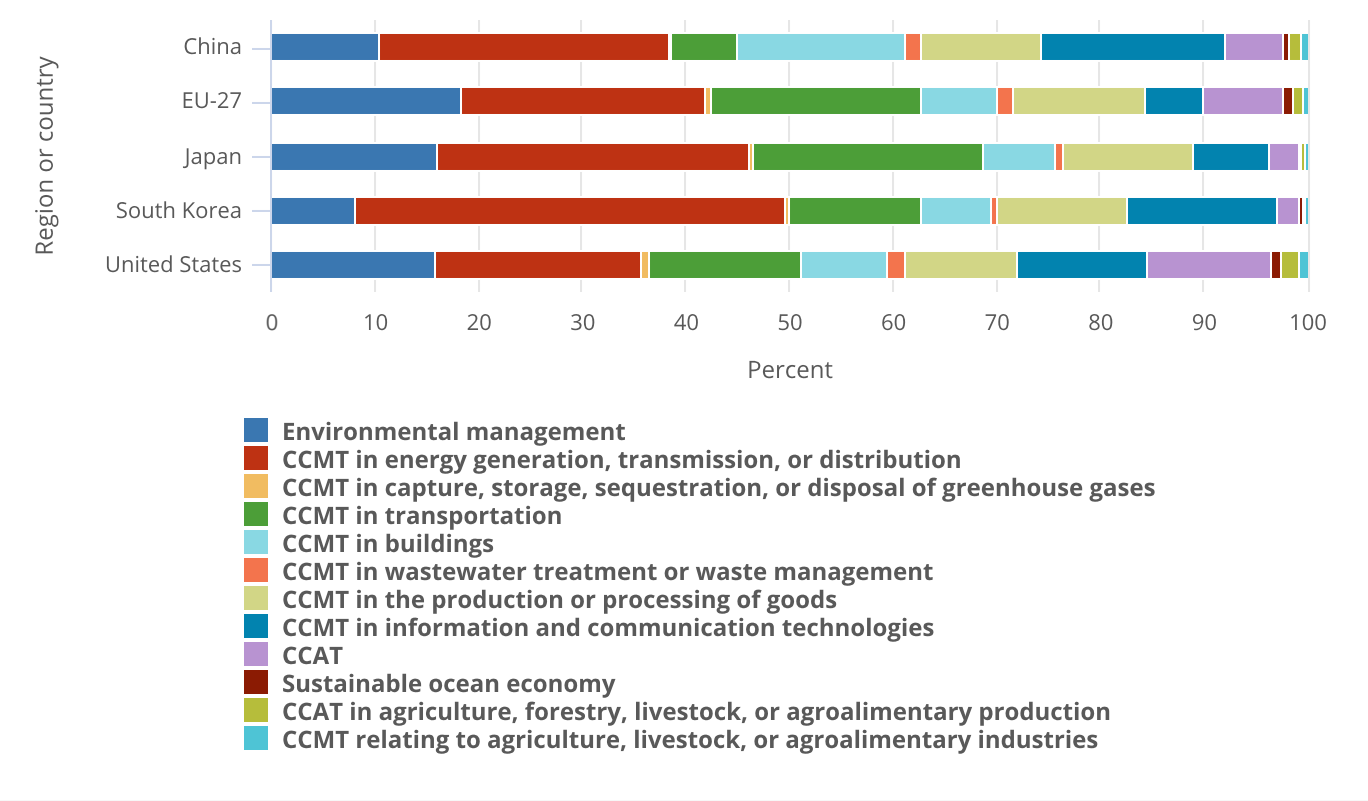
**Source(s):**
National Center for Science and Engineering Statistics; Science-Metrix; PatentsView, USPTO, accessed June 2023.

*Science and Engineering Indicators*

The percent distribution of each region's or country's patenting across environmental sustainability technology areas shows where its patenting activity is greatest. For each of the five leading regions or countries in environmental sustainable technology patenting, climate change mitigation technologies in energy generation, transmission, or distribution represent the largest share of patents (**Figure INV-B**).

Figure INV-B

**Share of environmental sustainability technology patents for the top 5 regions or countries, by technology area: 2011–22**




CCAT = climate change adaptation technology; CCMT = climate change mitigation technology; EU-27 = European Union.

**Note(s):**
Patent and Trademark Office (USPTO) patents are allocated according to patent inventorship information. USPTO patents are fractionally allocated among regions, countries, or economies based on the proportion of residences of all named inventors. Patents are classified under the World Intellectual Property Organization (WIPO) classification of patents, which classifies International Patent Classification (IPC) codes under 35 technical fields. IPC reformed codes take into account changes that were made to the WIPO classification in 2006 under the eighth version of the classification and were used to prepare these data. However, because PatentsView only provides the original IPC codes as they appeared on patents and not the IPC reformed codes, current Cooperative Patent Classification codes on patents were converted back to the most recent IPC classification to prepare these statistics. Fractional counts of patents were assigned to each technological field on patents to assign the proper weight of a patent to the corresponding technological fields under the classification. Beginning in 2020, the United Kingdom was no longer a member of the EU. China includes Hong Kong. United States includes Puerto Rico and all other U.S. territories.

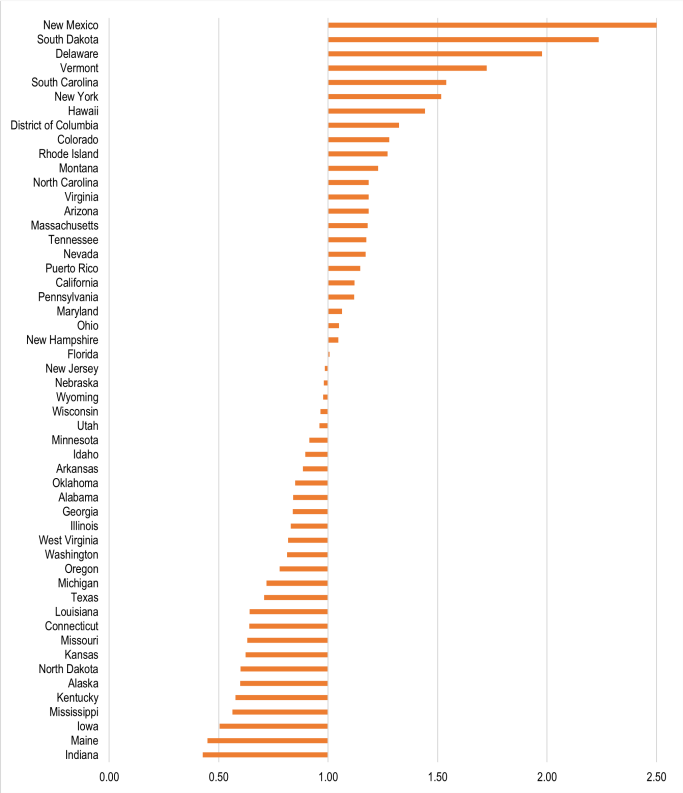
**Source(s):**
National Center for Science and Engineering Statistics; Science-Metrix; PatentsView, USPTO, accessed June 2023.

*Science and Engineering Indicators*

Based on inventor addresses within the United States, the state of New Mexico has the highest degree of specialization in patents in the critical or emerging technology of renewable energy generation and storage among all states. Inventors in New Mexico are 2.5 times more specialized in this technology than would be expected (**Figure INV-C**). For environmental management technologies, Louisiana has the highest degree of specialization, more than 2.1 times what would be expected (**Figure INV-D**). Supplementary tables and public-use data sets released with this report provide annual state-level USPTO patent counts by sustainability category that will allow for additional analysis (File USPTO environmental and critical technology patent data).

Figure INV-C

## Location quotients of U.S. states for patents in climate change mitigation technologies in energy generation, transmission, or distribution: 2011–22




CCMT = climate change mitigation technology.

**Note(s):**
Patents are attributed to states using a fractional count based on the states listed as the residences of inventors. Location quotient measures each state's concentration of patenting in a technology area among sustainable technologies relative to the U.S. concentration of patenting in that area.

**Source(s):**
National Center for Science and Engineering Statistics; Science-Metrix; PatentsView, USPTO, accessed June 2023.

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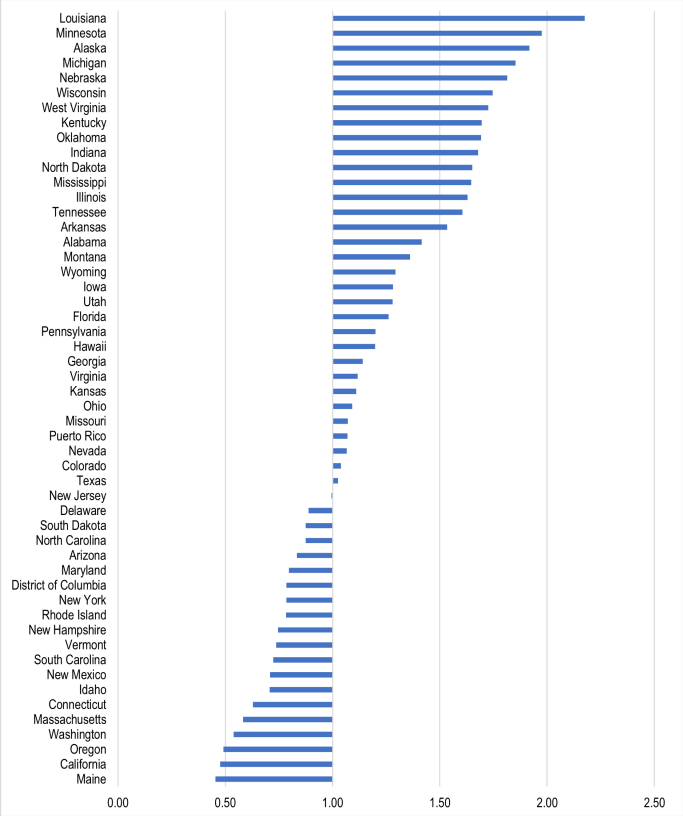
Figure INV-D

## Location quotients of U.S. states for patents in environmental management: 2011–22




**Note(s):**
Patents are attributed to states using a fractional count based on the states listed as the residences of inventors. Location quotient measures each state's concentration of patenting in a technology area among sustainable technologies relative to the U.S. concentration of patenting in that area.

**Source(s):**
National Center for Science and Engineering Statistics; Science-Metrix; PatentsView, USPTO, accessed June 2023.

*Science and Engineering Indicators*

* A location quotient of 1.0 in each technology means that particular subregion and the entire area are equally specialized in the technology based on patents granted. A location quotient greater than 1.0 means that the subregion is relatively more specialized than the entire area in that technology. A public-use file released with this report provides region, country, or economy data along with U.S. state-level data for these patents (File USPTO environmental and critical technology patent data).

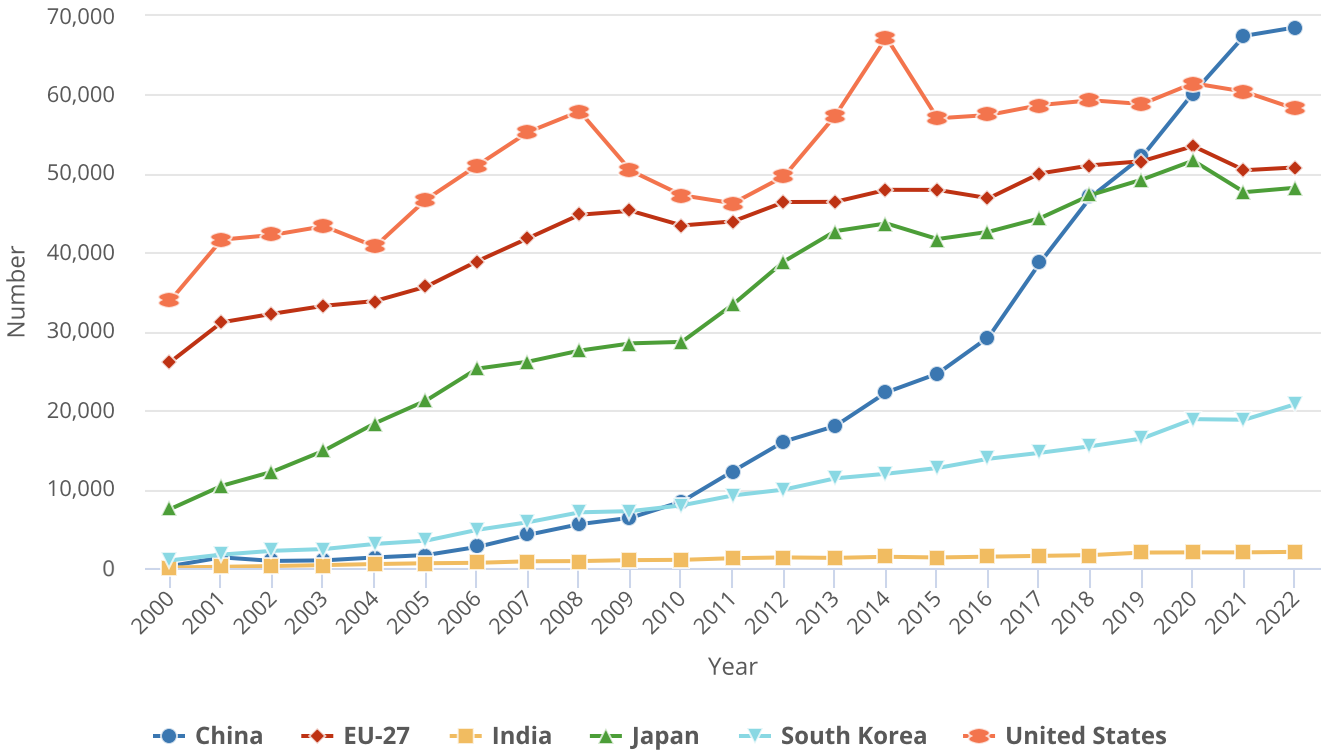
## Global Trends in Patenting Activity

In contrast to the U.S.-focused data presented earlier in this report from USPTO, this section presents global trends using a more inclusive global data set that is based on patent application information rather than patents granted. Patent applications filed under the Patent Cooperation Treaty (PCT) show the number of inventions whose owners have sought international protection across many countries or economies simultaneously. The data source in this section is the World International Property Organization (WIPO) database and the unit of measurement is a patent application filed under the PCT. This treaty allows a patent to gain protection in multiple jurisdictions, and use of these application data avoids double counting across these jurisdictions. These data have different characteristics compared with USPTO data on patents granted. Compared with patents filed solely in an inventor's home jurisdiction, fewer patents are filed under the PCT. Other differences are that not all applications are subsequently granted and that not all patented inventions appear in the application data. Also, these PCT application data are classified based on the receiving office, which usually corresponds to the location of the inventor. Taiwan is not a party to the PCT, so it is not represented in the data. Table SINV-11 through Table SINV-16 provide data by country and broad technology area.

China, the United States, the EU-27, and Japan are leading jurisdictions in terms of the number of PCT applications filed in 2022. Of these, the fastest growth over the preceding 10-year period occurred in China (330%) and South Korea (110%). In 2015, the United States had more than twice the number of PCT applications as China, the two countries had similar application numbers in 2020, with China's applications exceeding those of the United States for the first time in 2021 (**Figure INV-5**).

**Figure INV-5**

**PCT applications for selected regions, countries, and economies: 2000–22**




EU-27 = European Union; PCT = Patent Cooperation Treaty.

**Note(s):**
Figures are based on publication year of PCT applications. Countries are allocated using the receiving office for each PCT application, which is based on the location of the inventors. In cases where PCT applications are filed directly with the World Intellectual Property Organization via its international bureau, the priority country of the earliest document in the same patent family is used (i.e., where the first application in the patent family was filed). Beginning in 2020, the United Kingdom was no longer a member of the EU. China includes Hong Kong.

**Source(s):**
National Center for Science and Engineering Statistics; EP Bibliographic Data (EBD), European Patent Office; 1790 Analytics, accessed June 2023.

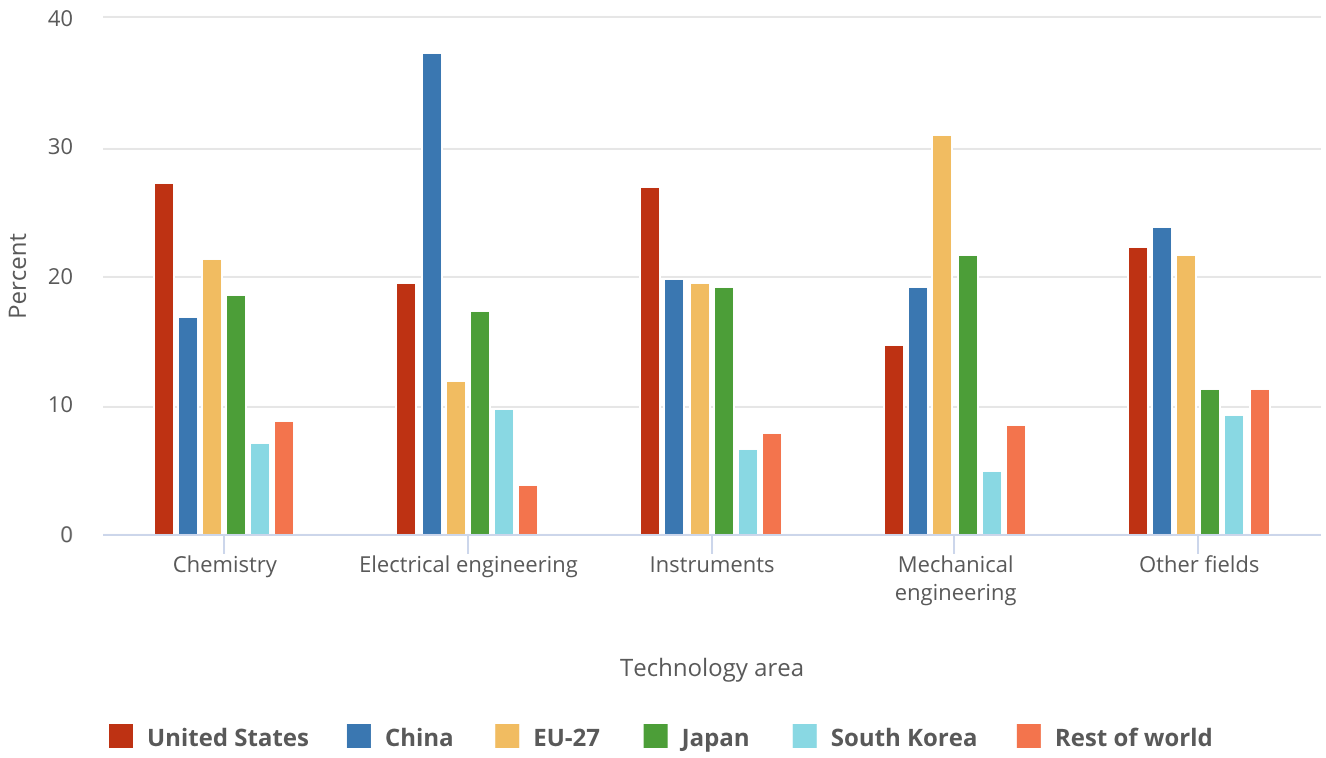
*Science and Engineering Indicators*

## International Patents, by Broad Technology Category

Chemistry, electrical engineering, instruments, mechanical engineering, and other fields are broad categories for the technology areas of utility patents (Table SINV-3). At the national level, both chemistry and instruments were technology areas with greatest participation by U.S. inventors. In 2022, inventors from the United States were granted 27% of chemistry patents and 27% of instruments patents; inventors from China had 37% of the PCT patents granted in electrical engineering (**Figure INV-6**).

**Figure INV-6**

**PCT applications for selected technology areas, by selected region, country, or economy: 2022**




EU-27 = European Union; PCT = Patent Cooperation Treaty.

**Note(s):**
Figures are based on publication year of PCT applications. China includes Hong Kong. Technology areas are derived from the World Intellectual Property Organization (WIPO) concordance of International Patent Classifications to technology categories available at https://www.wipo.int/ipstats/en/. Countries are allocated using the receiving office for each PCT application, which is the location of the inventors. In cases where PCT applications are filed directly with WIPO via its international bureau, the priority country of the earliest document in the same patent family is used (i.e., where the first application in the patent family was filed). See Table SINV-11 through Table SINV-16.

**Source(s):**
National Center for Science and Engineering Statistics; EP Bibliographic Data (EBD), European Patent Office; 1790 Analytics, accessed July 2023.

*Science and Engineering Indicators*

## Global Patenting Activity in Artificial Intelligence

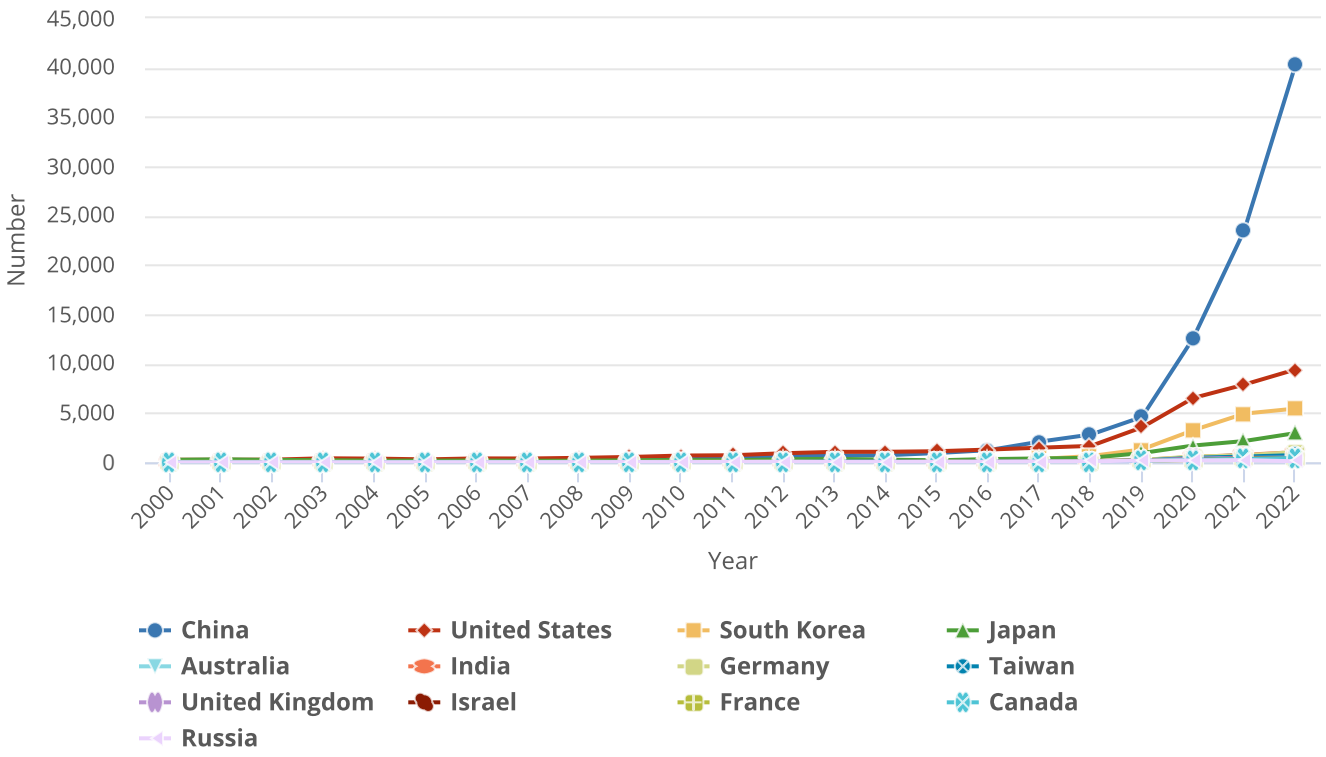
This section examines trends over time in AI patenting across regions, countries, and economies. AI is identified as a critical or emerging technology (NSTC 2022). The technology-level analysis of international patent family data from the European Patent Office's Global Patent Index database covers years since 2000 with AI patents granted, rather than applications, as the unit of measurement.

This presentation contains 13 categories based on 3 distinct dimensions of AI patents that are categorized using a taxonomy developed by the Association for Computing Machinery and employed in previous studies of AI patenting by WIPO (WIPO 2019). *AI techniques* are defined by how the invention works, with categories such as machine learning, logic models, and fuzzy logic. *Functional applications* reflect what the invention does, with categories including computer vision, control systems, measurement and testing, and knowledge representation (Table SINV-18). *Application fields* reflect where the invention is designed to be used, with categories of life sciences, transportation, energy management, and industrial and manufacturing applications.[2]

Based on this taxonomy, about 190,000 AI patents were granted worldwide between 2000 and 2022 (Table SINV-17). In 2022, about 40,000 AI patents were granted to inventors with addresses from China; the comparable figure for the United States was about 9,000 (**Figure INV-7**). Machine learning, personal devices and computing, and computer vision were categories that had the highest number of patents received, based on technology, application, or field. Among the United States, China, Japan, and South Korea, inventors with addresses in China had the highest number of patents in all three categories (**Figure INV-8**). Within the United States, inventors received the highest number of patents in machine learning, followed by personal devices and telecommunications applications (**Figure INV-8**).[3]

**Figure INV-7**

**Worldwide utility patents in AI granted to inventors, by selected country or economy: 2000–22**




AI = artificial intelligence.

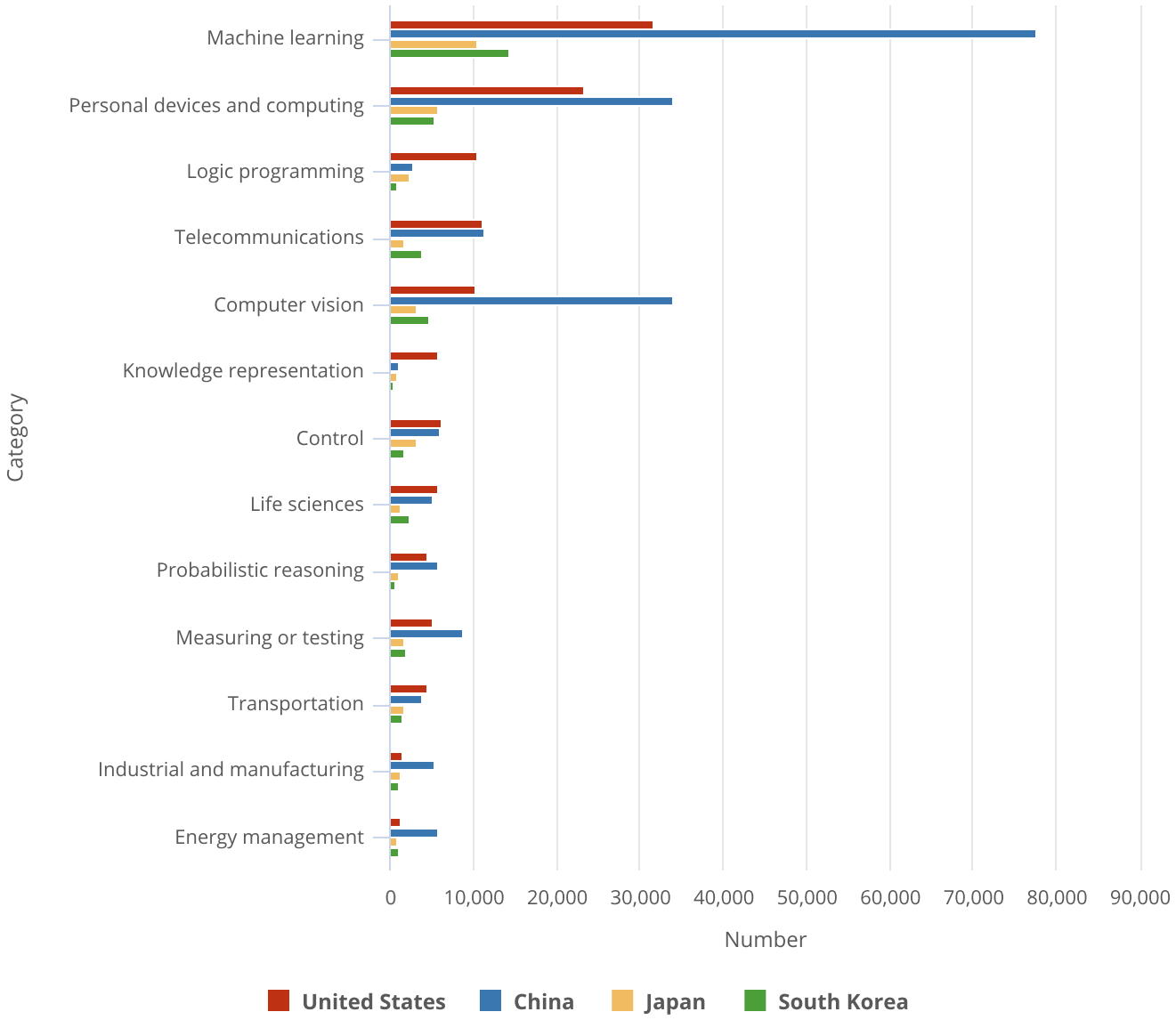
**Note(s):**
Granted patents for all patent authorities are allocated according to patent inventorship information. AI patents are identified and divided into categories using filters consisting of Cooperative Patent Classifications and International Patent Classifications plus keywords and phrases. Details of these filters can be found at https://github.com/georgetown-cset/1790-ai-patent-data/. Only the first granted patent in each patent family is counted so as to avoid double counting the same invention. Patent families containing no granted patents are excluded. Country assignments are based on fractional counting of countries of residence of inventors as listed in the associated record from the Global Patent Index. If no inventor countries are listed, the priority country is used (i.e., where the first application in the patent family was filed). China includes Hong Kong.

**Source(s):**
National Center for Science and Engineering Statistics; European Patent Office Global Patent Index; 1790 Analytics, accessed June 2023.

*Science and Engineering Indicators*

**Figure INV-8**

**Worldwide granted utility patents in AI techniques, functional applications, and application fields, by selected country: 2000–22**




AI = artificial intelligence.

**Note(s):**
Granted patents for all patent authorities are allocated according to patent inventorship information. AI patents are identified and divided into categories using filters consisting of Cooperative Patent Classifications and International Patent Classifications plus keywords and phrases. Details of these filters can be found at https://github.com/georgetown-cset/1790-ai-patent-data/. Only the first granted patent in each patent family is counted so as to avoid double-counting the same invention. Patent families containing no granted patents are excluded. Country assignments are based on fractional counting of inventor locations as listed in the associated record from the Global Patent Index. If no inventor countries are listed, the priority country is used (i.e., where the first application in the patent family was filed). China includes Hong Kong.

**Source(s):**
National Center for Science and Engineering Statistics; European Patent Office Global Patent Index; 1790 Analytics, accessed June 2023.

*Science and Engineering Indicators*

In addition to AI, there are critical or otherwise important technologies within the technologies such as chemistry, electrical engineering, or instruments. USPTO patenting activity for the technologies funded by Congress in recent legislation is described in the sidebar **Patenting That Addresses CHIPS and Science Act Technologies**.

SIDEBAR

### Patenting That Addresses CHIPS and Science Act Technologies

The CHIPS and Science Act, passed in 2022, provides research funding in several technical areas identified as important to competitiveness and national security. While semiconductor technology was highlighted in coverage of the act, several technological areas were identified within the legislation (Congress.gov 2022). **Table INV-B** provides preliminary and prototype classifications and patent counts for 2022 for the technologies within the legislation that link to technologies within existing utility patent classes. By this measure, there were 190,000 Patent and Trademark Office utility patents granted in 2022 in technology areas that correspond to CHIPS and Science Act technologies, about half of which were granted to U.S. inventors. By this measure, over half of the patents granted in artificial intelligence, machine learning, autonomy, and related advances; robotics, automation, and advanced manufacturing; biotechnology, medical technology, genomics, and synthetic biology; and data storage, data management, distributed ledger technologies, and cybersecurity, including biometrics, were awarded to inventors who resided in the United States. A public-use file released with this report provides region, country, or economy data along with U.S. state-level data for the 10 subcategories shown in **Table INV-B** (also see File USPTO environmental and critical technology patent data).

**Table INV-B**

**USPTO utility patents granted in critical technology categories: 2022**

(Number)

| Category | Worldwide | U.S. inventors |
|---|---|---|
| All critical technology categories | 192,754 | 85,739 |
| Artificial intelligence, machine learning, autonomy, and related advances | 16,288 | 8,245 |
| High-performance computing, semiconductors, and advanced computer hardware and software | 42,064 | 19,529 |
| Quantum information science and technology | 2,019 | 907 |
| Robotics, automation, and advanced manufacturing | 4,450 | 2,356 |
| Natural and anthropogenic disaster prevention or mitigation | 15,402 | 6,146 |
| Advanced communications technology and immersive technology | 28,056 | 13,384 |
| Biotechnology, medical technology, genomics, and synthetic biology | 21,853 | 11,366 |
| Data storage, data management, distributed ledger technologies, and cybersecurity, including biometrics | 18,246 | 9,551 |
| Advanced energy and industrial efficiency technologies, including (but not limited to) the purposes of electric generation | 29,150 | 8,968 |
| Advanced materials science, including composites 2D materials, other next-generation materials, and related manufacturing technologies | 15,226 | 5,287 |

USPTO = Patent and Trademark Office.

**Note(s):**
Patents are allocated according to patent inventorship information. Patents are credited on a fractional-count basis (i.e., for patents with collaborating institutions, each institution receives fractional credit on the basis of the proportion of inventors from participating institutions). See File USPTO environmental and critical technology patent data.

**Source(s):**
National Center for Science and Engineering Statistics; Science-Metrix; PatentsView, USPTO, accessed June 2023.

*Science and Engineering Indicators*

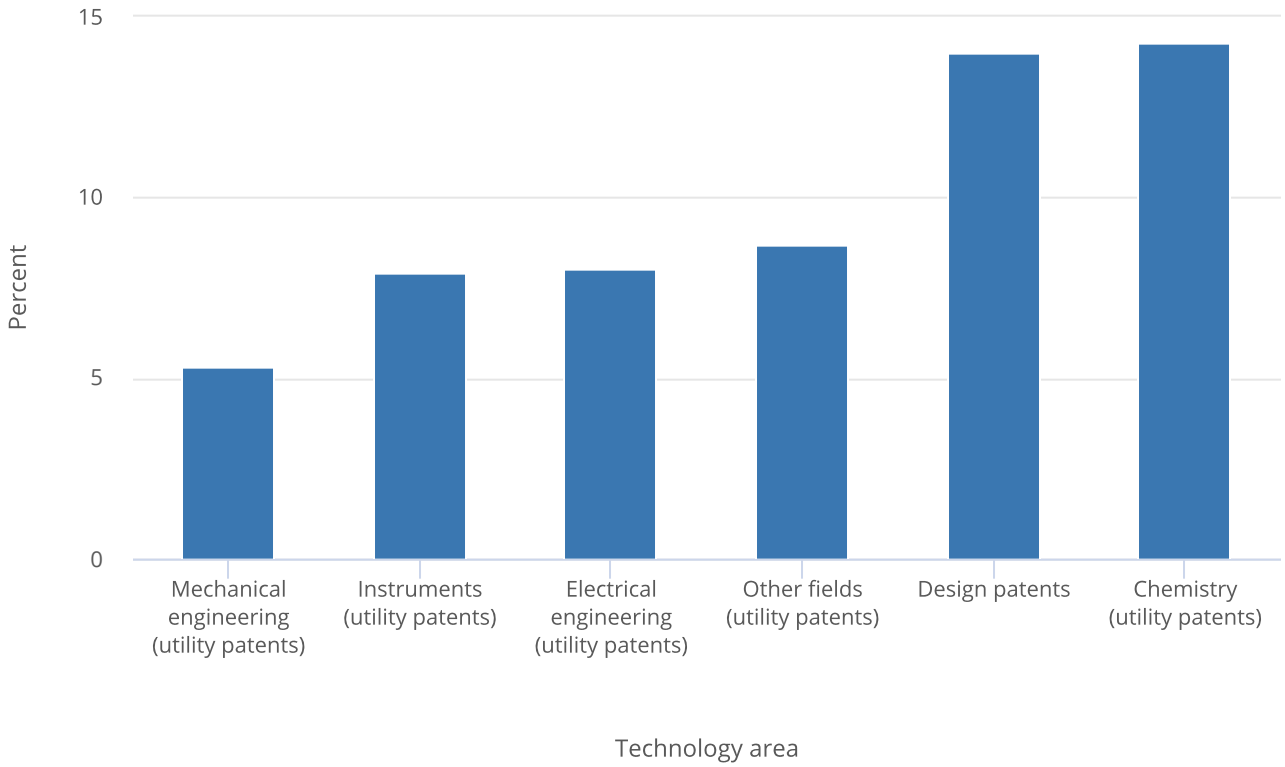
## Counting Women as Patented Inventors

The information required to register a patent generally includes an inventor's name but not their gender. Thus, comprehensive longtime sources of information on patenting by gender are scarce. Computer matching of inventor names to their most likely gender is often used along with verification against data sets of known inventors and their gender.[4] Analyses like these have shown that patenting activity is unevenly distributed among men and women, with men much more likely to be inventors named on granted patents (USPTO, Office of the Chief Economist 2020; WIPO 2020).

This section reports on the prevalence of women as inventors in design patents and utility patents in broad technology areas. The analysis is based on USPTO data and uses the WIPO Gender Name Dictionary drawn from a data set of worldwide patents to assign inventors to a gender (Martinez et al. 2021). The methodology is further described in the **Technical Appendix** to this report. For all patents granted from 2000 through 2022, the share of inventors who are women is highest in chemistry-related utility patents and design patents (based on female names) on patents granted (14% each), and mechanical engineering has the smallest share (5%) over the 22-year period (**Figure INV-9**). Across all fields, women have increased their participation in patenting, with the fastest increase in electrical engineering, where the share of women inventors increased from 5% in 2000 to 10% in 2022. The category with the highest share in 2022 is chemistry (18%), followed closely by design patents (16%) (**Figure INV-10**).

**Figure INV-9**

**Inventors with female names on granted USPTO patents, by technology area: 2000–22**




USPTO = Patent and Trademark Office.

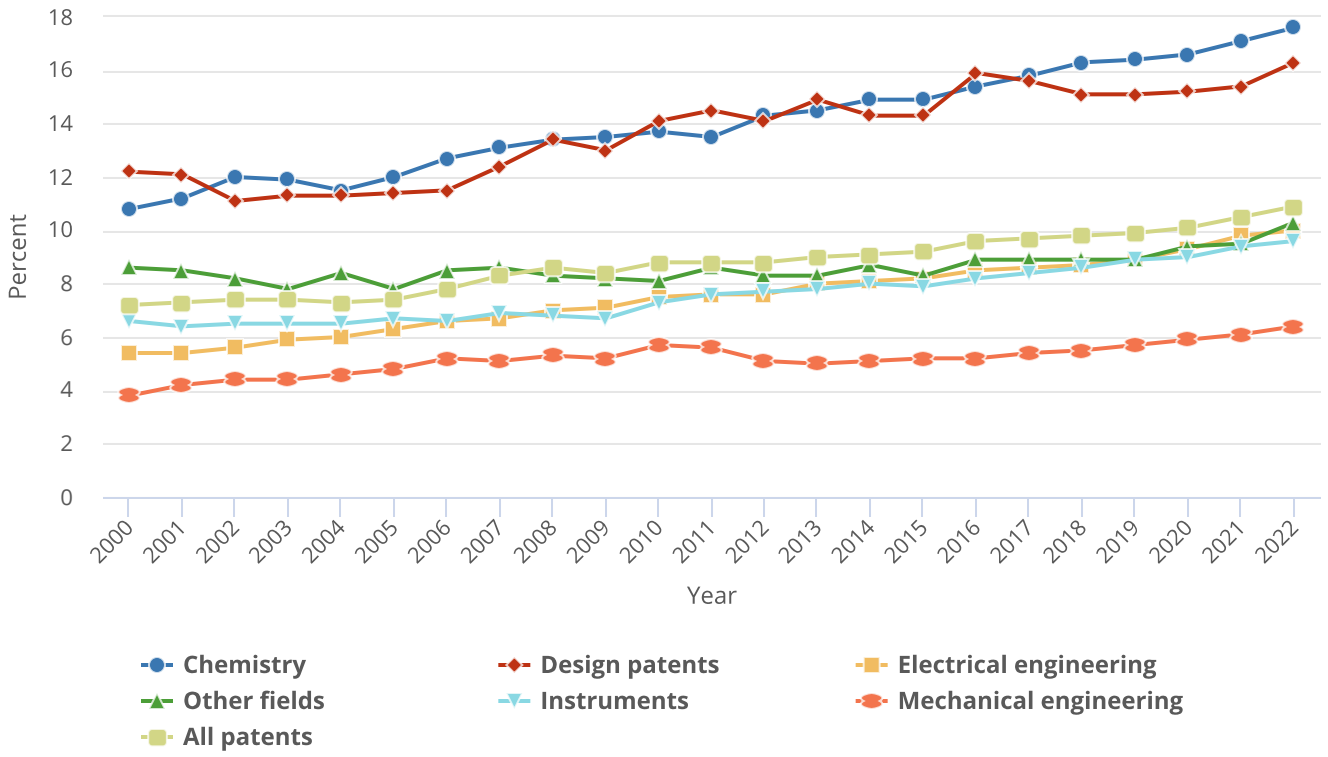
**Note(s):**
The analysis of patenting by gender is based on patents granted by USPTO. Fractional counting of inventors is used, with the credit for each patent divided equally between the inventors. The gender of inventors is determined using the World Intellectual Property Organization (WIPO) World Gender-Name Dictionary Version 2.0, available at https://dataverse.harvard.edu/dataverse/WGND. The process for matching inventor names to genders is based on the WIPO guidelines described at https://tind.wipo.int/record/45020?ln=en. Technology areas are based on the WIPO concordance of International Patent Classifications to technology categories available at https://www.wipo.int/ipstats/en/.

**Source(s):**
National Center for Science and Engineering Statistics; USPTO Bulk Data Storage System (BDSS); 1790 Analytics, accessed June 2023.

*Science and Engineering Indicators*

**Figure INV-10**

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




USPTO = Patent and Trademark Office.

**Note(s):**
The analysis of patenting by gender is based on patents granted by USPTO. Fractional counting of inventors is used, with the credit for each patent divided equally between the inventors. The gender of inventors is determined using the World Intellectual Property Organization (WIPO) World Gender-Name Dictionary Version 2.0, available at https://dataverse.harvard.edu/dataverse/WGND. The process for matching inventor names to genders is based on the WIPO guidelines described at https://tind.wipo.int/record/45020?ln=en. Technology areas are based on the WIPO concordance of International Patent Classifications to technology categories available at https://www.wipo.int/ipstats/en/.

**Source(s):**
National Center for Science and Engineering Statistics; USPTO Bulk Data Storage System (BDSS); 1790 Analytics, accessed June 2023.

*Science and Engineering Indicators*

Academic research on the share of women as inventors has highlighted factors outside of the technology field. Once women are in the science and engineering (S&E) workforce, factors that are associated with the increased participation of women as patented inventors include collaboration with university advisors in graduate programs. This collaboration is associated with higher rates of first-time patenting by women, identifying a role for mentorship at universities in the invention process (Delgado and Murray 2021, 2022).

## Knowledge Transfer Indicators: Putting Information to Use

Both formal R&D and informal activities like learning-by-doing produce new knowledge. Knowledge transfer encompasses the many activities whereby newly created knowledge is shared with those who can apply it, develop it, or transform it into new outputs, inventions, and innovations. That knowledge can be transferred through the dissemination of the information embedded in documented R&D outputs, such as publications, patents, and software; through direct organization-to-organization interaction and collaboration; and via both formal and informal interaction among individuals. Coauthorship of research publications across business, academia, and government is used to measure the transfer of knowledge across sectors. Citations to the peer-reviewed scientific literature appearing in patents provide evidence of the application of scientific knowledge in inventions and highlight knowledge transfer within and between sectors (such as between universities and businesses).

Knowledge embedded in technology constitutes a special case of knowledge transfer often referred to as *technology transfer* and is tracked for universities as well as for the federal government. Indicators discussed in this thematic report include both the narrower case of technology transfer and the broader category of knowledge transfer.

The institutional performers of R&D activity are covered in detail in the forthcoming *Indicators 2024* report "[2024] Research and Development: U.S. Trends and International Comparisons" and the *Indicators 2024* report "[2024] Academic Research and Development." Knowledge transfer also includes transfer between individuals, transfer from one organization to another, and transfer to new fields of study and domains of application.

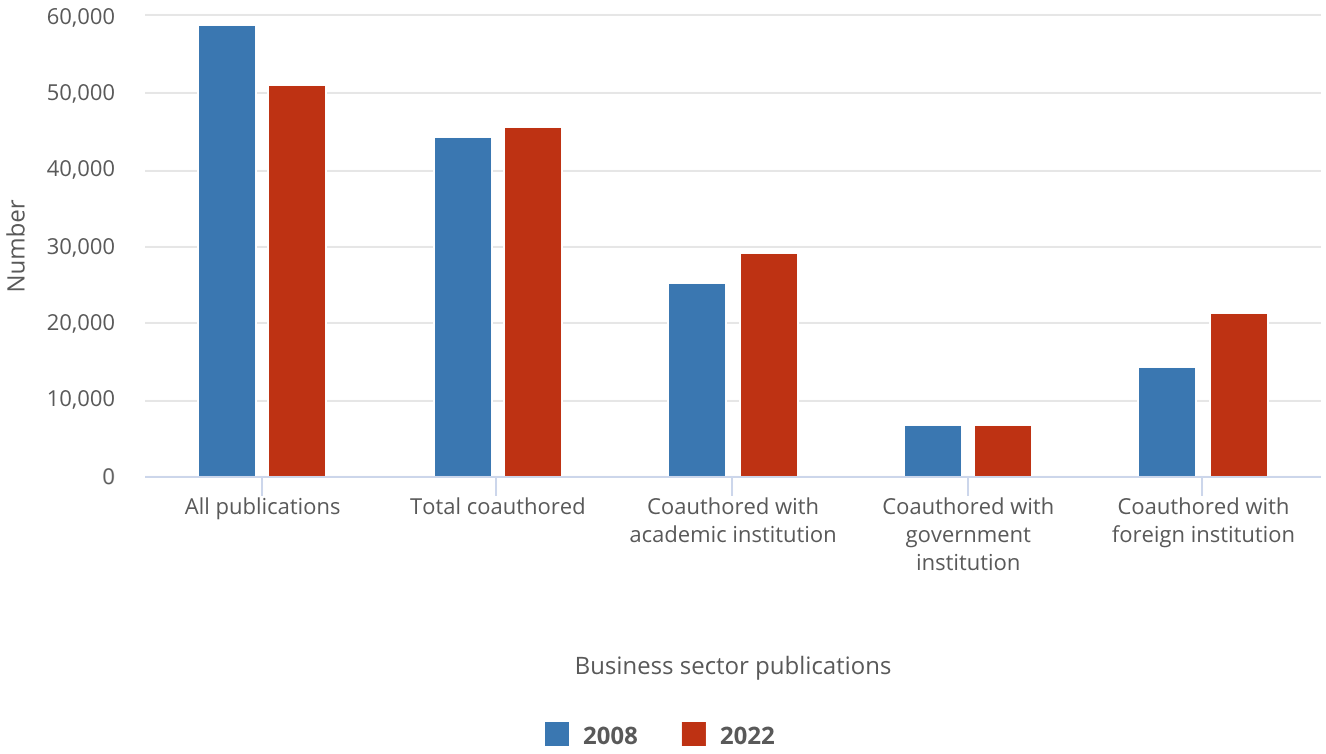
### Business Collaborations and Patent Citations to Published Literature

All parties have the potential to benefit when business, academia, and government agencies collaborate. Through collaboration, the participants share access to advanced tools, emerging technologies, unpublished or private data, and technical expertise. Coauthorship of peer-reviewed publications in the Scopus database is an indicator of such collaborations. The Scopus database is an abstract and citation database of scholarly literature that is also used in the *Indicators 2024* report "[2024] Publications Output: U.S. Trends and International Comparisons."

To calculate collaboration activity, each author is credited once for their participation in the article. On this basis, more than 51,000 publications included authors with U.S. business affiliations.[5] In 2022, over 45,600 (90%) of business-authored publications were coauthored with authors from other institutions, up from about 44,000 (75%) in 2008 (**Figure INV-11**). Collaborations between U.S. business authors and U.S. academic authors grew by almost 4,000 publications to more than 29,000 in 2022 (**Figure INV-11**). There were about 7,000 coauthored publications with U.S. government and U.S. business institutions, about 13% of all business-authored publications in 2022 (**Figure INV-11**).

**Figure INV-11**

**Business sector publications coauthored with academic, government, and foreign institutions: 2008 and 2022**




**Note(s):**
Publications are classified by their publication year and are assigned to a sector based on the institutional address(es) listed within the author information. Each publication is credited to a sector based on the institution type. Each collaborating institution is credited as coauthoring in this figure when the listed authors come from different sectors. The publication is counted as one count in the sector (whole counting). Publications can be authored by collaborators in multiple sectors; thus, the sum of publications coauthored with various sectors can exceed the total. Publications from unknown U.S. sectors are not shown.

**Source(s):**
National Center for Science and Engineering Statistics; Elsevier; Scopus abstract and citation database, accessed May 2023.

*Science and Engineering Indicators*

Consistent with the overall increase of international collaboration in peer-reviewed literature (NSB 2021a), the largest increase in collaboration for business-authored publications is with international authors. Among the business-coauthored publications, this category of cooperation grew the most. From 2008 to 2022, the number and proportion of publications coauthored between U.S. businesses and foreign collaborators increased, reaching about 21,500 (42%) of all business-authored publications in 2022 versus about 14,500 in 2008 (25%) (**Figure INV-11**). Publications, citations, and collaborations in peer-reviewed literature are covered in greater depth in the *Indicators 2024* report "[2024] Publications Output: U.S. Trends and International Comparisons."

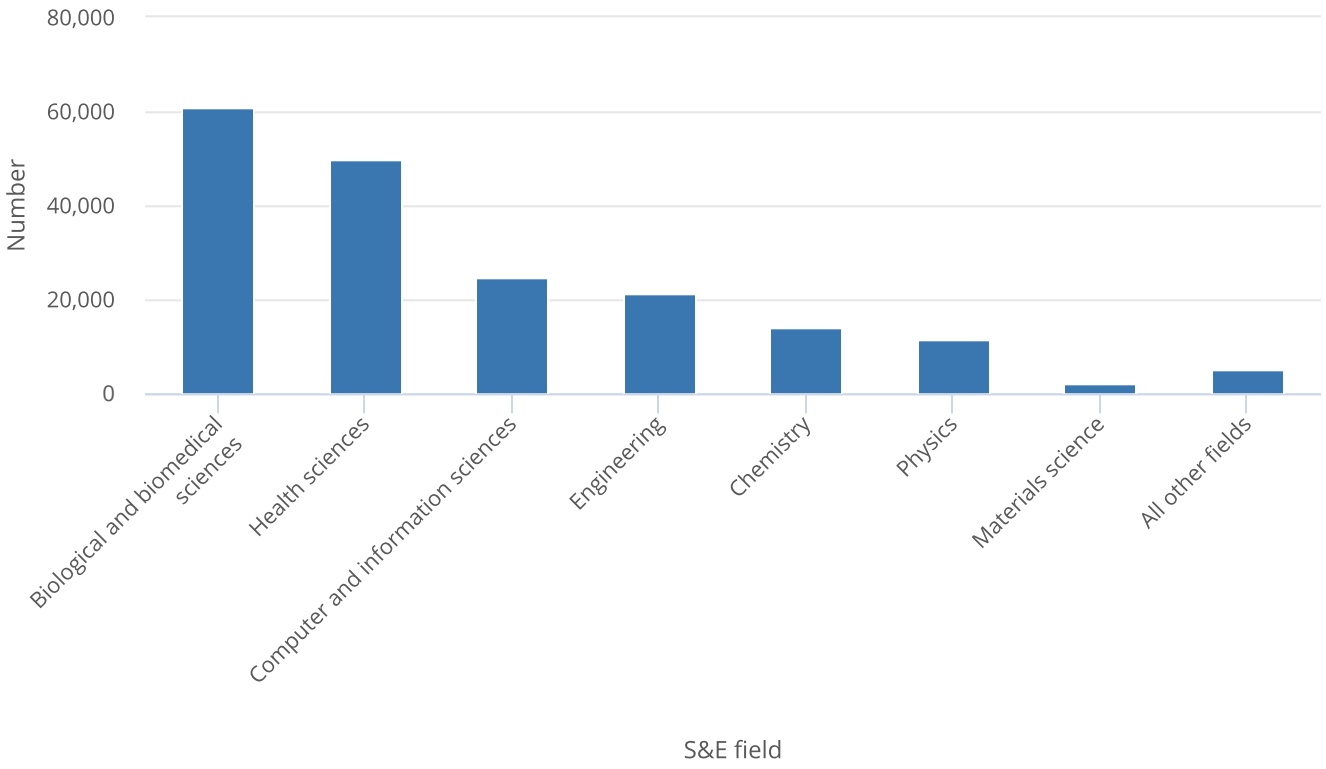
## Publications Cited in Patents

When peer-reviewed publications from any author are cited in the reference section of patent documents, the linkage between the two documents indicates that the scientific literature may have contributed knowledge to the patented invention. Analyses of these citations show the disproportionately large role of academic publications in the nonpatent literature cited in patents, pointing to the importance of academic research in invention (Table SINV-21). Of almost 634,000 citations to S&E articles in patents in 2022, about 30% were to articles from the U.S. academic sector (Table SINV-21).[6]

By field of science, biological and biomedical sciences are cited more often than any other S&E field in U.S.-granted patents; this is true for U.S. authors affiliated with academia, business, or federal laboratories. However, the scale of these citations varies substantially among sectors: for S&E publications in the biological and biomedical sciences, those with academic authors were cited by patents 61,000 times, while those publications with business authors were cited 13,000 times and those with federal authors were cited 5,000 times (Table SINV-21). In addition to biological and biomedical sciences, health sciences publications are cited next most frequently in patent documents. U.S. academic authors accounted for almost 50,000 health sciences citations in patent documents (**Figure INV-12**).

**Figure INV-12**

**Citations of U.S. academic S&E articles in USPTO utility patents, by S&E field of the articles cited: 2022**




USPTO = Patent and Trademark Office.

**Note(s):**
See Table SINV-21 for additional detail.

**Source(s):**
National Center for Science and Engineering Statistics; Science-Metrix; PatentsView, USPTO, accessed June 2023; Elsevier, Scopus abstract and citation database, accessed May 2023.

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## Federal Publications Cited in Patents

At the department or agency level and across disciplines, the Department of Energy (DOE) has the highest number of peer-reviewed publications by federal government authors, about 19,100 in 2022, followed by Department of Health and Human Services (HHS) with 14,000. Publications by federal government authors affiliated with HHS received about 16,000 citations in patent documents in 2022, and those affiliated with DOE authors received the next highest number of citations with about 11,100 citations (**Table INV-2**). The role of these agencies in knowledge transfer is illustrated by the relative magnitudes of these publications and patent citations compared with the magnitude of USPTO patents granted to inventors from federal departments or agencies. Only inventors affiliated with the Department of Defense (DOD) and DOE were granted more than 400 utility patents in 2022 (**Table INV-2**).

**Table INV-2**

**USPTO utility patent and publication metrics for selected federal departments or agencies: 2022**

(Number)

| Metric description | USDA | DOC | DOD | DOE | HHS | DHS | DOI | DOT | VA | EPA | NASA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Publications cited in granted USPTO patents, by author's affiliated agency | 1,689 | 1,505 | 4,614 | 11,116 | 16,063 | 61 | 134 | 29 | 6,027 | 127 | 1,277 |
| Publications with authors from U.S. federal agencies, by author's affiliated agency | 6,422 | 4,209 | 9,160 | 19,100 | 13,923 | 157 | 2,725 | 181 | 13,422 | 672 | 6,303 |
| Patents granted to U.S. federal agencies, by inventor's agency of employment | 22 | 37 | 465 | 425 | 147 | 43 | 1 | 1 | 64 | 8 | 73 |

DHS = Department of Homeland Security; DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; DOI = Department of the Interior; DOT = Department of Transportation; EPA = Environmental Protection Agency; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; USDA = Department of Agriculture; USPTO = Patent and Trademark Office; VA = Department of Veterans Affairs.

**Note(s):**
Data are presented by calendar year. Patents are credited on a whole-count basis (i.e., each participating federal agency on a patent is credited for the entire patent, regardless of coassignments). Articles are credited on a whole-count basis (i.e., each participating federal agency on an article receives credit for the entire article, regardless of coauthors). The sum of the individual federal agencies may exceed the total across agencies because articles may have authors from multiple federal agencies.

**Source(s):**
Science-Metrix using USPTO data indexed in PatentsView, accessed June 2023; Science-Metrix from data provided in Scopus (Elsevier) database, accessed May 2023.

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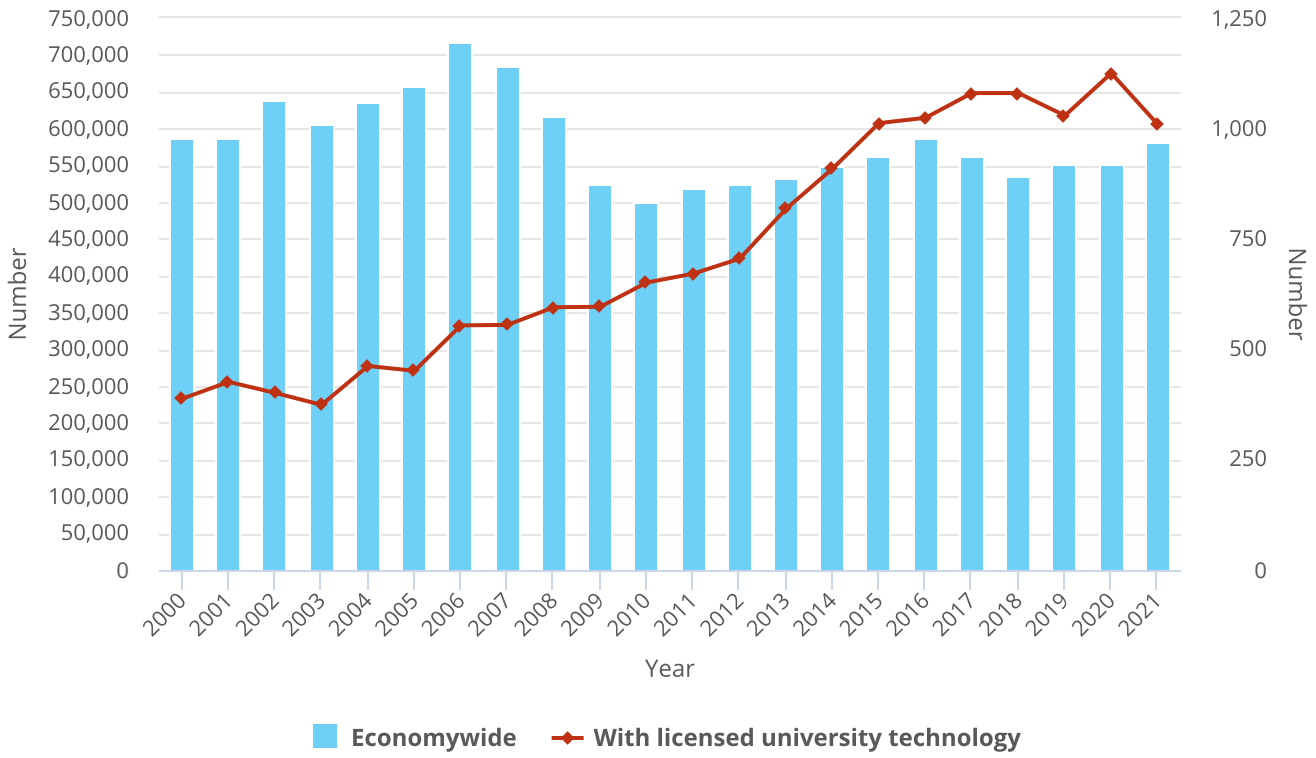
## Startup Companies and University Knowledge Transfer Activities

Change in the number of business establishments created in a given year is an aspect of business dynamism that reflects both broad economic factors as well as the impact of technology transfer to the business sector. For example, in several of the years preceding the global financial crisis, more than 600,000 U.S. establishments were less than 1 year old; that number of new establishments has not been reached in any year since 2008 (**Figure INV-13**).

**Figure INV-13**

**Annual economywide business startups and startups with licensed university technology: 2000–21**




**Note(s):**
Business startups are establishments born within the last 12 months. University startups are based on a survey question that asks how many startup companies were formed in a given year that were dependent on the licensing of the institution's technology for initiation. Startup companies reported by universities in AUTM data refer only to those companies that were formed in the reporting year specifically to develop the technology being licensed.

**Source(s):**
Census Bureau, Business Dynamics Statistics, economywide data through 2021, available at https://data.census.gov/table?q=BDSTIMESERIES.BDSEAGE&tid=BDSTIMESERIES.BDSEAGE&hidePreview=true, accessed October 2023; and AUTM, Statistics Access for Technology Transfer (STATT) Database, Version 4.2, accessed April 2023.

*Science and Engineering Indicators*

A small subset of those startups is formed specifically to develop and license university technology. These startups represent a technology commercialization component of knowledge transfer by university faculty, staff, and students. In addition, for many technology-based startups, possession of a patent or an exclusive option to license a patent is an important factor in attracting external financing. In each year between 2015 and 2021, more than 1,000 businesses were reported as startups by universities in AUTM data (**Figure INV-13**). These startup companies reported by universities in AUTM data refer to companies that were formed in the reporting year specifically to develop the technology being licensed (AUTM 2022).

Patented inventions can be licensed directly to an external party, or an exclusive option can be granted for licensing rights at a future date. According to AUTM, U.S. universities issued almost 8,800 new licenses or options in 2021. Increasingly, university technology licenses or license options are executed by startups and small firms (those with fewer than 500 employees). In 2011, startups and small businesses accounted for 69% of new licenses or options—by 2021, this portion had increased to 78% (**Table INV-3**). Most university-related startups are in the home state of the research university (66%) (**Figure INV-14**). The number of university-related startups launched annually increased steadily through 2017 and reached a peak of 1,125 in 2020 before declining slightly in 2021 (**Figure INV-14**).

**Table INV-3**

**University technology licenses or license options executed, by company characteristic: 2011, 2016, and 2021**

(Number)

| Company characteristic | 2011 | 2016 | 2021 |
|---|---|---|---|
| All licenses, total active | 6,085 | 7,726 | 10,409 |
| New licenses or options executed | 5,862 | 7,165 | 8,769 |
| Startups | 898 | 1,415 | 1,480 |
| Small companies | 3,124 | 3,598 | 5,344 |
| Large companies | 1,840 | 2,152 | 1,945 |

**Note(s):**
AUTM collects data on invention and patent-related activities of its member universities and hospitals. Responding institutions may report for any 12-month period ending in the identified year. Startup companies reported by universities in AUTM data refer only to those companies that were formed in the reporting year specifically to develop the technology being licensed. Counts of licenses to startups and small companies are mutually exclusive. Small companies are those with fewer than 500 employees.

**Source(s):**
AUTM, AUTM Licensing Survey (various years), accessed April 2023.

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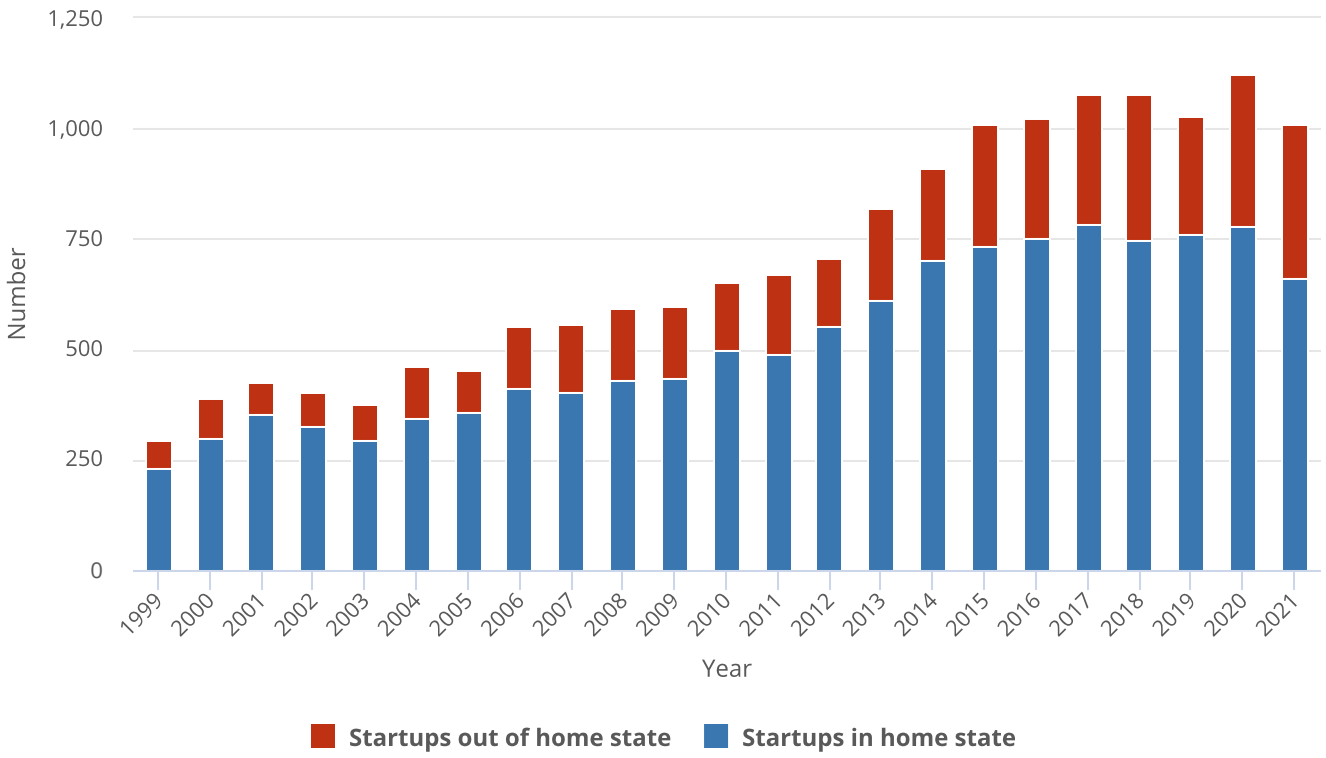
**Figure INV-14**

**Startup companies based on licensed university technology, by company location: 1999–2021**




**Note(s):**
The survey question asks how many startup companies were formed in a given year that were dependent on the licensing of the institution's technology for initiation. Startup companies reported by universities in AUTM data refer only to those companies that were formed in the reporting year specifically to develop the technology being licensed.

**Source(s):**
AUTM, Statistics Access for Technology Transfer (STATT) Database, Version 4.2, accessed April 2023.

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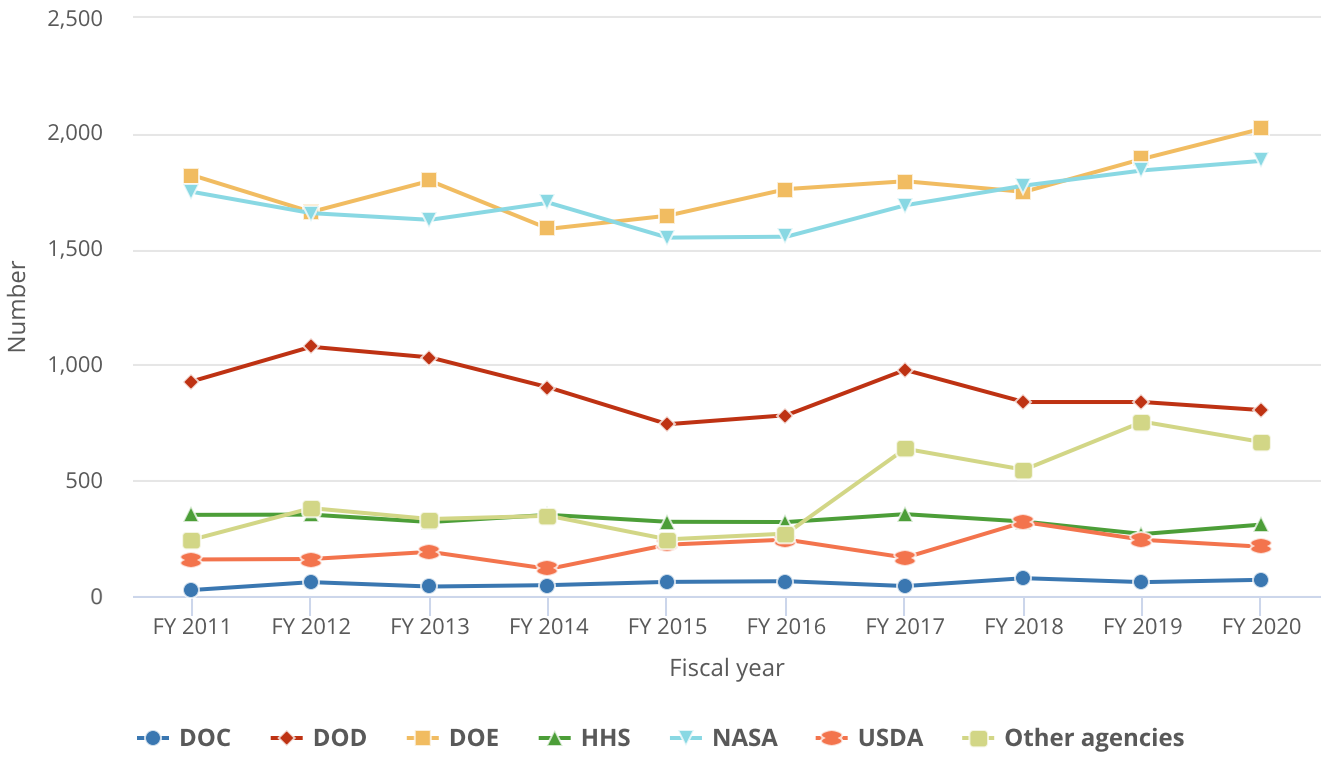
## Federal Government Knowledge Transfer Support

Multiple indicators provide insight into how federal R&D contributes to innovation through knowledge transfer. Federal laboratories facilitate knowledge transfer in various ways, with several measures reported annually by congressional mandate. These measures include R&D spending, invention disclosures, patenting, licensing, and peer-reviewed publications (NIST 2022). Additionally, federal laboratories and federal science-funding agencies support startups in many ways, including through material transfer agreements and collaborative research. Researchers at these laboratories are required to report the development of novel techniques and technologies to laboratory management as *invention disclosure*. While each federal agency has its own process for determining when a researcher is required to file an invention disclosure, the disclosure form is designed to provide the laboratories with sufficient notice to file for patent protection on promising inventions. Two agencies (DOE and National Aeronautics and Space Administration) accounted for over 60% of federal agency invention disclosures in each year from 2011 to 2020, with collectively more than 3,000 disclosures each year (**Figure INV-15**).

**Figure INV-15**

**Invention disclosures reported by selected agencies: FYs 2011–20**




DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; USDA = Department of Agriculture.

**Note(s):**
Federal employees are required to report inventions in a reasonable time through the agency's Invention Disclosure Form. The number of invention disclosures refers to the number of Invention Disclosure Forms submitted to an agency's management during the fiscal year.

**Source(s):**
National Institute of Standards and Technology, Federal Lab Technology Transfer Database, October 2022, and *Summary Report on Federal Laboratory Technology Transfer FY2020*, https://www.nist.gov/tpo/reports-and-publications, accessed May 2023.

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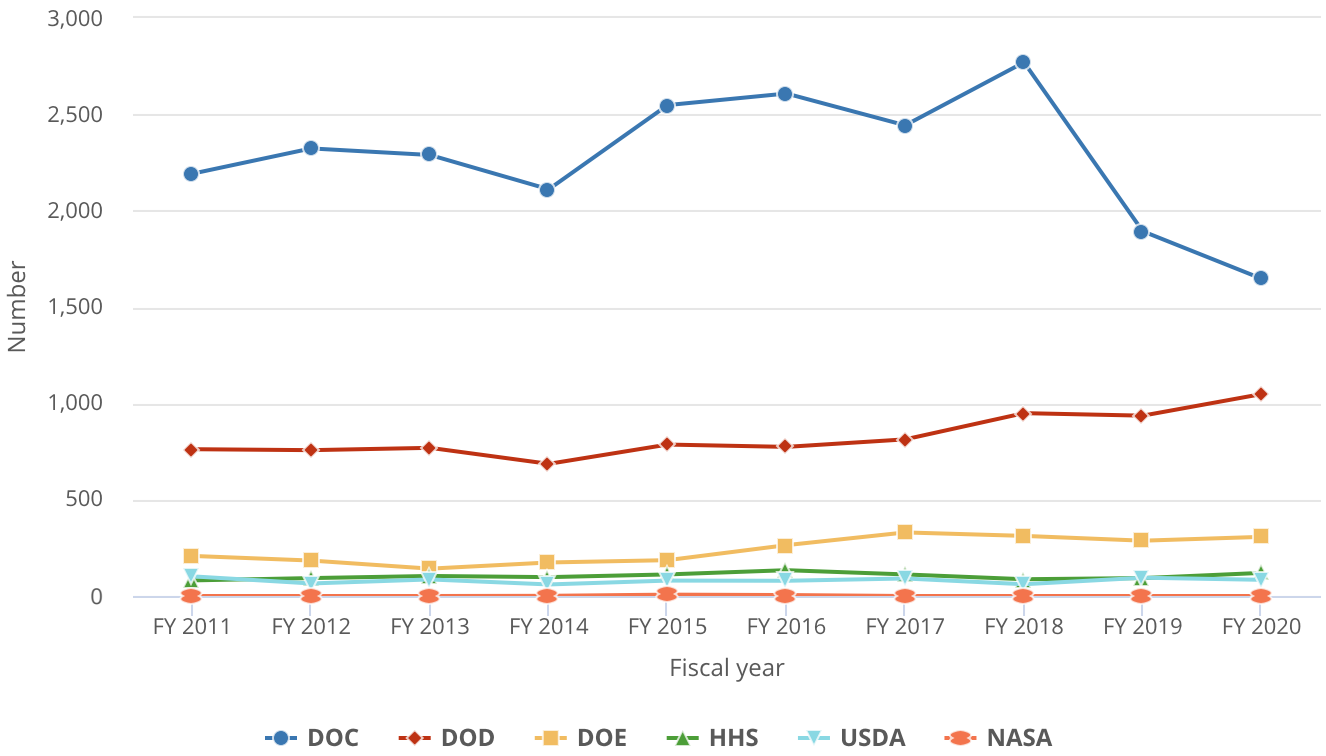
Collaborative relationships include cooperative R&D agreements (CRADAs), of which the traditional type involves an agreement between a federal agency or laboratory and one or more nonfederal organizations. The nonfederal organization (a business, nonprofit, or other government entity) provides some of its own resources for research activity. In exchange, the nonfederal organization is granted the option for an exclusive license to the resulting technologies, if any. Nontraditional CRADAs provide material transfer or other forms of federal technical assistance that may result in protected information. The Department of Commerce (DOC) consistently enters into the highest number of CRADAs (**Figure INV-16**) due to the cooperative research activity at the National Institute of Standards and Technology, which works closely with industry on standards development, metrology techniques, and other research areas with high commercial relevance (DOC 2020). In addition to the technology transfer metrics described here, federal agencies also release data sets and open-source software, and they engage in science activities with the public (see sidebar **Federal Support for Open Science and Public Engagement in Science**).

**Figure INV-16**

**New CRADAs signed by selected agencies: FYs 2011–20**




CRADA = Cooperative Research and Development Agreement; DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; USDA = Department of Agriculture.

**Note(s):**
A CRADA is an agreement between a federal laboratory and a nonfederal entity that is executed under the authority of 15 U.S. Code § 3710a and that includes a research plan or statement of work.

**Source(s):**
National Institute of Standards and Technology, Federal Lab Technology Transfer Database, October 2022, and *Summary Report on Federal Laboratory Technology Transfer FY2020*, https://www.nist.gov/tpo/reports-and-publications, accessed May 2023.

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SIDEBAR

## Federal Support for Open Science and Public Engagement in Science

The White House and other federal agencies declared 2023 to be a year of open science, highlighting information about federal activities that share the results of its research and other work (OSTP 2023). In addition to knowledge creation through publications and patenting, the federal government also shares knowledge it has supported through access to data sets and to software code. As of October 2023, more than 250,000 data sets have been shared (Data.gov). The measures reported here are from federal websites; they are not based on mandatory reporting or comprehensive administrative data. As a result, they can be understood as a limited view of the activity described.

Open-source software provides a form of knowledge transfer through the sharing of digital tools. The U.S. federal government supports the sharing of software developed by and for the federal government through its federal Source Code Policy, which provides a framework for government code to be released and reused through open-source software licensing. This policy allows software created for narrow federal purposes to be reused elsewhere within the

federal government, multiplying its value to the government, and outside of the federal government, further extending its impact. In 2009, only the Department of Energy (DOE), the Department of Commerce, and the National Aeronautics and Space Administration (NASA) used open-source platforms to share software with other users; by 2023, 26 federal departments and agencies did so, based on data at Code.gov.

Federal support for individuals to participate in organized science activity is one way that knowledge about the conduct of science is transferred to the lay public to use. *Public science*, or *citizen science*, is a form of open collaboration in which individuals or organizations participate as volunteers in scientific progress. Data collected from the U.S. federal government website CitizenScience.gov (https://www.citizenscience.gov/#) provide the number of citizen science projects per agency. While the federal government uses the term *citizen science* as well as *crowdsourcing*, this thematic report has adopted the more accurate and inclusive term *public science*.

In 2023, there were 579 projects sponsored by U.S. federal agencies and departments and reported on CitizenScience.gov (**Table INV-C**). With 174 projects, the National Park Service leads federal agencies and departments in sponsoring public science projects, followed by the National Science Foundation (with 77 projects) and the National Oceanic and Atmospheric Administration (with 60 projects) (**Table INV-C**). The sharing of data sets and of open-source software projects comprise another aspect of open science for the government. As of 2020, NASA has made publicly available more than 32,000 data sets, and DOE has made public almost 2,000 software projects (**Table INV-D**).

**Table INV-C**

**Cumulative federally sponsored public science projects on CitizenScience.gov, by federal department or agency: 2022**

(Number)

| Sponsor | Number |
|---|---|
| Total | 579 |
| National Park Service | 174 |
| National Science Foundation | 77 |
| National Oceanic and Atmospheric Administration | 60 |
| Environmental Protection Agency | 47 |
| Geological Survey | 44 |
| Department of Agriculture | 37 |
| National Aeronautics and Space Administration | 28 |
| Forest Service | 21 |
| Fish and Wildlife Service | 16 |
| Smithsonian Institution | 14 |
| National Institutes of Health | 12 |
| Department of Energy | 8 |
| Department of the Interior | 8 |
| Centers for Disease Control and Prevention | 7 |
| Bureau of Land Management | 4 |
| All other U.S. federal projects | 22 |

**Source(s):**
CitizenScience.gov, tabulated by RTI International, April 2023.

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**Table INV-D**

**Knowledge products posted by selected federal agencies: 2020**

(Number)

| Agency | Data sets | Software code |
|---|---|---|
| DOD | 378 | 17 |
| DOE | 2,868 | 1,948 |
| HHS | 2,041 | 179 |
| NASA | 32,089 | 1,257 |

DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration.

**Note(s):**
Data are cumulative as of March 2020. Data are reported for the agencies whose laboratories have the largest R&D budgets.

**Source(s):**
National Academies of Sciences, Engineering, and Medicine, 2021, *Advancing Commercialization of Digital Products from Federal Laboratories*, Table 7.2, https://doi.org/10.17226/26006; Data.gov; Code.gov.

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As individual contributors, developers with federal agency or department affiliations have also made extensive contributions to open-source software, based on information from the GitHub platform (Table SINV-29). The *Indicators 2022* report "[2022] Invention, Knowledge Transfer, and Innovation" provides more extensive discussion of agency-specific information on open-source repositories (NSB ***Indicators 2022***: **Table INV-4**) as well as information about international collaboration in the development of open-source software (NSB ***Indicators 2022***: **Figure INV-A**).

## Innovation Indicators: Introducing New Products and Processes

The implementation of new ideas in the form of products or processes with real-world applications is what separates innovations from inventions. Access to financing is an essential component of the translation of new knowledge into innovations. This section presents a range of indicators of innovation output, starting with data on the funding of innovation through federal programs and through private venture capital. Often, these two kinds of funding work together, with federal funding providing the earlier stage of financial capital.

High rates of innovation activity in the business sector indicate a dynamic economy, whether at the local, regional, or national level (Hall and Jaffe 2018). A key indicator of business innovation activity is the proportion of companies within an industry that introduce new or significantly improved products and processes. Self-reported industry-level data for the United States are provided on the introduction of new or significantly improved products and processes by U.S. businesses, from a joint NCSES and Census Bureau survey.

Trademark registrations from the USPTO "capture the moment at which products or services are introduced into the market, turning inventions into innovations" (von Graevenitz, Graham, and Myers 2022:227–28). Thus, trademarks represent another direct measure of innovative output by firms. Compared with patenting, trademarking is easier and less costly, and it does not have the same requirements regarding novelty (Millot 2009); consequently, small and new businesses apply for trademarks more frequently than they apply for patents (Greenhalgh et al. 2011; Seip, Castaldi, and Flikkema 2019). Therefore, trademarks can reveal service, marketing, and organizational innovation that would not otherwise be captured because the source of innovation is not always tied to technological advances (Castaldi, Block, and Flikkema 2020).

The central role of the business sector in innovation activity has shaped the available data, and most indicators of innovation address the private sector. Notwithstanding the availability of data, however, a diverse set of actors that span the economic sectors of the economy contributes to the creation of innovative output, including universities, government agencies, and public scientists.

### Small Business Innovation Research

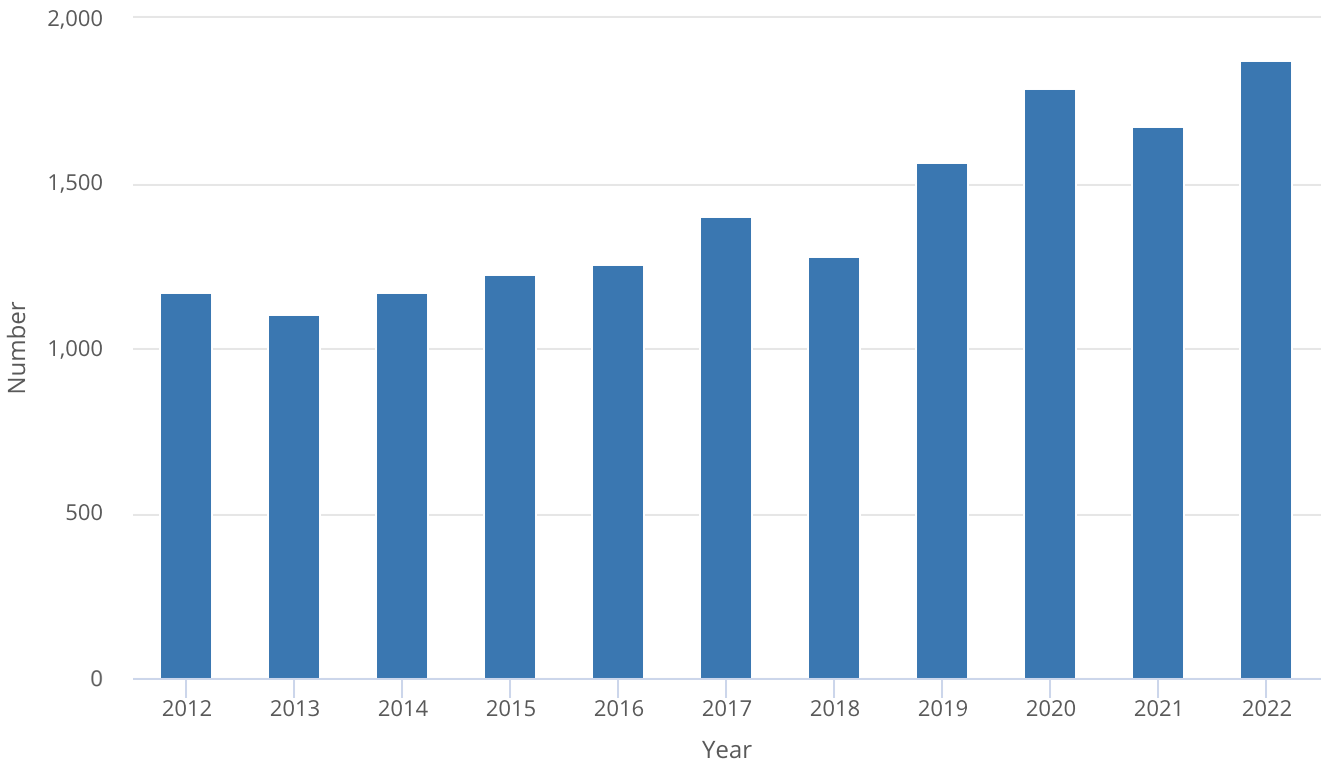
One type of federal government support is the Small Business Innovation Research (SBIR) program. SBIR was established in legislation by the Small Business Innovation Development Act of 1982 (P.L. 97-219) to increase the participation of small firms in federally funded R&D. Federal agencies with over $100 million per year in extramural research spending must establish an agency-specific SBIR program, under the framework and guidelines set by the Small Business Administration (SBA). Over time, the program's objectives have expanded to include the promotion of participation by women-owned and socially disadvantaged businesses and to encourage the commercialization of innovations developed with federal R&D funding. In 1992, Congress established a complementary program, the Small Business Technology Transfer (STTR) program, which supports small firms seeking to commercialize technologies developed at universities and other research institutes.

As of FY 2022, each U.S. federal government agency with over $100 million in R&D expenditures is required to spend 3.2% of its extramural research budget on its SBIR program. There are currently 11 agencies operating SBIR programs, and 5 of those agencies also have STTR programs. Agencies with over $1 billion in R&D spending per year must also operate an STTR program, with funding set at 0.45% of that agency's extramural budget (SBA 2023b).

SBIR funds are awarded at two levels. From the perspective of funding innovation, Phase II awards provide more direct assistance to firms seeking to get new products and services to market. Through these Phase II SBIR awards, federal agencies that fund R&D provide direct support for technology development and commercialization to over 1,000 firms per year. The number of firms receiving Phase II SBIR and STTR awards each year rose from 1,171 in 2012 to 1,870 in 2022 (**Figure INV-17**). At the agency and department level, the largest share of awardees was funded by DOD (50%) (**Figure INV-18**).

**Figure INV-17**

**Firms receiving Phase II SBIR or STTR awards: 2012–22**




SBIR = Small Business Innovation Research; STTR = Small Business Technology Transfer.

**Note(s):**
Firms receiving multiple SBIR or STTR Phase II awards in the same year are counted only once for that year.

**Source(s):**
Small Business Administration, SBIR/STTR Award database, accessed August 2023.

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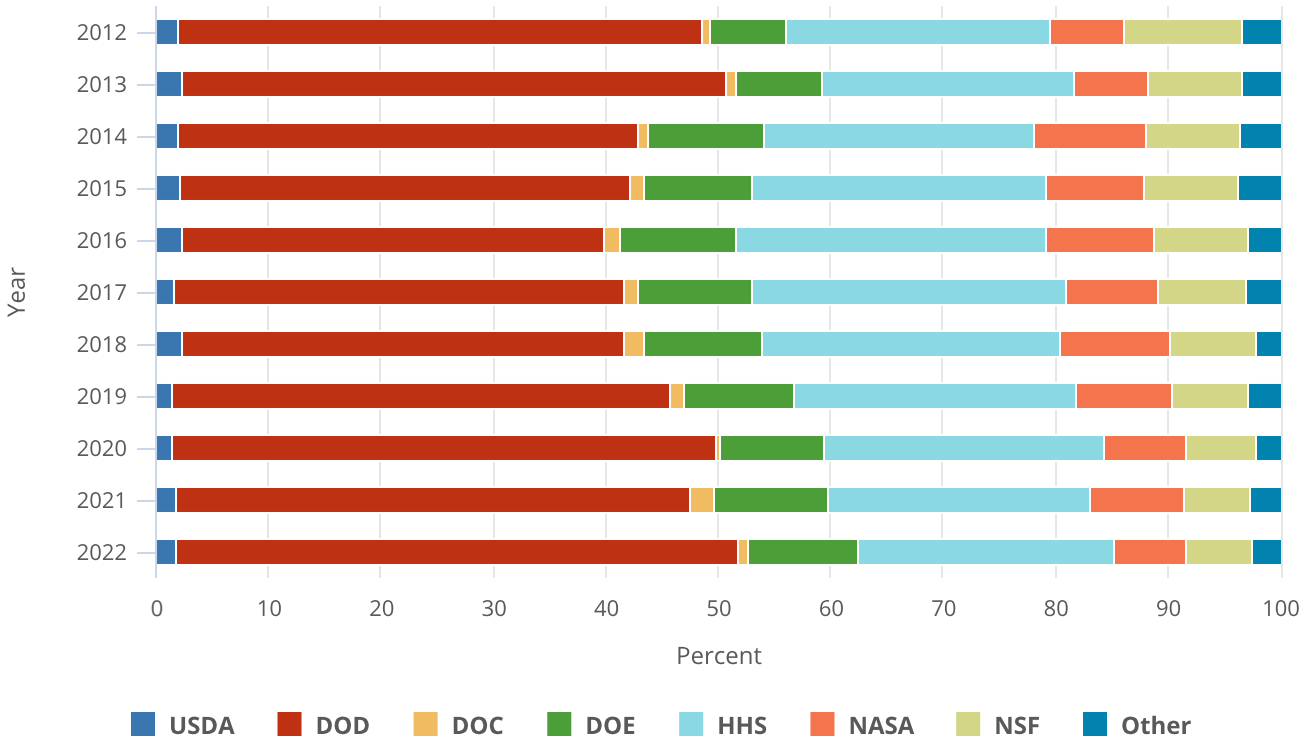
**Figure INV-18**

**Firms receiving Phase II SBIR or STTR awards, by awarding agency: 2012–22**




DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; SBIR = Small Business Innovation Research; STTR = Small Business Technology Transfer; USDA = Department of Agriculture.

**Note(s):**
Firms receiving multiple SBIR or STTR Phase II awards in the same year are counted only once for that year. "Other" includes awards from Department of Education, Department of Homeland Security, Department of Transportation, and Environmental Protection Agency.

**Source(s):**
Small Business Administration, SBIR/STTR Award database, accessed August 2023.

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## Venture Capital and Innovation

Venture capital is a particularly important indicator of innovation because venture investors tend to invest in companies with products that they believe have a significant likelihood of achieving market success. Venture capital-backed firms that become publicly traded are more likely to have recorded R&D expenditures compared to publicly traded firms that were not originally venture backed (Lerner and Nanda 2020). In this regard, data on venture capital investment trends can be viewed as leading indicators of the innovative output expected from startups because those funds are used to create innovations.

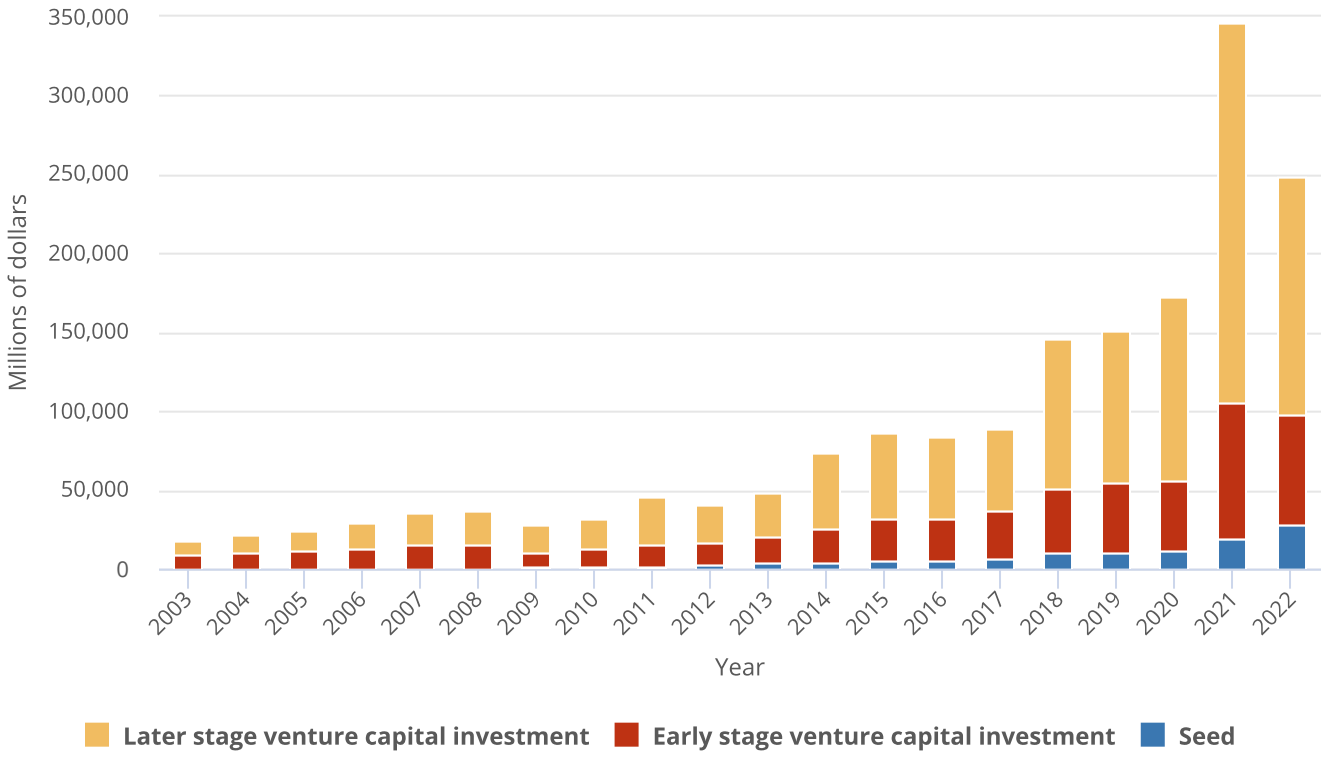
Venture capital investment primarily funds high-risk and early stage firms. The funding for venture capital flows from large institutional investors, called limited partners (e.g., pension funds, university endowments, private equity funds, and foundations), to venture investors, who then select the firms to support. Early stage firms give up equity ownership shares in exchange for these investments. These equity shares are not easily traded, so the venture investors (and their limited partners) only receive compensation when the early stage firm has a public stock offering or is acquired by a larger firm. Since early stage firms have a high rate of failure, venture investors deploy capital across a portfolio of these firms, expecting that one successful investment will compensate for the many that yield no returns.

Worldwide, venture capital investments ranged between $300 billion and $400 billion between 2018 and 2020. In 2021, however, these investments experienced an unprecedented boom. Global venture investments almost doubled between 2020 and 2021, reaching an all-time high of more than $740 billion. This historic increase in 2021 was followed by a decrease to about $540 billion in 2022, a decline of 27% (Table SINV-31).

Venture capital investments within the United States followed a similar pattern, with about $350 billion invested in 2021, followed by a 28% decline to $250 billion in 2022. About $150 billion of venture capital invested in U.S. firms in 2022 involved later-stage funding, a 38% decline from the 2021 peak of $240 billion in 2021 (**Figure INV-19**). Later-stage investment capital accounted for over 60% of U.S. venture capital funding in 2022 (**Figure INV-19**). Although a smaller share of overall venture capital, seed funding increased 30% between 2021 and 2022, reflecting strength in early stage companies.

**Figure INV-19**

**Venture capital investment received by firms headquartered in the United States, by deal stage: 2003–22**



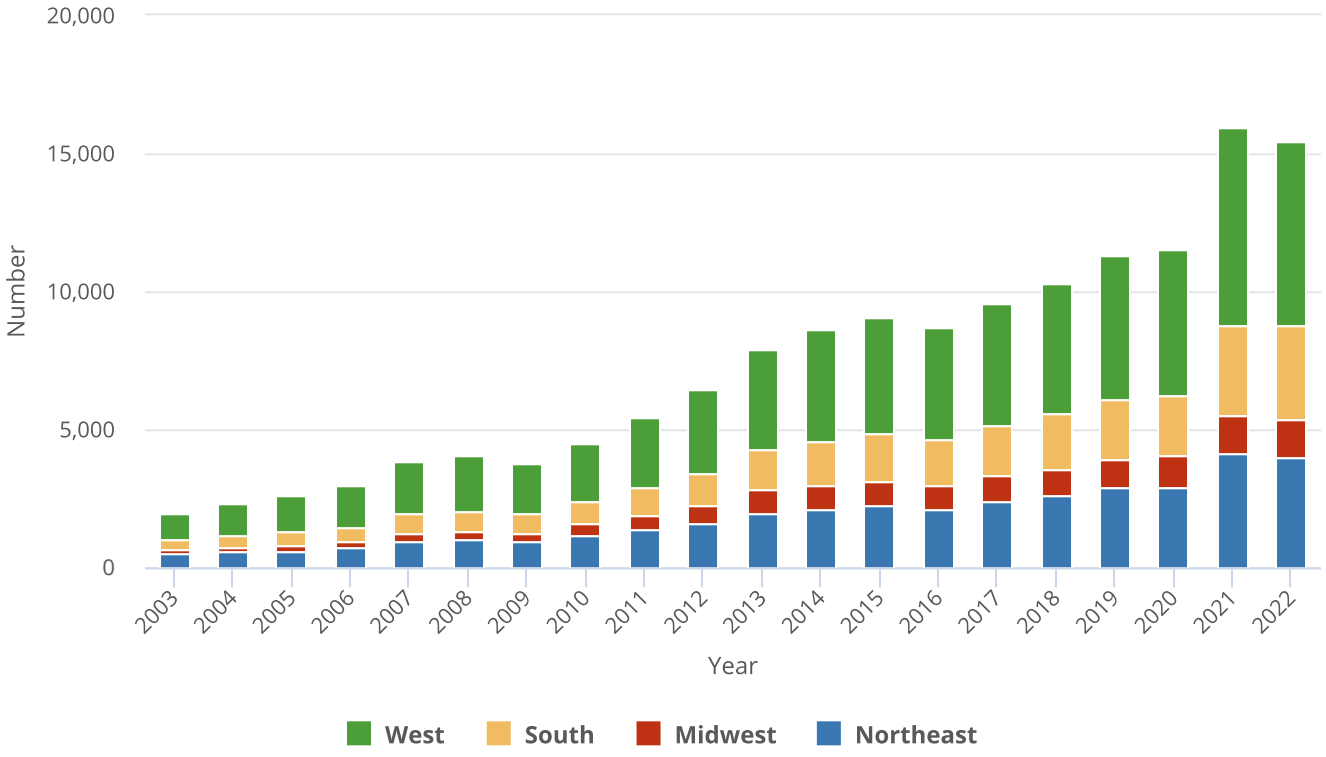

**Note(s):**
Deal stage is the stage as reported, based on the maturity of the firm receiving the venture investment.

**Source(s):**
PitchBook, venture capital and private equity database, special tabulations, accessed September 2023.

Geographically, firms in the western United States continued to account for the largest share of firms receiving venture capital funding in 2021 and 2022 (45% and 43%, respectively), followed by firms in the Northeast (26% and 26%, respectively) (**Figure INV-20**). The rapid increase in venture investment activity in the United States did not affect the overall geographic concentration of that activity.

**Figure INV-20**

**Firms headquartered in the United States receiving venture capital investment, by Census region: 2003–22**




**Note(s):**
Regions are defined by the Census Bureau for the Economic Census. See https://www.census.gov/programs-surveys/economic-census/guidance-geographies/levels.html.

**Source(s):**
PitchBook, venture capital and private equity database, special tabulations, accessed September 2023.

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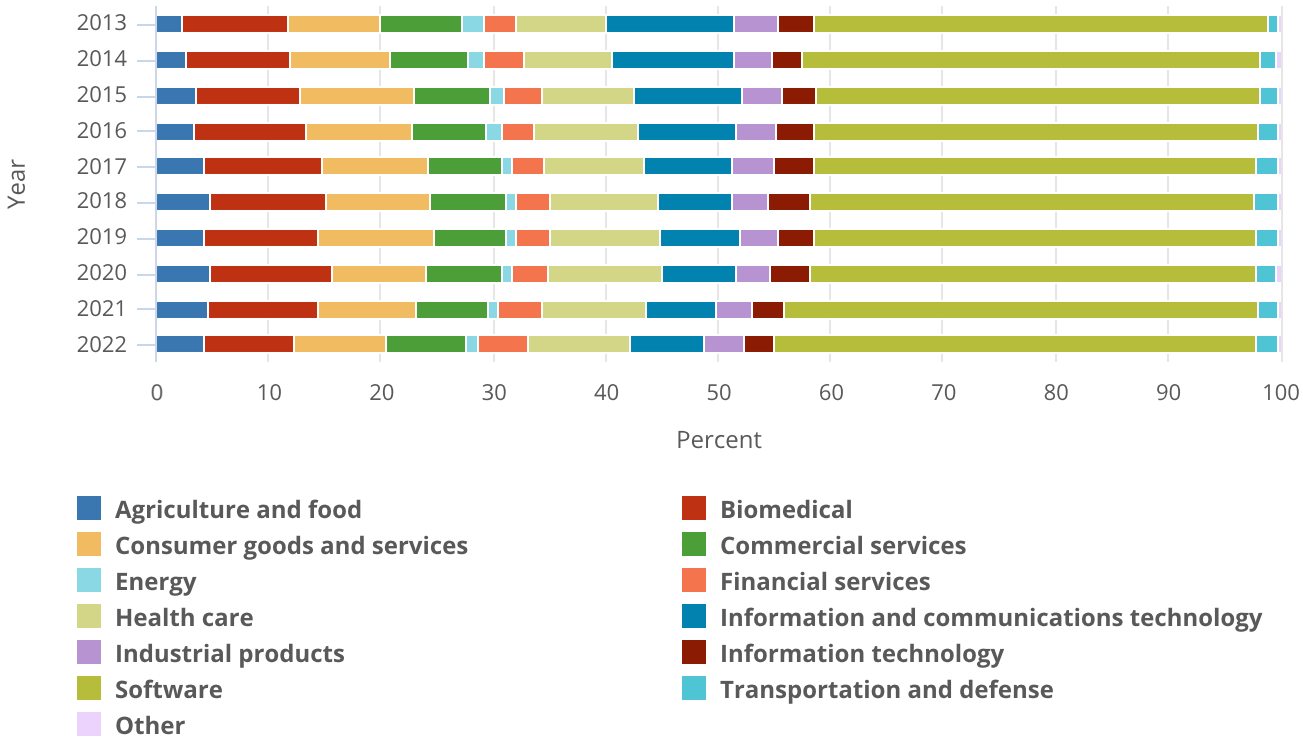
At the industry level, software firms have accounted for the largest share of firms receiving venture capital investments each year since 2013. These firms accounted for 43% of firms receiving venture capital investment in 2022, representing an increase in share of 2.4 percentage points compared to 2013 (**Figure INV-21**). Health care and biomedical firms were the next highest in terms of share for 2021 and 2022. Overall, the distribution of firms receiving venture capital funding each year by industry remained roughly similar from 2013 to 2022.

**Figure INV-21**

**Firms headquartered in the United States receiving venture capital investment, by industry: 2013–22**




**Note(s):**
Industry categories are aggregates of PitchBook Primary Industry Codes based on product or service markets. See Table SINV-33.

**Source(s):**
PitchBook, venture capital and private equity database, special tabulations, accessed September 2023.

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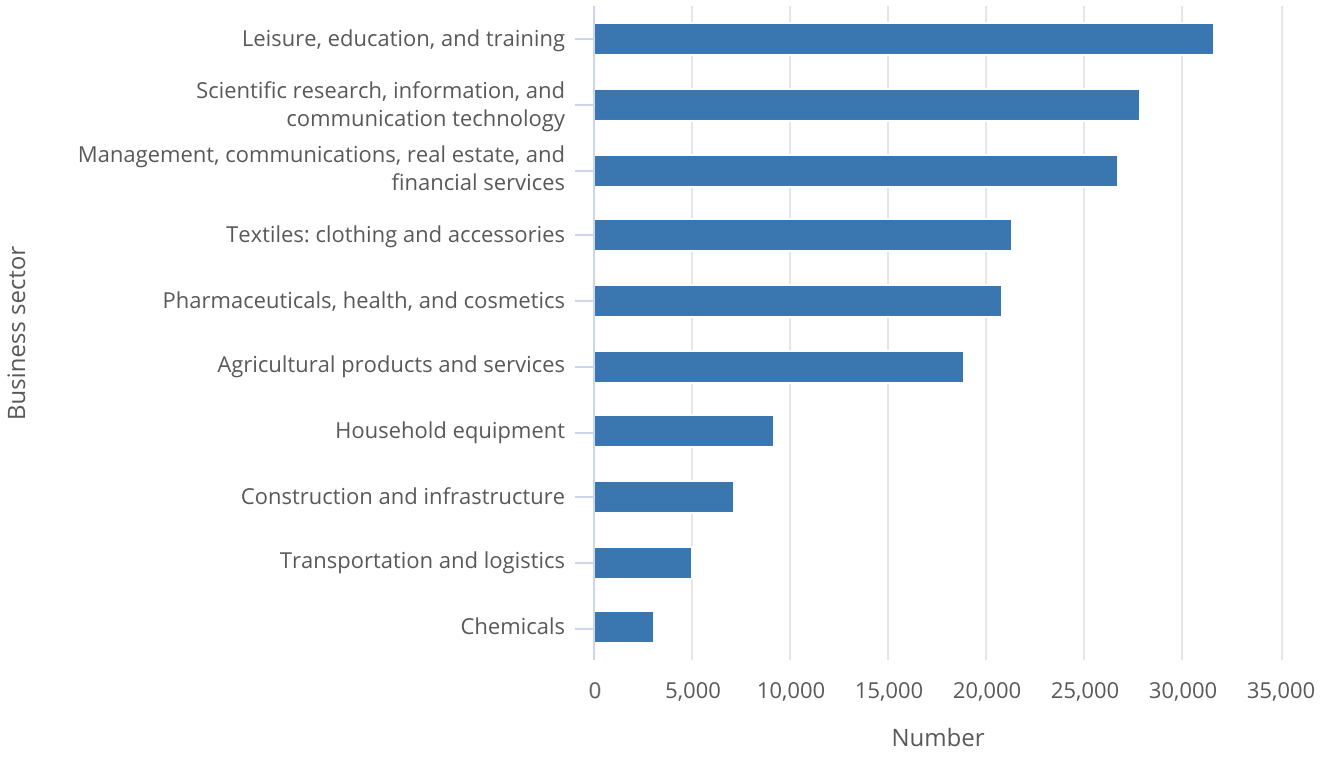
## Trademarks: U.S. Trends

Products receiving trademark protection provide an indication of industries with high innovation activity. Trademarking allows firms that engage in R&D and patenting to appropriate greater returns from their innovations, suggesting a useful and separate innovation indicator from patenting (Dinlersoz et al. 2018; Castaldi, Block, and Flikkema 2020). In 2022, the USPTO registered 333,000 trademarks to owners across the world, including 172,000 to U.S. owners (Table SINV-35). Along with other types of invention and innovation, in the pandemic year of 2020 the number of USPTO trademarks registered dropped 9% from the year before, rebounding in 2021 (Table SINV-35). Across product types, knowledge-intensive products and services account for high numbers of trademarks; of the 172,000 U.S. registered trademarks in 2022, the highest numbers are in the categories of leisure, education, and training; scientific research, information, and communication technology; and management, communications, real estate, and financial services (**Figure INV-22**). Table SINV-34 through Table SINV-48 provide product level detail. A supplemental workbook released with this report provides annual county-level data (File USPTO trademarks, by county and product).

**Figure INV-22**

**U.S.-registered USPTO trademarks, by business sector: 2022**




USPTO = Patent and Trademark Office.

**Note(s):**
Trademarks are allocated according to holder information and are fractionally allocated to regions, countries, or economies based on the proportion of residences of all named holders. Trademarks are classified under the Nice Classification of goods and services, which classifies trademarks under 34 categories of goods and 11 categories of services; see https://www.wipo.int/classifications/nice/en/. Fractional counts of trademarks were assigned to each category to assign the proper weight of a trademark to the corresponding category under the classification. See Table SINV-34 through Table SINV-47 for other years and countries. See Table SINV-35 for detail on the 10 aggregate business sectors.

**Source(s):**
National Center for Science and Engineering Statistics; Science-Metrix; USPTO data hosted by Reed Tech (LexisNexis), accessed June 2023.

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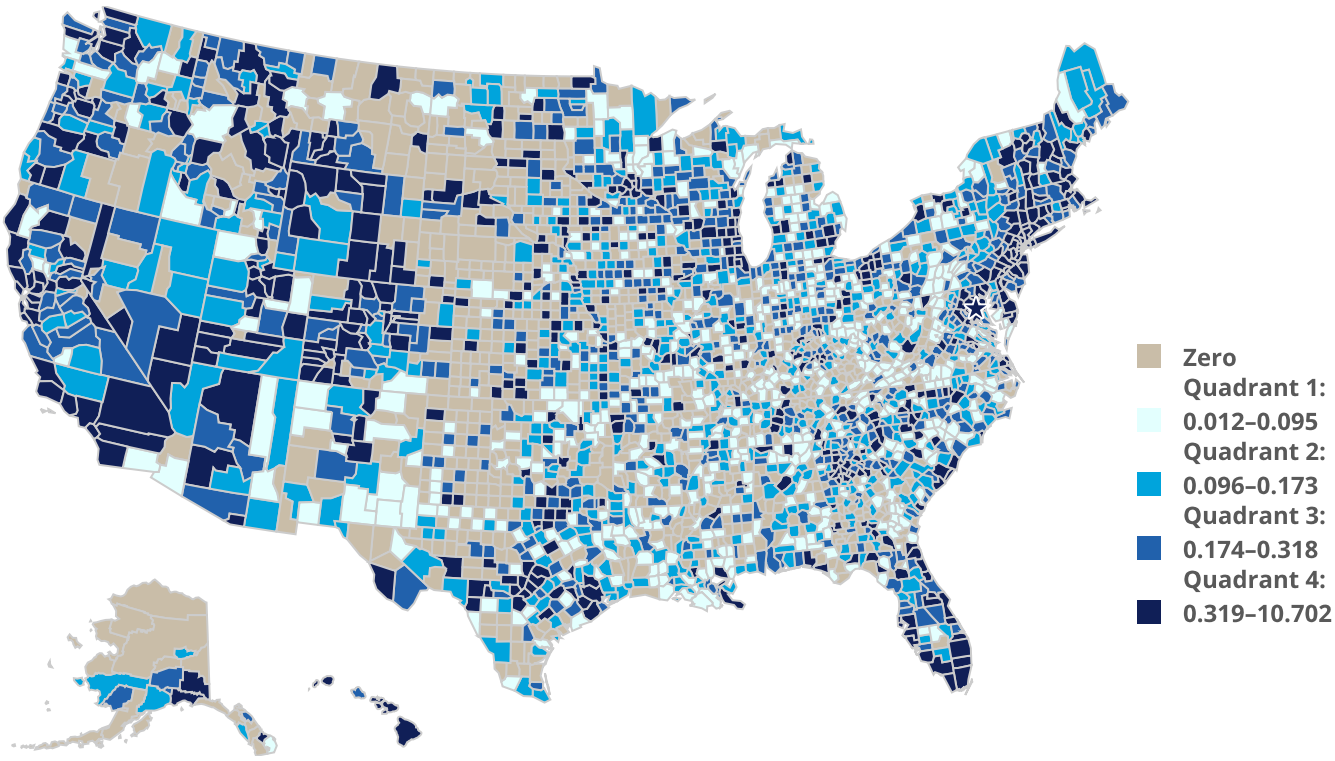
Trademark activity is unevenly spread across the United States, with more intensive activity along the coasts, the Rocky Mountain region, parts of Texas, and the Great Lakes region (**Figure INV-23**). In 2022, almost 75% of all counties had at least one trademark issued, making trademark activity more geographically disbursed across the interior of the United States compared with the regional patenting described in this thematic report's section **Invention Indicators: Protecting Useful Ideas**, in which 64% of counties had at least one patent. The top three counties in 2022 for trademark intensity are Sheridan County in Wyoming, followed by Teton County, also in Wyoming, and then by New York County in New York State.

**Figure INV-23**

**Registered USPTO trademarks per 1,000 residents, by U.S. county: 2022**




USPTO = Patent and Trademark Office.

**Note(s):**
USPTO trademarks are allocated according to holder information. U.S. addresses were geocoded to 3,143 U.S. counties according to U.S. states, U.S. cities, and ZIP Codes appearing in these addresses. Trademarks are classified under the 11th edition of the Nice Classification of goods and services, which classifies trademarks under 34 categories of goods and 11 categories of services. Fractional counts of trademarks were assigned to each category to assign the proper weight of a trademark to the corresponding category under the classification. These counts are then grouped under 10 industry sectors following a mapping defined by Edital. See File USPTO trademarks, by county and product for additional detail.

**Source(s):**
National Center for Science and Engineering Statistics; Science-Metrix; USPTO data hosted by Reed Tech (LexisNexis), accessed June 2023. Population data from the Census Bureau accessed June 2023 at https://www2.census.gov/programs-surveys/popest/tables/2020-2022/counties/totals/co-est2022-pop.xlsx.

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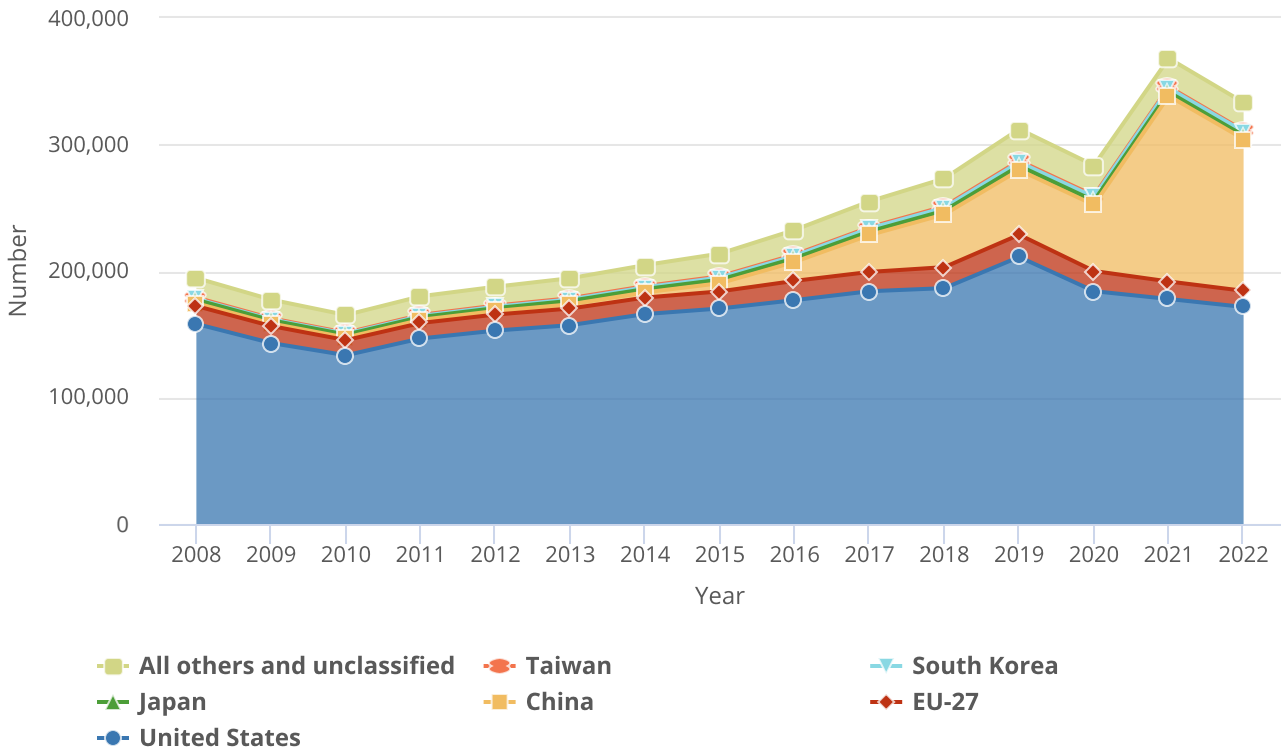
At the international level, the internationalization of commerce has coincided with an increasing share of USPTO trademarks registered to foreign assignees. The number of foreign-registered USPTO trademarks has grown more rapidly in recent years than the number of USPTO trademarks registered to U.S. assignees (**Figure INV-24**). While those assigned to the United States grew by 12% between 2012 and 2022, the number of USPTO trademarks assigned to China grew from 2,810 to 120,004. For South Korea, the growth rate was 185% (**Figure INV-24**).

**Figure INV-24**

**Registered USPTO trademarks, by selected region, country, or economy: 2008–22**




EU-27 = European Union; USPTO = Patent and Trademark Office.

**Note(s):**
Trademarks are allocated according to holder information. Trademarks are fractionally allocated among regions, countries, or economies based on the proportion of residences of all named holders. Trademarks are classified under the 11th edition of the Nice Classification of goods and services, which classifies trademarks under 34 categories of goods and 11 categories of services. Fractional counts of trademarks were assigned to each category to assign the proper weight of a trademark to the corresponding category under the classification. See Table SINV-48 for additional countries. Beginning in 2020, the United Kingdom was no longer a member of the EU. China includes Hong Kong.

**Source(s):**
National Center for Science and Engineering Statistics; Science-Metrix; USPTO data hosted by Reed Tech (LexisNexis), accessed June 2023.

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As noted with USPTO utility patents, factors behind the increase in trademark activity in China include government subsidies that exceed the cost of filing for foreign trademark applications and government mandates requiring an increase in trademark filing (USPTO 2021).

## Business Innovation

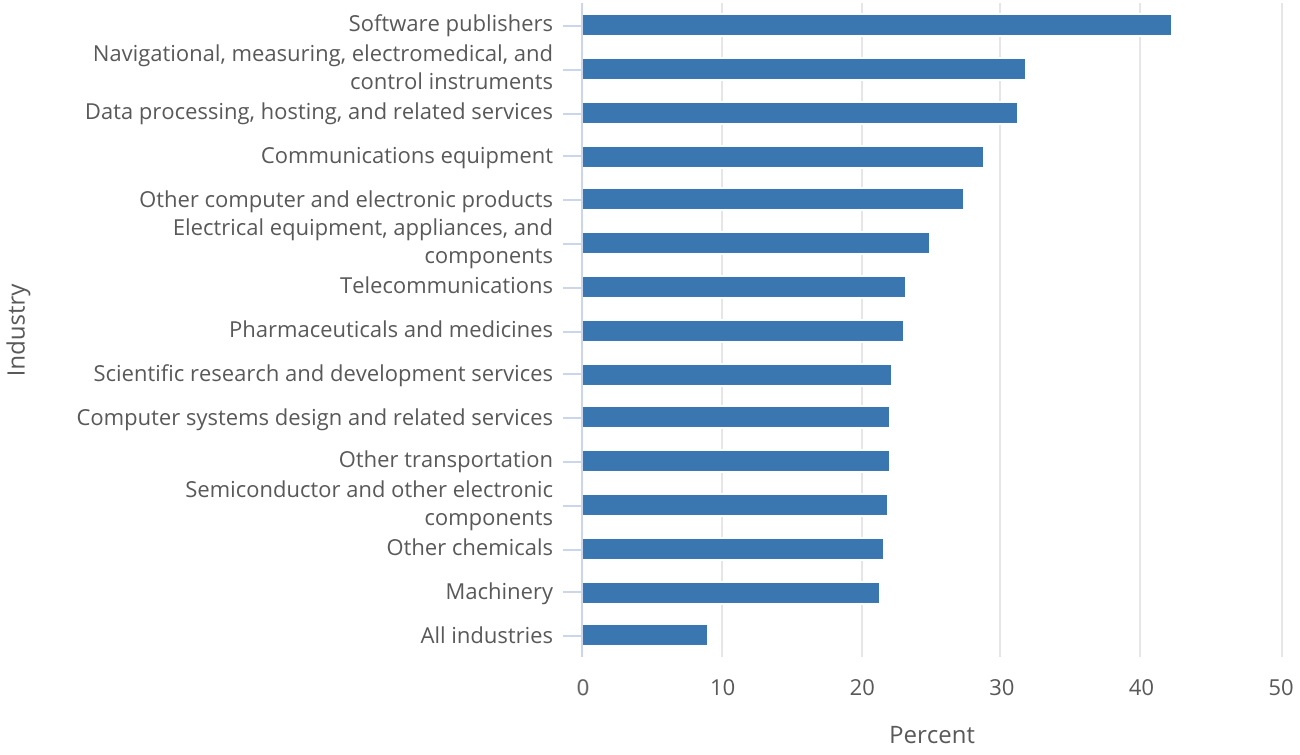
The business innovation activity indicator reported here is the proportion of companies within an industry that report introducing new or significantly improved products, which can be goods or services. The data reported here are based on the business innovation survey framework of the *Oslo Manual* (OECD/Eurostat 2018).[7]

This analysis includes three consecutive survey years of self-reported business product innovation data, allowing for analysis over time. Time series analysis necessitates narrowing the focus reported on here to product innovation because process innovation is measured less frequently. Process innovation was included together with product innovation in the *Indicators 2022* report "[2022] Invention, Knowledge Transfer, and Innovation" report section "[2022] Innovation Indicators: Introducing New Products and Processes."

In the United States, about 9% of companies introduced a product innovation between 2018 and 2020, based on data reported through the Annual Business Survey (ABS) (Kindlon and Anderson 2023). Companies in the software publishing industry have among the highest rates of reported innovation; 42% of companies reported introducing a product innovation between 2018 and 2020 (**Figure INV-25**). Although industries employ many different technologies and thus cannot all be matched one to one, **Figure INV-25** shows that companies in the semiconductor and other electronic components industry, where semiconductor technology is situated, have more than twice the overall innovation rate compared with all industries (22%).

**Figure INV-25**

**Share of 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-innovating companies are self-reporting, based on having introduced a new or improved product that differs significantly from the firm's previous products and that has also been introduced on the market or brought into use by the firm. These products may be goods or services.

**Source(s):**
National Center for Science and Engineering Statistics and Census Bureau, 2021 Annual Business Survey: Data Year 2020, Table 26; Kindlon A, Anderson G, 2023, *Product Innovation Trends 2016–18 to 2018–20: Findings from the Annual Business Survey*, NSF 23-331, available at https://www.nsf.gov/statistics/2023/nsf23331/.

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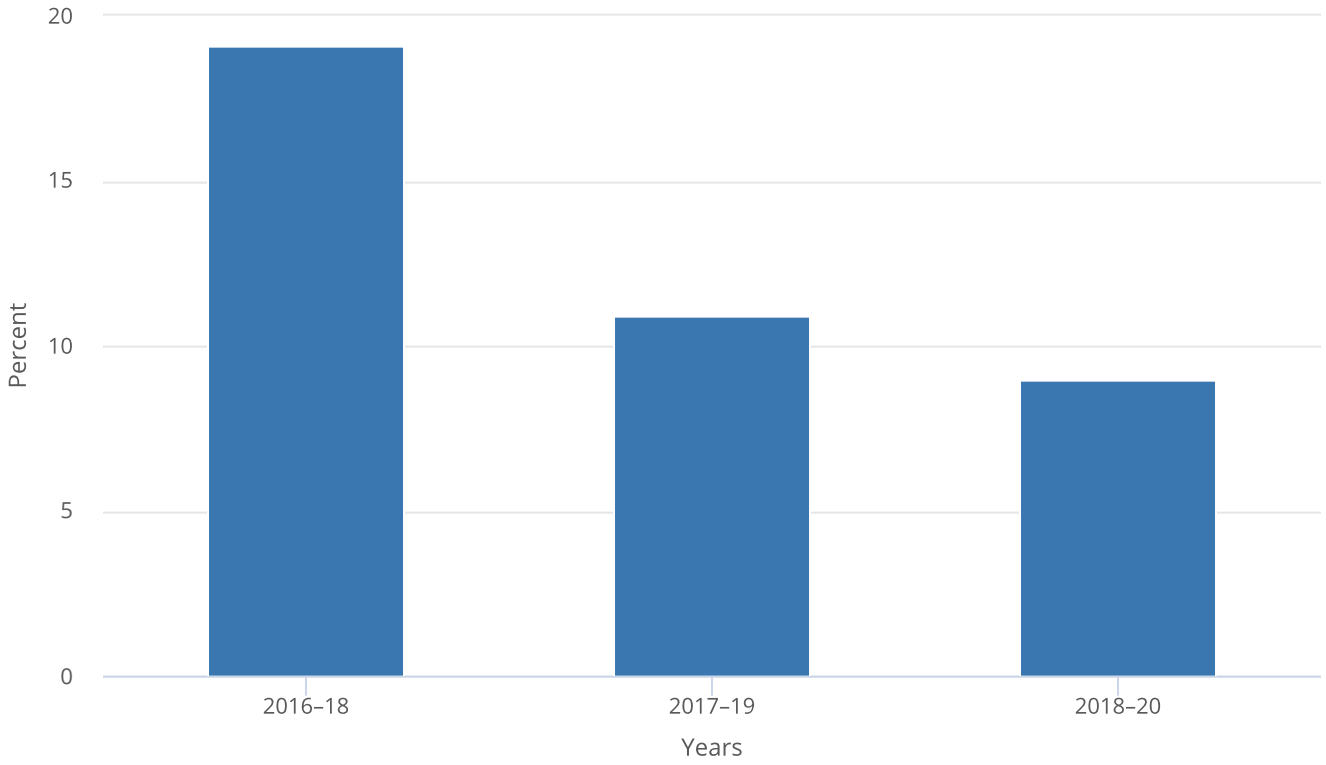
With the 2020 data year, three consistently measured time periods can be compared for self-reported business product innovation for U.S. companies. Across three annual surveys, the incidence of product innovation decreased from about 19% for the 3-year period ending in 2018 to 9% for the 3-year period ending in 2020 (**Figure INV-26**). The recent availability of expanded innovation data from companies with fewer than 10 employees, known as *microbusinesses*, in the ABS data allows for deeper analysis into what kind of companies are accounting for this change in product innovation incidence over time. Statistically significant decreases took place in service-producing companies rather than those that produce goods. Further, the decrease in the incidence of service innovation has been concentrated in businesses with fewer than 10 employees (Kindlon and Anderson 2023).

**Figure INV-26**

**Share of U.S. companies reporting product innovation: 2016–18, 2017–19, and 2018–20**




**Note(s):**
Product-innovating companies are self-reporting, based on having introduced a new or improved product that differs significantly from the firm's previous products and that has also been introduced on the market or brought into use by the firm. These products may be goods or services.

**Source(s):**
Kindlon A, Anderson G, 2023, *Product Innovation Trends 2016–18 to 2018–20: Findings from the Annual Business Survey*, NSF 23-331, available at https://www.nsf.gov/statistics/2023/nsf23331/.

*Science and Engineering Indicators*

## Conclusion

A dynamic system of innovation activities, including invention, the transfer of knowledge, and the introduction of new products and processes, generates outcomes that range from new vaccines to counter a pandemic to advances in machine learning. Historically, participation has tended to be limited to higher-income regions, countries, and economies; within these locations, participation has tended to be limited to higher-income men. These trends are changing.

Intellectual property indicators, such as patenting and trademarks, show where new products and processes are emerging. Patenting and trademark activity by middle-income countries is increasing. This increasing participation of middle-income countries in intellectual property registration and other innovation activities results in both collaboration opportunities and competition challenges. Additionally, with the global supply chain being reliant on international S&E capacity, this interconnectedness generates widespread risk in terms of national security, transmission of disease, and disruption in global and domestic economies.

Both international collaboration and collaboration across sectors within and between countries contribute to globally important innovation activity. Domestically, annual statistics on knowledge transfer at universities and federal laboratories show that overall growth in research collaborations, technology licensing, and support for startups were slowed during the COVID-19 pandemic.

The process of innovation, from R&D to invention to the release of a new product, can be a long one, and recent data suggest that, overall, the incidence of this activity is declining. Based on self-reported company data, the introduction of a new product that is significantly different from other products by U.S. businesses as assessed over a 3-year period declined from 19% in 2017 to 9% in 2020.

The regional and demographic differences in invention activities (patenting) and innovation activities (trademarking) show that these critical activities are unevenly distributed among demographic groups and among geographic regions. Women also participate throughout the system, although their numbers are fewer than those for men.

Geographically, county data for the United States on patenting and trademark activity show that the intensity of innovation activities takes place unevenly across the country, with more dense activity in urban and metropolitan areas, along the East Coast and West Coast, and in the Northeast. This is consistent with patterns from other countries as well, where R&D, highly skilled workers, and patenting tend to concentrate in metropolitan areas (Planes-Satorra and Paunov 2017). Concentration supports local growth while other regions, lacking these attributes, grow more slowly. The underparticipation of large sections of the population provides an opportunity to increase innovation in multiple dimensions.

The data highlighted in this report also illustrate shifts in the locations and types of R&D activities and associated outputs. Chief among these shifts is the rise of China as a global contributor to inventive output. Another clear shift is the growing role of universities in private sector innovation. The last decade has seen a 50% increase in the number of university licenses and license options to private sector entities. This growth is due to university technology transfer to startups and other small companies; however, the scale of this activity relative to the overall economy is small. Invention, knowledge transfer, and innovation are indispensable to improving national and global health, well-being, and security.

# Glossary

## Definitions

**Copyright:** A legal protection for original works of authorship, including literary, dramatic, musical, architectural, cartographic, choreographic, pantomimic, pictorial, graphic, sculptural, and audiovisual creations. Definition from Copyright Office, **https://www.copyright.gov/help/faq/definitions.html**; accessed March 2023.

**Design patent:** A grant of a property right to an inventor to protect the visual ornamental characteristics of an article of manufacture.

**Economic sectors:** Economic activity is organized in national economic accounts into four sectors: business, government, nonprofits serving households, and households. This organization has also been recommended for innovation statistics (OECD/Eurostat 2018). In the statistical data in this report, public universities and private nonprofit universities are shown together as *academic* institutions. The term *individuals* refers to the *household* economic sector.

**European Union (EU-27):** The EU comprises 27 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. As of 2020, the United Kingdom is not a member of the EU.

**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).

**Intellectual property:** Creations of the mind including inventions, literary and artistic works, and symbols, names, images, and designs used in commerce. Industrial intellectual property includes patents, utility models, trademarks, and industrial designs. Intellectual property covered by copyright includes literary, artistic, and musical works. Available at **https://www.wipo.int/about-ip/en/**; accessed March 2023.

**International patents:** These are original patents that have been 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.

**Invention:** Any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof (USPTO 2020).

**Knowledge transfer:** The process by which technology or knowledge developed in one place or for one purpose is applied and used in another place for the same or a different purpose. This transfer can occur freely or through exchange and be deliberate or unintentional. Technology transfer represents a specific case of knowledge transfer that involves the transfer of knowledge embedded in technology.

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

**Patent and Trademark Office (USPTO) patent:** As defined by 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 December 2023.

**Patent family:** See *international patents*.

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

**Priority patent:** The first patent filed in a family of subsequent patents that refers to the original patent. The original filing may be domestic or from another jurisdiction.

**Technical field in patents:** *Chemistry*: Biotechnology, pharmaceuticals, organic fine chemistry, microstructural and nanotechnology, chemical engineering, macromolecular chemistry and polymers, basic materials chemistry, materials, metallurgy, surface technology, coating, environmental technology, food chemistry. *Electrical engineering*: Computer technology, electrical machinery, apparatus and energy, semiconductors, digital communication, telecommunications, audio-visual technology, basic communication processes, information technology methods for management. *Mechanical engineering*: Other special machines, engines, pumps, and turbines; transport; mechanical elements; machine tools; textile and paper machines; thermal processes and apparatus; handling. *Instruments*: Medical technology, measurement, analysis of biological materials, optics, control. *Other categories*: Civil engineering, other consumer goods, furniture, games.

**Technology transfer:** The process by which technology or knowledge developed in one place or for one purpose is applied and exploited in another place or for another purpose. In the federal setting, technology transfer is the process by which existing knowledge, facilities, or capabilities developed under federal research and development funding are used to fulfill public and private needs.

**Trade secret:** Information that fulfills all the following requirements, as defined by the Patent and Trademark Office: "Either actual or potential independent economic value by virtue of not being generally known, has value to others who cannot legitimately obtain the information, and is subject to reasonable efforts to maintain its secrecy." Available at **https://www.uspto.gov/ip-policy/trade-secret-policy**; accessed December 2023.

**Trademark:** A word, phrase, symbol, design, or a combination thereof, that identifies and distinguishes the source of the goods of one party from those of others. In this report, trademark refers to both goods and services.

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

## Key to Acronyms and Abbreviations

**ABS:** Annual Business Survey

**AI:** artificial intelligence

**CCAT:** climate change adaptation technologies

**CCMT:** climate change mitigation technologies

**COVID-19:** Coronavirus Disease 2019

**CRADA:** cooperative research and development agreement

**DOC:** Department of Commerce

**DOD:** Department of Defense

**DOE:** Department of Energy

**EPO:** European Patent Office

**EU-27:** European Union

**HHS:** Department of Health and Human Services

**KTI:** knowledge and technology intensive

**NASA:** National Aeronautics and Space Administration

**NCSES:** National Center for Science and Engineering Statistics

**NIST:** National Institute of Standards and Technology

**OECD:** Organisation for Economic Co-operation and Development

**PCT:** Patent Cooperation Treaty

**R&D:** research and development

**S&E:** science and engineering

**SBIR:** Small Business Innovation Research

**STTR:** Small Business Technology Transfer

**USDA:** Department of Agriculture

**USPTO:** Patent and Trademark Office

**WIPO:** World Intellectual Property Organization

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## Notes

**1** A patent count of less than 1.0, but more than 0.0, can occur when there are two or more different county addresses on the patent. The patent count is divided across the relevant counties.

**2** A patent may be included in more than one category within a dimension and also be classified along more than one dimension. For example, a patent describing a machine learning-based image processing tool for an autonomous vehicle will be counted in all three dimensions (i.e., AI technique: machine learning; functional application: computer vision; application field: transportation).

**3** These categories are not mutually exclusive.

**4** These analyses are based on algorithms that match names to the usual gender associated with that name, an inexact but still useful process.

**5** These affiliations are identified in the documents through a two-step process that starts with automatic assignment based on unambiguous words, such as “company,” “university,” or “Canada,” followed by a second step that manually identifies ambiguous entries.

**6** The tabulated data for peer-reviewed publications are from the Scopus database used in the ***State Indicators*** report (NSB 2021b). The same taxonomy of disciplines for fields of S&E and the classification of sectors that produce publications from that report are used here.

**7** An alternative approach that surveys for business behavior that is consistent with continuous product and process improvement systems rather than self-reporting of innovation is described in a recent research paper by Tian, Wojan, and Goetz (2022).

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## Correction(s)

**22 May 2025**: Due to an automation issue, Table SINV-2 was missing rows. It has been updated to show the full table.

**13 March 2024**: The titles, descriptions, and callouts of data files **SWBINV-1, SWBINV-2, and SWBINV-3** were inadvertently switched between the three files. These items have been corrected in all locations; the data values within the files are unchanged.