Innovation

Invention, Knowledge Transfer, and Innovation

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Executive Summary

Key takeaways:

- New and improved products and processes emerge from the U.S. science and engineering (S&E) enterprise through an interconnected system of invention, knowledge transfer, and innovation. This system is characterized by both competition and collaboration.
- Intellectual property registration data, such as patents and trademarks, provide indicators of invention and the introduction of new products; they are growing in number as digitization increases the importance of intellectual property protection. Patent and trademark applications more than doubled globally between 2008 and 2017, with middle-income countries worldwide rapidly increasing their participation in this activity.
- Engineering-related patents, both electrical and mechanical, made up about half of all patents granted by the U.S. Patent and Trademark Office (USPTO) in 2018. Two areas of information and communication technologies (ICT)—computer technology and digital communication—grew quickly since 2000 and received particularly large numbers of patents. Patent-intensive industries in the United States are also research and development (R&D) intensive; that is, these industries spend higher proportions of their sales on R&D.
- Patent family data provide an internationally comparable count of inventions, notwithstanding variations in strategic interests and patent standards. In 2018, China received about half (334,000) of these global patents, an eightfold increase over the prior decade. Inventors from the United States, the European Union (EU), Japan, and South Korea each receive a smaller number of these patents than those from China.
- Universities and federal labs invent and patent as well as transfer knowledge and technology through research collaborations, technology licensing, and support for startups. These activities are aimed at bridging the risky steps of invention, financing, development, and commercialization.
- Venture capital provides external funding to finance the introduction of viable new technologies and products into the market. The large economies of the United States and China receive the greatest amounts of this funding. The EU and the rest of Asia receive significantly less.
- One in six U.S. firms with five or more employees report having introduced an innovation between 2014 and 2016. Industries active in the digital economy have an outsized impact on innovation rates. ICT-producing industries report some of the highest rates of innovation.

Innovation brings new products and technologies into society through an interrelated system of activities by the business sector, universities, government entities, and individuals. Relationships among institutions underpin the environment in which ideas become innovations and diffuse through society. This *innovation system* environment is complex, encompassing financing, public infrastructure, tax and regulatory policies, intellectual property protection, and social attitudes toward risk. Three distinct but interrelated components of this environment are invention, knowledge transfer, and innovation. This report covers the composition and trends of these components. The report primarily uses U.S. and international statistical and administrative data including data from the USPTO, National Center for Science and Engineering Statistics, Bureau of Labor Statistics, National Institute of Standards and Technologies, and, internationally, the Organisation for Economic Co-operation and Development and the World Intellectual Property Organization.

Patents are indicators of invention that cover part of inventive activity. Companies choose a variety of strategies to protect their inventions, including trademarks and trade secrets; many inventions are also shared through open access. Growth in patenting also reflects both inventive activity and an overall trend toward increased importance of intellectual property protection, especially for information that can be digitized. Globally, as economies participate in increasingly digital international trade activity, intellectual property protections in middle-income countries have risen.

The USPTO issued over 300,000 patents in 2018, almost double the amount issued in 2008. Engineering-related patents, both electrical and mechanical, comprise about half of all USPTO patents. Computer technology and digital communication, both ICT-related areas within electrical engineering, receive notably large numbers of patents.

Of the 309,000 patents issued by the USPTO in 2018, more than half (53%) were granted to foreign inventors, growing from about 46% in 2000. Japan and the EU continue to account for the largest numbers of foreign USPTO patent grantees, followed by South Korea. Although inventors from China account for a relatively small number of USPTO patents, they have seen a rapid increase in the numbers of these patents granted.

As in the United States, about half of the patents granted in any recognized national or regional jurisdiction (patent families) worldwide are electrical or mechanical engineering patents. In this global measure, China receives about half of the patent families issued; inventors from the United States, the EU, Japan, and South Korea receive a smaller number of these patents than inventors from China.

Trademarks protect the names and symbols used with products in national and regional markets and historically have primarily been an activity of high-income economies. With the rapid worldwide growth of trademark applications since the turn of the century, this has changed. Middle-income countries Brazil and China make up much of this growth, with China's contribution large and fast growing.

The USPTO registered 273,000 trademarks in 2018, including 184,000 to U.S. assignees. USPTO trademarks to foreign assignees make up an increasing share of total trademarks; the number of foreign trademarks has grown 37% over the last decade, compared with a 17% increase in the number of trademarks to U.S. assignees.

Knowledge transfer is a key component of the U.S. innovation system; this takes place through market transactions and licensing as well as through formal and informal collaboration activities of universities, federal labs, and researchers in the business community. Technology transfer programs focus on bridging the risky steps of invention, financing, development, and commercialization.

Researchers from universities and federal labs collaborate with business-sector researchers directly through joint research and publications; both the number and share of these articles have increased over the last decade. The U.S. business sector coauthored 27,000 S&E articles with U.S. academics and 7,000 with government authors in 2018. The number of internationally coauthored articles by U.S. business authors tripled over the same time. Research transfer can also be less direct: two-thirds of citations to research articles in patent applications are to articles with academic affiliations.

A second indicator of knowledge transfer is the sharing of university and federally developed technology and inventions through collaborative agreements and licensing of technology. Universities reported 46,000 active licenses in 2017 as well as over 1,000 university-affiliated startups using licensed technology. Many startups continue to survive as ongoing businesses, with universities reporting more than 6,000 startups still in operation in 2017. Federal labs reported almost 9,000 active licenses in FY 2016. Federal agencies directly support technology transfer of their research through awards to small businesses for innovation, commercialization, and technology transfer; this amounted to over $3 billion to over 5,000 awardees in 2018.

As new technologies develop, venture capital flows play a key role in transforming ideas into innovation—the actual introduction of new or improved products and processes. Over the last decade, the venture capital market has shifted from a U.S.-centric structure toward a more globalized market with the Asian region growing rapidly. The United States received 44% ($119 billion) of total global venture capital funds, followed by China with a global share of 36% ($97 billion). Within the United States, two-thirds of this venture capital investment is focused in ICT and health care. ICT-producing and health care–related industries in the United States report introducing new products and processes at a higher rate compared with the U.S. average of one in six (between 2014 and 2016).

Over time, the overall impact of innovation and S&E knowledge in society extends well beyond innovating firms. In terms of economic output, new products and processes can increase output or decrease costs for others outside the firm. The speed and direction of the changes in ratio of outputs to inputs can be measured as multifactor productivity. This measure has risen more slowly in the United States and other high-income countries in the last decade relative to earlier decades.

Introduction

Invention, knowledge transfer, and innovation are distinct but interrelated components of a complex system for transforming creativity and knowledge from science and engineering (S&E) into benefits to society and the economy. Long-term impacts of the innovation process emerge as knowledge, inventions, and innovations diffuse through society. Major advances such as electricity, engines, sanitation systems, chemicals and pharmaceuticals, and telecommunication have had widespread benefits where developed as well as around the world (Gordon 2016). The innovation process has the potential for less desirable outcomes as well, including rapid obsolescence of some job skills, increased inequality across regions and groups of people, vulnerability of systems to attacks, and ethical issues raised by new technologies.

The innovation process is multidimensional. Forming a complete picture of this process requires indicators on actors as individuals as well as through institutions including industry, government, academia, and nonprofits. It also requires indicators of the physical capital and infrastructure, both public and private; intangible capital; and publicly available knowledge that enable innovation.

This report covers innovation-related activities, such as patenting and registration of trademarks, as well as the creation of intangible capital, such as software, research and development (R&D), and other creative originals.[1] Furthermore, the report describes university and government efforts to make their technologies available for commercial development and to support the creation of new businesses. The first section discusses *invention* and provides patenting data by sector and technology area as well as an international comparison of patenting activity. Both utility and design patents are presented. Design patents protect the visual characteristics of an invention, while a utility patent protects the way that the invention works. The *Beyond Patents* section covers trademarks. Trademarks protect symbols, words, or designs that distinguish the source of products.

The next section of the report focuses on *knowledge transfer*, including technology-transfer activity data for academic institutions and the federal government. Within the U.S. innovation system, these institutions have a special role creating basic research insights as well as supporting activities to transfer science and technology (S&T) knowledge into use. Technology transfer activities include invention disclosures, patenting, licensing, and collaborative R&D agreements. Citations from patent documents to peer-reviewed literature acknowledge the priority and foundation of S&E knowledge. Coauthorships between authors affiliated with businesses and authors from other sectors are indicators of collaboration across sectors. The last section focuses on *innovation*, with indicators of the emergence of new and improved products, funding for new businesses through venture capital, and the number and employment effects of small and fast-growing firms. Changes in productivity provide a longer-term perspective on the technological change that innovation brings about and its impact on economic growth.

Invention: U.S. and Comparative Global Trends

An invention brings something new into being and has a practical bent. Examples include a design, hybrid flower, mechanical device, software program, or commercial product. When these inventions are registered as intellectual property, the resulting records provide useful indicators of invention. For U.S. firms, trade secrets, trademarks, and design patents are all important for intellectual property protection (*Indicators 2018*, section "**Invention: United States and Comparative Global Trends**.")

Although there is more to invention than patenting, patents are primary indicators of invention, providing valuable technological and geographic detail. For patenting purposes, invention is defined as the production of something potentially useful, previously unknown, and nonobvious. The U.S. patenting system provides inventors with the exclusive right to make, use, or sell their invention, or in the words of the Patent Act of 1790, "any improvement therein not before known or used," so long as the invention is deemed "sufficiently useful and important" (USPTO 2002). USPTO data provide patenting measures by technology area for all patents registered in the United States, including those patents that are granted outside of businesses and to foreign entities. (See sidebar **There Is More to Invention Than Patenting**.)

Utility patents provide protection for the way something works. A design patent protects the way something looks and the way it is shaped, specifically the visual ornamental characteristics of articles of manufacture (USPTO 2018). For U.S. inventors, plant patents protect hybridized plants, such as roses. Trademarks protect the symbols used in commercial activity and often appear in conjunction with new products and processes. For U.S. R&D-performing firms, trademarks are as important as patents in protecting intellectual property (NCSES 2018).

The **Technical Appendix** provides more information on the intellectual property data used in this report.

SIDEBAR

There Is More to Invention Than Patenting

Inventors often have economic motivations to keep the details of their inventions secret. The patenting system provides the legal right for a limited time to exclude others from making, using, offering for sale, or selling the invention, in exchange for public disclosure of the technical information in the granted patent. Extensive publicly available administrative data exist for patents and their inventors, and extensive databases allow for systematic insights into these patents. In the absence of other comprehensive data on invention, patent data provide unique and useful insights into the inventions deemed valuable enough to patent. However, analysis of these data requires caution.

One caveat is that most patented inventions are never commercialized; they are neither representative of all inventions nor are they measures of innovation. Conversely, many valuable inventions that are commercialized are not patented. Companies choose a variety of strategies to protect their inventions and intellectual property. For example, U.S. companies rate trade secrets higher than patents in their importance for protecting intellectual property, which is true even for R&D-performing firms.

In addition, patent protection may be sought for reasons other than intended commercialization. Privately owned patents may be obtained to block rivals and negotiate with competitors, to use in lawsuits, or to build "thickets" of patents to impede or raise others' costs of R&D and innovation (Cohen, Nelson, and Walsh 2000). Research suggests that some organizations and countries pursue "strategic patenting" to block competitors and to monetize patents through licensing and other activities (Ernst 2013:1–9). Other firms may respond by patenting defensively. New and emerging firms may seek patent protection to help obtain financing because investors perceive patents as potentially valuable for a firm's assets and future profitability. Finally, cross-country analysis indicates that international differences in taxes on corporate and patent income influence the choice of patent location for multinational firms (Organisation for Economic Co-operation and Development 2016:3). However, within these limitations, U.S. Patent and Trademark Office patent documents tell us when and in what technology areas inventors have decided to protect their intellectual property with patent protection. This rich detail, which also includes the name and address of the inventor and assignee, justifies presentation of the patent documents.

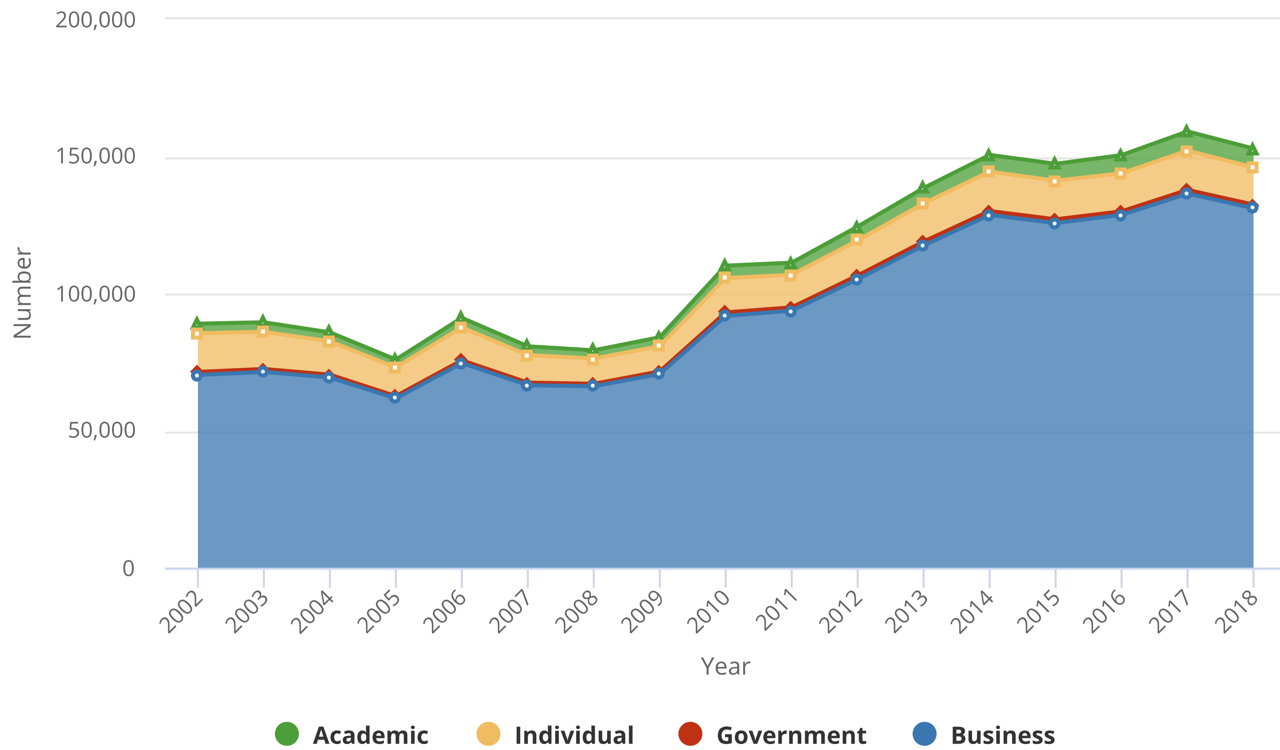
This report provides statistics on the relative extent to which private industry, the federal government (intramural research facilities and federally funded R&D centers), and higher education institutions account for a recent year's U.S. patent awards. There are marked differences in terms of the scale of economic resources directed toward patenting inventions among these sectors; the private business sector expends significantly more resources than either the federal government or higher education. Even so, each of these sectors has evolved substantial capacities for identifying potentially patentable inventions and filing patent applications in the United States and worldwide. Differences also exist within and across these sectors in the perceived net benefit of choosing patenting as a principal means of pursuing the further development and commercialization of inventions.

USPTO Patent Activity

The USPTO awarded 309,000 utility patents in 2018, nearly equally divided between foreign and domestic inventors (Table S8-1). Among U.S. assignees (those assigned the rights of ownership), businesses received by far the most patents (131,121 or 85%); individuals (9%), the academic sector (4%), and the government sector (1%) each received a relatively small share of patents (**Figure 8-1**).

FIGURE 8-1

USPTO patents granted to U.S. owners: 2002–18



USPTO = U.S. 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).

Source(s)

National Center for Science and Engineering Statistics, National Science Foundation; Science-Metrix; PatentsView, USPTO, accessed June 2019. See Table S8-1.

Science and Engineering Indicators

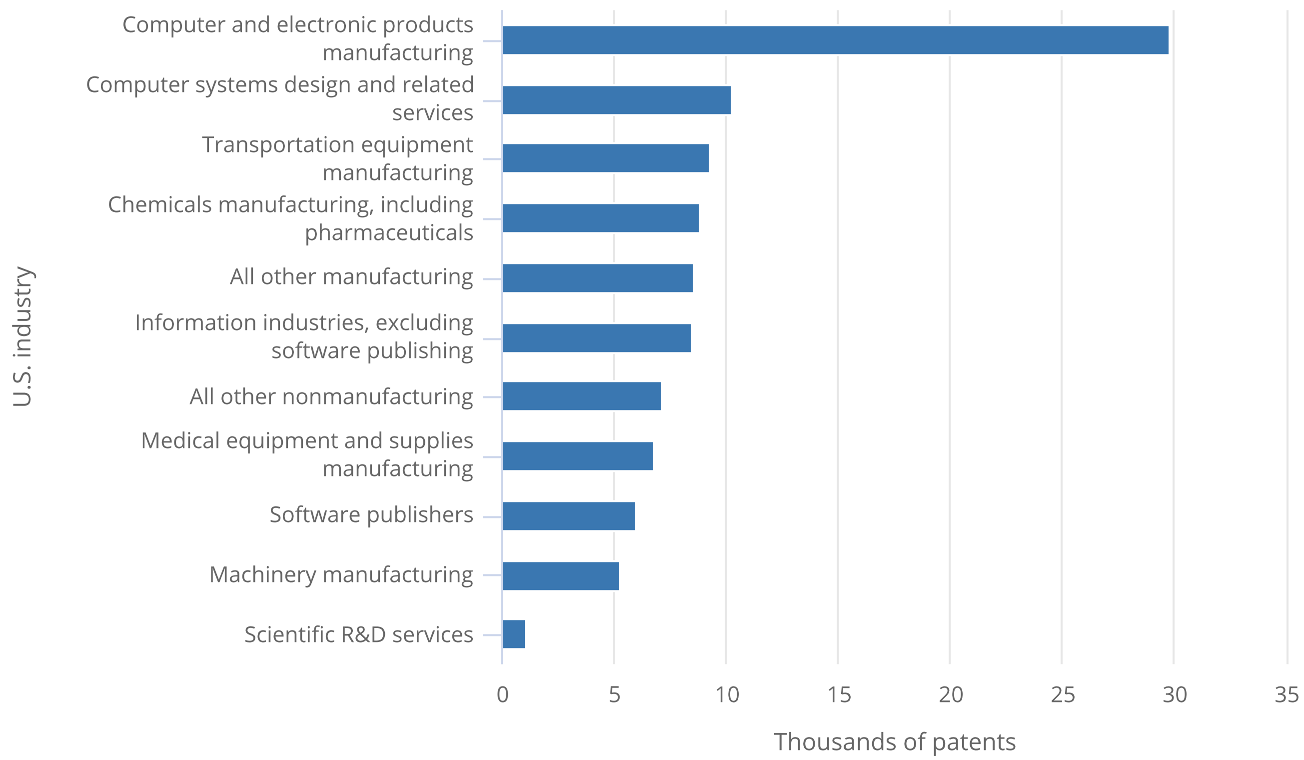
Among U.S. assignees, businesses have seen a rapid increase since 2009 in the number of patents granted, followed by more moderate growth after 2014. Patents issued to U.S. firms almost doubled (94%) between 2002 and 2017 (**Figure 8-1**). This increase in patenting reflects in part an overall trend toward the increased importance of intellectual property protection, especially for information that can be digitized (Organisation for Economic Co-operation and Development [OECD] 2017b). To put this in context with the growth in business R&D expenditures in the United States, patenting activity grew faster. Over the same period, businesses' domestic R&D expenditures rose 59%, after adjusting for inflation (NCSES 2020).

Patenting by U.S. Industries

The NCSES Business R&D Survey (BRDS) provides information on industry affiliation of U.S. inventors who receive USPTO patents. Data from BRDS show that the USPTO granted 102,000 utility patents to R&D-performing firms in the United States in 2017 (**Figure 8-2**). Firms in the computer and electronics manufacturing industry received the greatest number of patents, almost 30,000 in 2017 (**Figure 8-2**). These firms also report the highest level of domestic R&D performance in 2017, about $79 billion (**Figure 8-3**). In general, high R&D industries have high rates of patenting; the relative ranking differs, however. For example, the computer systems design and related services industry showed relatively high levels of U.S. patenting, while several other industries outspent it domestically in R&D. Conversely, the scientific R&D services industry performed more than $17 billion in R&D in 2017 while receiving only a little over 1,100 patents (**Figure 8-2** and **Figure 8-3**).

FIGURE 8-2

USPTO patents granted, by selected U.S. industry: 2017



USPTO = U.S. Patent and Trademark Office.

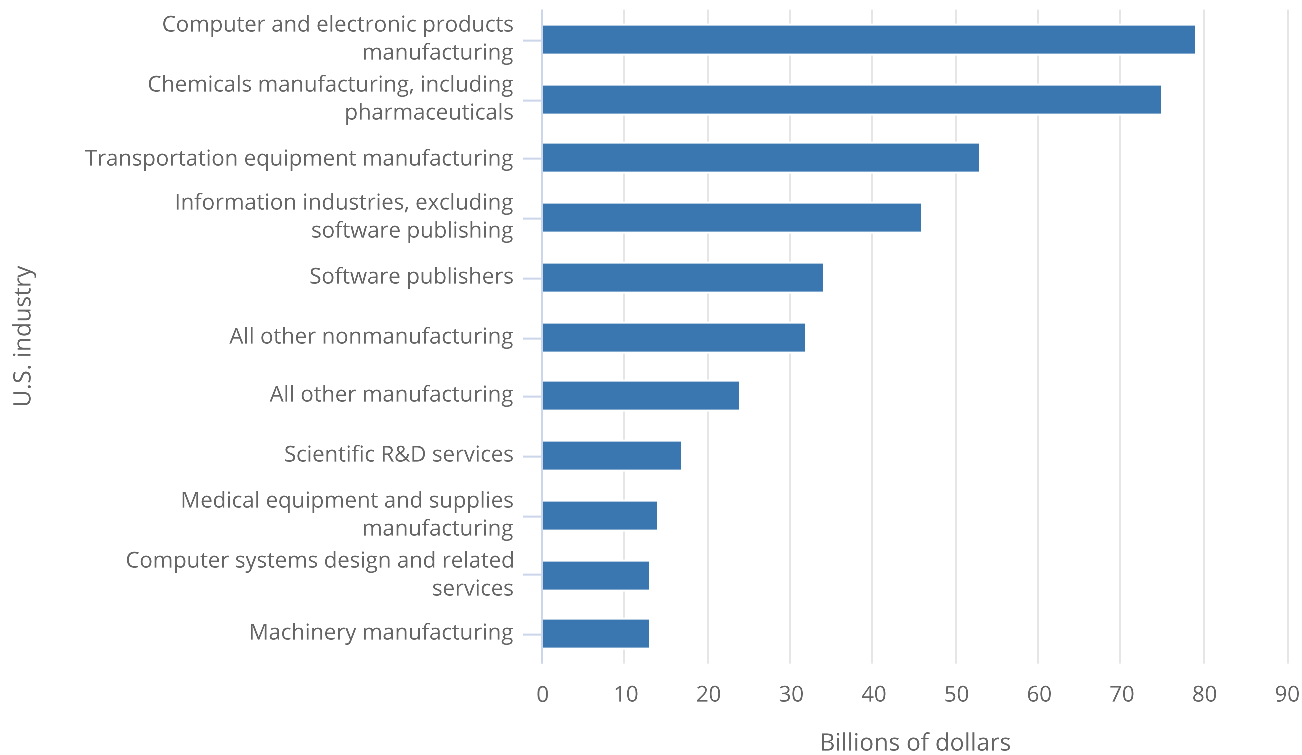
Note(s)
Industry classification is based on the dominant business code for domestic R&D performance, where available. For companies that did not report business codes, the classification used for sampling was assigned. Statistics are based on companies in the United States that reported to the survey, regardless of whether they did or did not perform or fund R&D. These statistics do not include an adjustment to the weight to account for unit nonresponse. For a small number of companies that were issued more than 100 patents by USPTO, survey data were supplemented with counts from **https://www.uspto.gov/**. Software publishers includes other publishing.

Source(s)
National Center for Science and Engineering Statistics, National Science Foundation, and U.S. Census Bureau, Business R&D Survey (BRDS), 2017.

Science and Engineering Indicators

FIGURE 8-3

Domestic R&D performance, by selected U.S. industry: 2017



Note(s)

Industry classification is based on the dominant business code for domestic R&D performance, where available. For companies that did not report business codes, the classification used for sampling was assigned. Statistics are based on companies in the United States that reported to the survey, regardless of whether they did or did not perform or fund R&D. These statistics do not include an adjustment to the weight to account for unit nonresponse. Software publishers includes other publishing. Medical equipment and supplies manufacturing includes miscellaneous manufacturing.

Source(s)

National Center for Science and Engineering Statistics, National Science Foundation, and U.S. Census Bureau, Business R&D Survey (BRDS), 2017.

Science and Engineering Indicators

Patenting by Universities and Federal Labs

The motivations to patent an invention may differ substantially from the motivations to create other types of knowledge. Business researchers more frequently engage in experimental development activity, which is directed toward creating or improving products or processes, than their academic and government counterparts. This increases opportunities for direct commercial applications of their work.

Relative to the amount of R&D performed, universities and federal labs receive fewer patents. In 2017, businesses accounted for more than 70% of the R&D performed in the United States; universities performed about 13% and government labs about 10% (NCSES 2020). Of the USPTO patents assigned to U.S. assignees in that year, academic institutions accounted for about 4%, and government labs even fewer at 0.8% (these shares were unchanged in the latest patent data for 2018) (**Figure 8-1**).

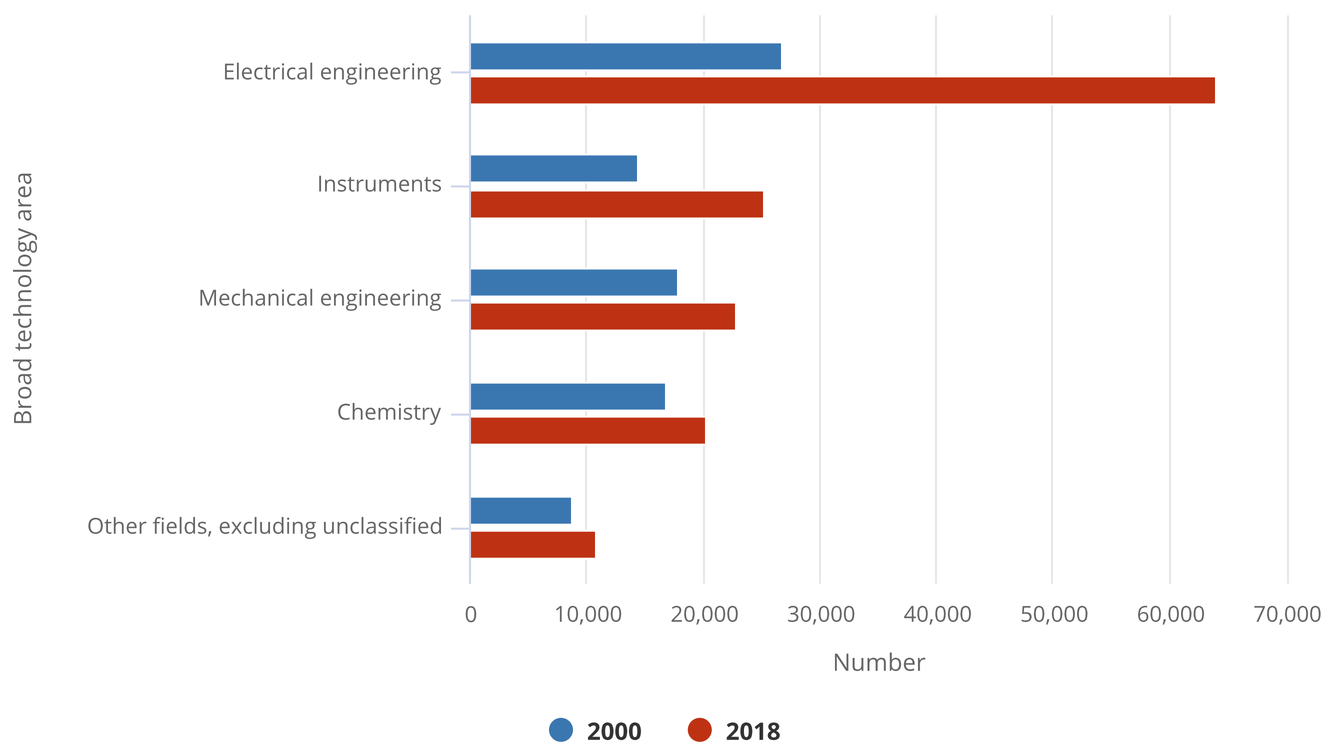
Research at universities and federal labs more frequently yields peer-reviewed articles than commercially oriented inventions. This disparity between R&D activity and patenting makes sense given the difference among the activities and goals of universities, federal labs, and businesses. Academic patenting also differs in terms of focus areas. Compared with other sectors, academic patenting is relatively more focused on pharmaceuticals, biotechnology, and medical technologies. In 2018, these three technology areas accounted for 41% of USPTO patents awarded to U.S. academic institutions, compared with 10% of USPTO patents to all sectors (Table S8-2, Table S8-4, Table S8-17, Table S8-19, and Table S8-20).

Patent Technology Areas and Patent Trends

The USPTO classifies patent data filings based on technology areas, and the detailed technology areas can be aggregated to analyze trends in patenting focus over time. For example, the electrical engineering technology area includes five subclasses, which are further subdivided into dozens of detailed categories or fields. This report provides annual data for USPTO and international patents based on the 35 technical fields described by the World Intellectual Property Organization (WIPO) for international comparisons.[2] **Figure 8-4** aggregates data on these 35 fields into five broad technology areas.

FIGURE 8-4

USPTO patents granted to U.S. inventors, by broad technology area: 2000 and 2018



USPTO = U.S. Patent and Trademark Office.

Note(s)

Civil engineering is included in Other fields. Patents are allocated geographically according to patent inventorship information. They are classified technologically under the World Intellectual Property Organization (WIPO) classification that is made up of 35 International Patent Classification (IPC) technical fields. Fractional counts of patents to each technological field assign the weight of a patent to the corresponding technological fields. For instance, a patent that is classified under five different technological fields will contribute 0.2 patent counts to each of its technological fields. Data across technical fields also sum up to the total number of USPTO-granted patents.

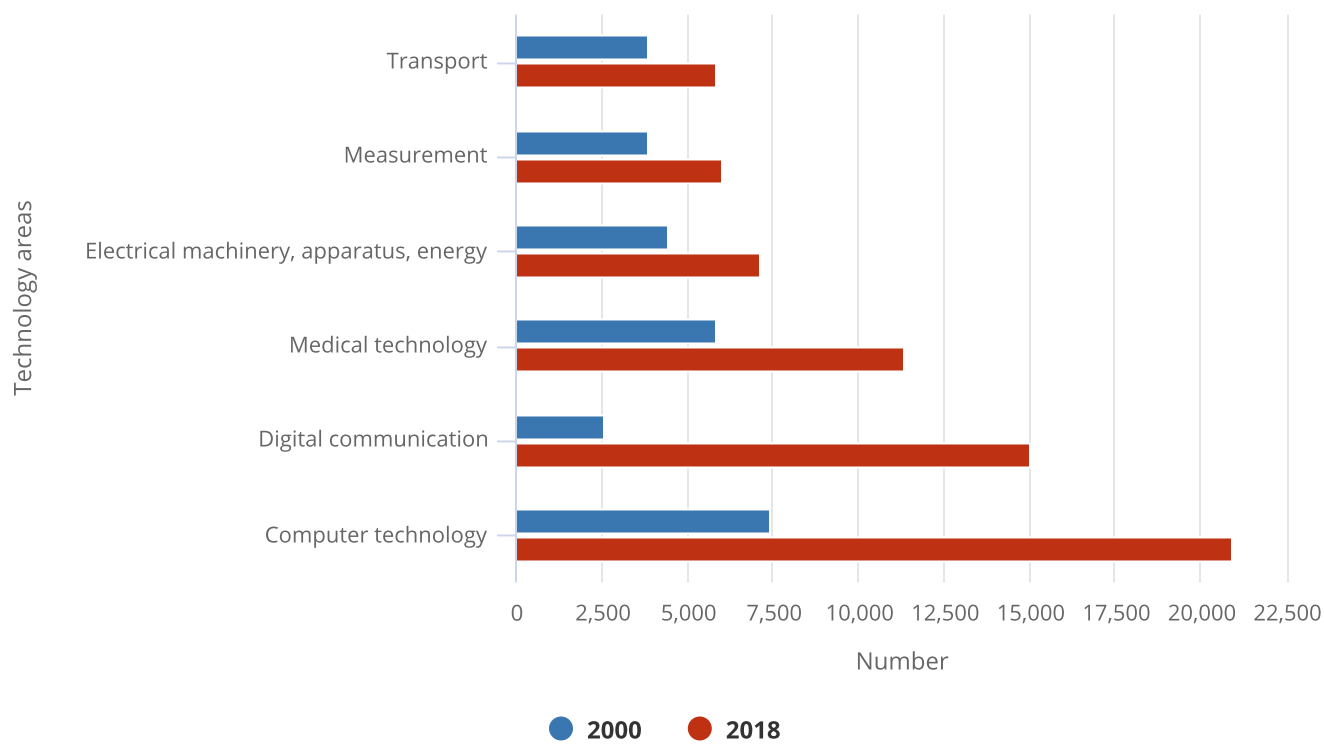
Source(s)
National Center for Science and Engineering Statistics, National Science Foundation; Science-Metrix; PatentsView, USPTO, accessed June 2019. See Table S8-5 through Table S8-39.

Science and Engineering Indicators

The USPTO patents granted to U.S. inventors can be grouped into engineering-related patents; both electrical and mechanical engineering patents made up about 60% of USPTO patents in 2018 (**Figure 8-4**). Patents related to instruments, chemistry, and other fields made up the remainder of USPTO patents to U.S. inventors in 2018. The number of electrical engineering patents more than doubled between 2000 and 2018 (**Figure 8-4**). The role of information and communication technologies (ICT) is evident here as well; 2 of the 35 technology fields, computer technology and digital communication, account for a large part of the increase in electrical engineering patents (**Figure 8-5**).

FIGURE 8-5

USPTO utility patents granted to U.S. inventors, by selected technology area: 2000 and 2018



USPTO = U.S. Patent and Trademark Office.

Note(s)
Patents are allocated geographically according to patent inventorship information. They are classified technologically under the World Intellectual Property Organization (WIPO) classification that is made up of 35 International Patent Classification (IPC) technical fields. Fractional counts of patents to each technological field assign the weight of a patent to the corresponding technological fields. For instance, a patent that is classified under five different technological fields will contribute 0.2 patent counts to each of its technological fields. Data across technical fields also sum up to the total number of USPTO-granted patents.

Source(s)
National Center for Science and Engineering Statistics, National Science Foundation; Science-Metrix; PatentsView, USPTO, accessed June 2019. See Table S8-5, Table S8-8, Table S8-10, Table S8-14, Table S8-17, and Table S8-36.

Science and Engineering Indicators

Health and medical inventions contribute to growth across these five broad technology areas; for example, patents in the analysis of biological materials and in medical technology contribute to the growth in patenting in instruments, and inventions in biotechnology and pharmaceuticals contribute to the growth in chemistry patenting. Similarly, advances in autonomous vehicles incorporate inventions in multiple areas, including optics, transport, electrical machinery, and chemicals.

Global Patent Trends and Cross-National Comparisons

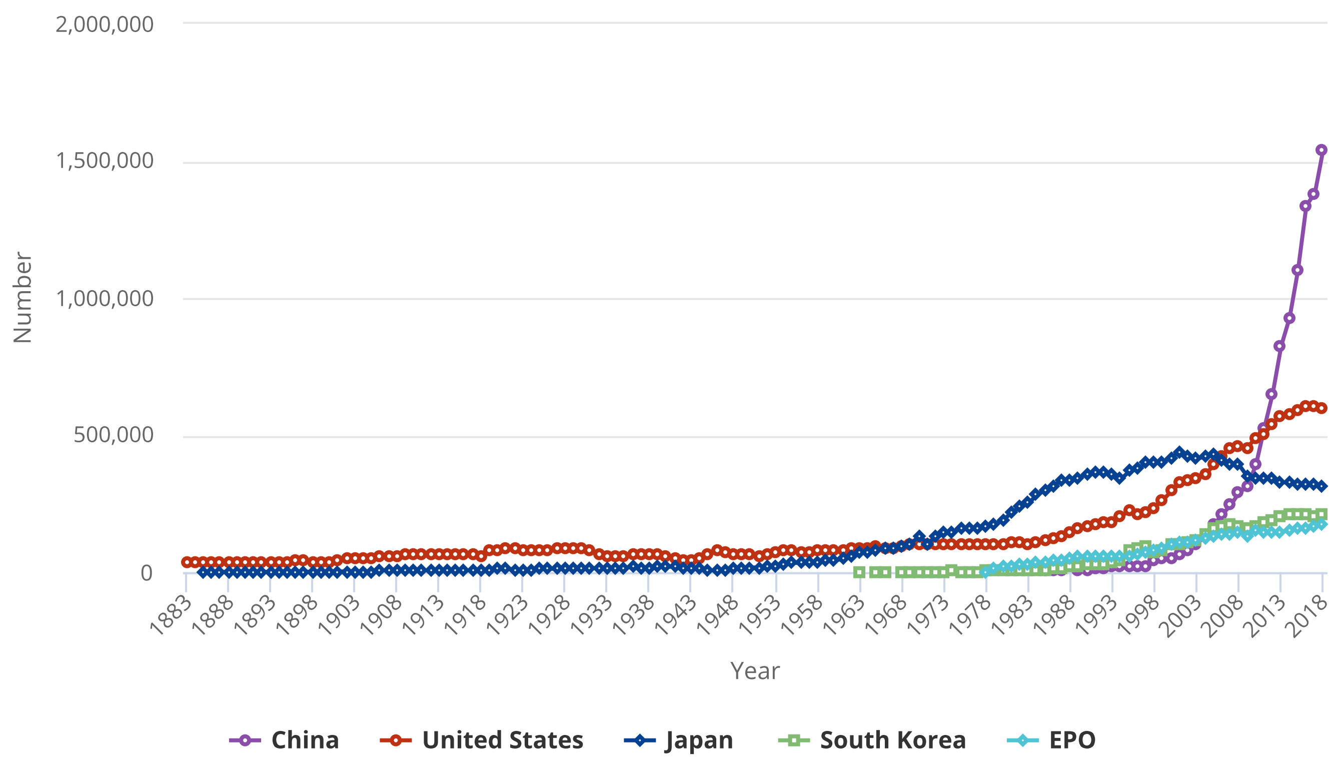
The data in this section present global patenting trends in three complementary ways; all three demonstrate rapid worldwide growth. First, the WIPO data provide a high-level view of patenting by the most active patent offices globally, indicating markets where this form of intellectual property protection is increasing over time. Second, international patent family data provide a more detailed view of emerging patented inventions across geography, based on inventor's address. International patent family data count each invention once as a family of related filings based on granting year of the first underlying invention. Patent families count inventions granted in at least one jurisdiction and count the invention only once, even if it is later protected elsewhere. Based on inventor addresses, inventors from China patent most frequently at the global level. Third, this report rounds out the global patent analysis focusing on the technology-level activity of U.S. and foreign inventors granted USPTO patents. These data show the increasing role of foreign inventors in USPTO patenting.

WIPO Patents

Historically, patenting grew exponentially in the second half of the 20th century. **Figure 8-6** shows patent applications for the top five offices worldwide: USPTO, National Intellectual Property Administration of the People's Republic of China, European Patent Office, Japan Patent Office, and Korean Intellectual Property Office. WIPO compiled these data; it collects patenting data from national offices and compiles patent statistics internationally. While the USPTO and the Japan Patent Office previously had the largest number of filings, China now receives the largest number of patent applications worldwide (WIPO 2019).

FIGURE 8-6

WIPO patent applications for top 5 patenting offices worldwide: 1883–2018



EPO = European Patent Office; WIPO = World Intellectual Property Organization.

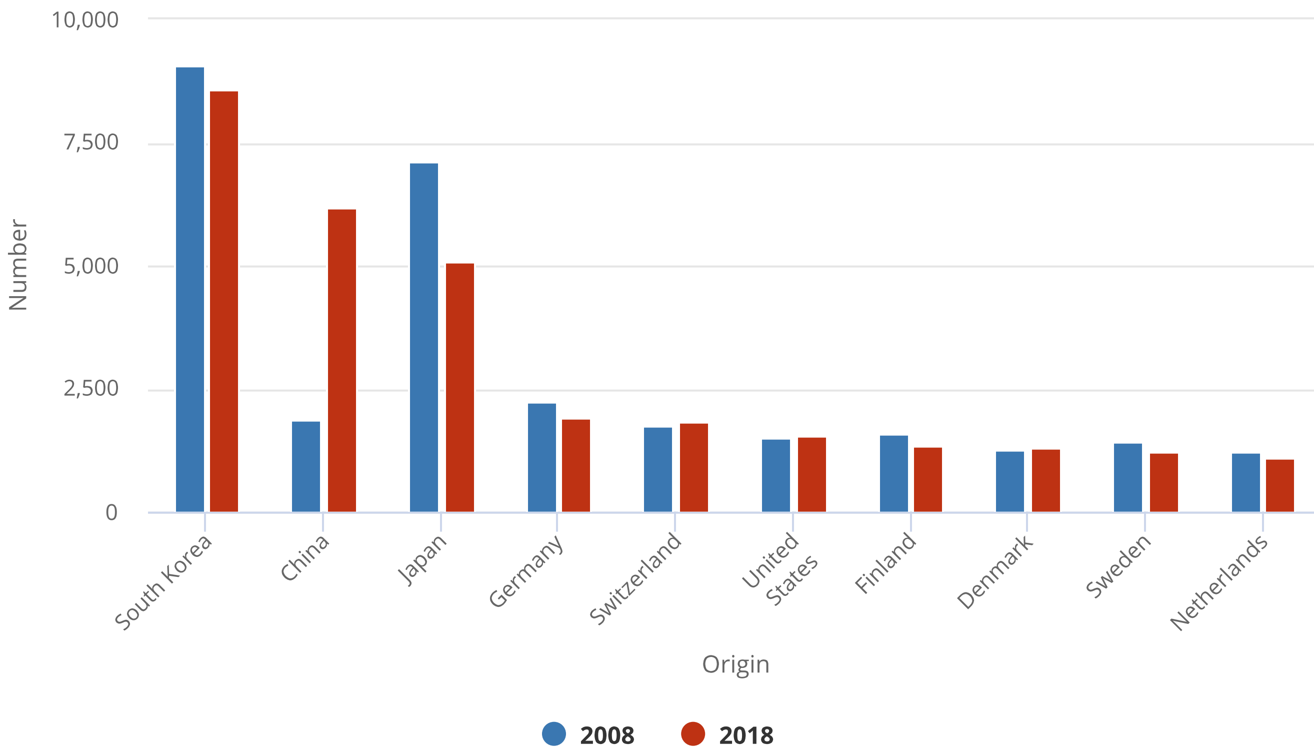
Source(s)
WIPO Statistics Database, accessed September 2019.

Science and Engineering Indicators

Patents as a ratio to gross domestic product (GDP) provides a normalization for the size of each economy. On this basis, South Korea has the largest number of patents, followed by China and Japan, according to the WIPO data (**Figure 8-7**). South Korea also has the highest ratio of R&D expenditures to GDP of the top 15 R&D-performing countries and economies (*Indicators 2020* report “Research and Development: U.S. Trends and International Comparisons”).

FIGURE 8-7

Resident patent applications per $100 billion GDP for the top 10 origins: 2008 and 2018



Note(s)

Amounts are in U.S. dollars.

Source(s)

World Intellectual Property Organization (WIPO) Statistics Database, compiled by WIPO in processing international applications and registrations through the Patent Cooperation Treaty and the Madrid and Hague Systems, accessed September 2019.

Science and Engineering Indicators

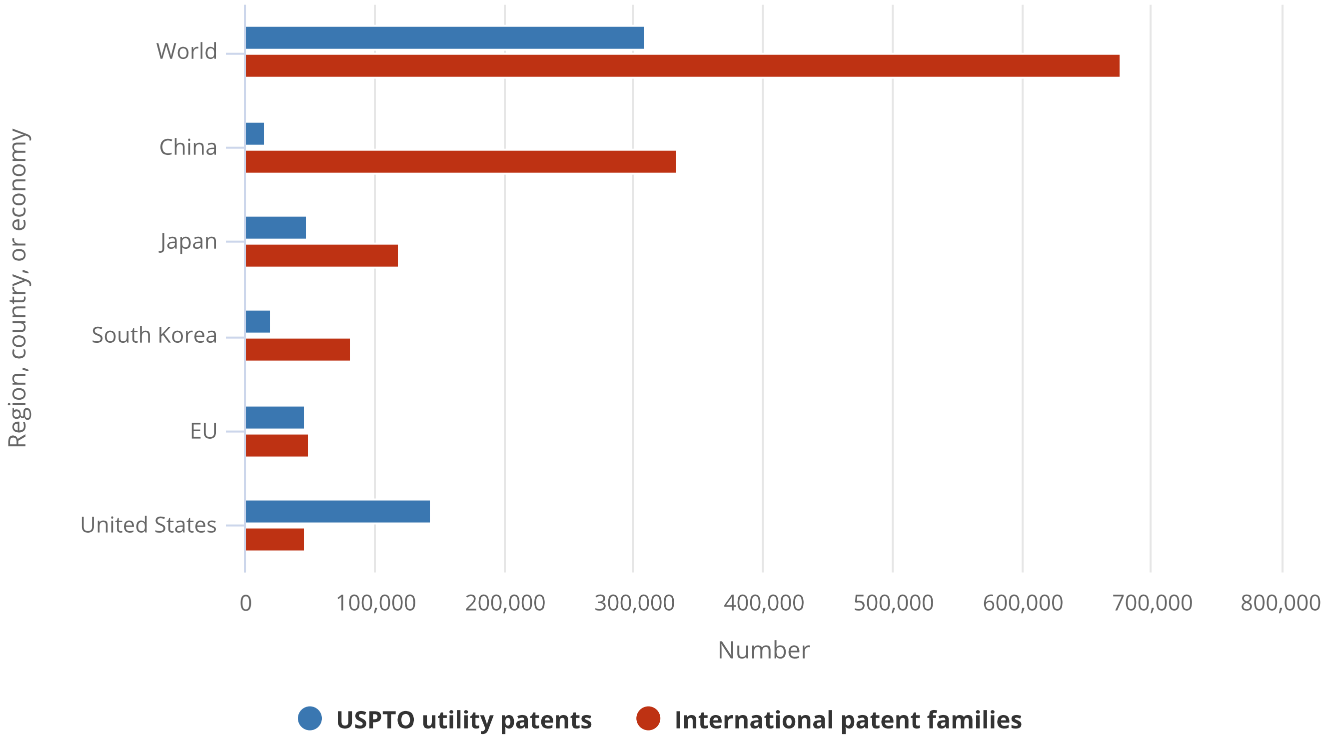
Patent Families

The patent family data described in this section account for patenting in international jurisdictions without double-counting. Patent offices register patents from resident inventors as well as foreign inventors; thus, a unique invention may be registered in more than one jurisdiction. Further, a patent may be modified or extended, adding to the total number of patents. The patent family statistics presented here count a unique underlying invention as the unit of measurement. Each patent family covers a group of related patents that have an original invention in common. All subsequent patents in a family refer to the first patent filed, called a priority patent; the original filing may be domestic or from another jurisdiction. For example, an invention patented in Japan may refer to an earlier patent in the United States. In this case, both the Japanese and the U.S. patent would be part of the same patent family. The composition of these patenting data differs from that of the USPTO data and shows both the breadth and growth of inventive activity around the world. Table S8-4 through Table S8-40 show the patent family data alongside the USPTO data.

In 2018, U.S. inventors received patents on approximately 46,000 international patent families compared with 144,000 separate patents issued by the USPTO (Table S8-4). **Figure 8-8** shows the scale of USPTO patents compared with international patent families for China, the European Union (EU), Japan, South Korea, the United States, and the world. Overall, China had the largest number (334,000) of international patent families granted in 2018; in 10 years this represents an increase of almost eightfold (43,500 in 2008) (Table S8-4).

FIGURE 8-8

USPTO utility patents and international patent families granted, by region, country, or economy: 2018



EU = European Union; USPTO = U.S. 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. International Patent Documentation (INPADOC) patent families across all patent offices covered in the Worldwide Patent Statistical Database (PATSTAT) are counted according to the year of the first granted patent in the patent family. Patent families are allocated according to patent inventorship information found on the priority patent of the INPADOC families. To account for missing ownership information in PATSTAT for some offices, a method designed by de Rassenfosse et al. (2012) is used to fill missing information on priority patents using information in successive filings within the families (see technical documentation for details). Patent families are fractionally allocated among regions, countries, or economies based on the proportion of residences of all named inventors. The EU includes 28 member countries. China includes Hong Kong.

Source(s)

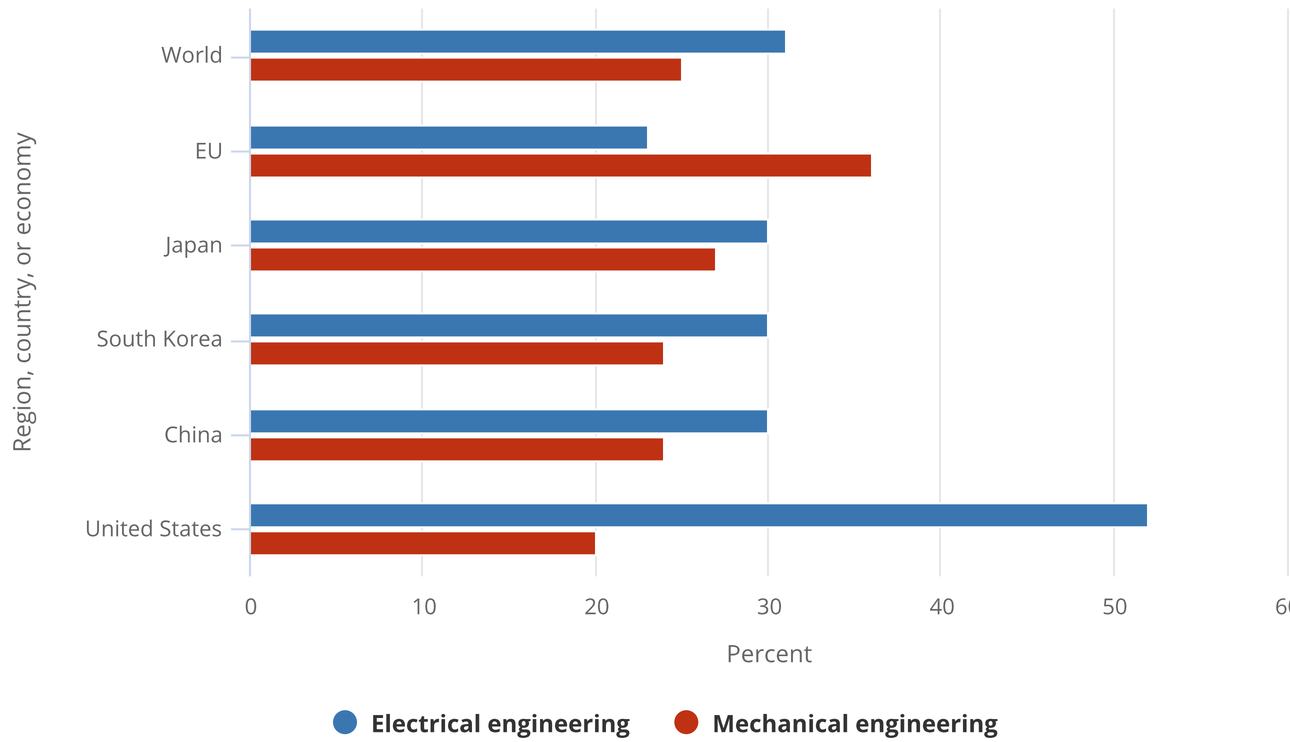
Science-Metrix; PATSTAT; PatentsView, USPTO, accessed June 2019. See Table S8-4.

Science and Engineering Indicators

By technology area, electrical engineering patents make up almost a third (31%) of international patent families; mechanical engineering patents make up another quarter (**Figure 8-9**). For inventors from China, electrical engineering patents comprise almost a third of international patent families granted in 2018 (**Figure 8-9**). In comparison, electrical engineering comprised 45% of USPTO patents granted to U.S. inventors in 2018 (**Figure 8-4**).

FIGURE 8-9

Share of electrical and mechanical engineering patents in selected region's, country's, or economy's international patent families granted in 2018



EU = European Union; USPTO = U.S. 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. International Patent Documentation (INPADOC) patent families across all patent offices covered in the Worldwide Patent Statistical Database (PATSTAT) are counted according to the year of the first granted patent in the patent family. Patent families are allocated according to patent inventorship information found on the priority patent of the INPADOC families. To account for missing ownership information in PATSTAT for some offices, a method designed by de Rassenfosse et al. (2012) is used to fill missing information on priority patents using information in successive filings within the families (see technical documentation for details). Patent families are fractionally allocated among regions, countries, or economies based on the proportion of residences of all named inventors. The EU includes 28 member countries. China includes Hong Kong. The broad technology areas of electrical and mechanical engineering are defined using patent technology categories from the World Intellectual Property Organization (2018).

Source(s)

National Center for Science and Engineering Statistics, National Science Foundation; Science-Metrix; PatentsView, USPTO, accessed June 2019. See Table S8-4 through Table S8-12 and Table S8-29 through Table S8-36.

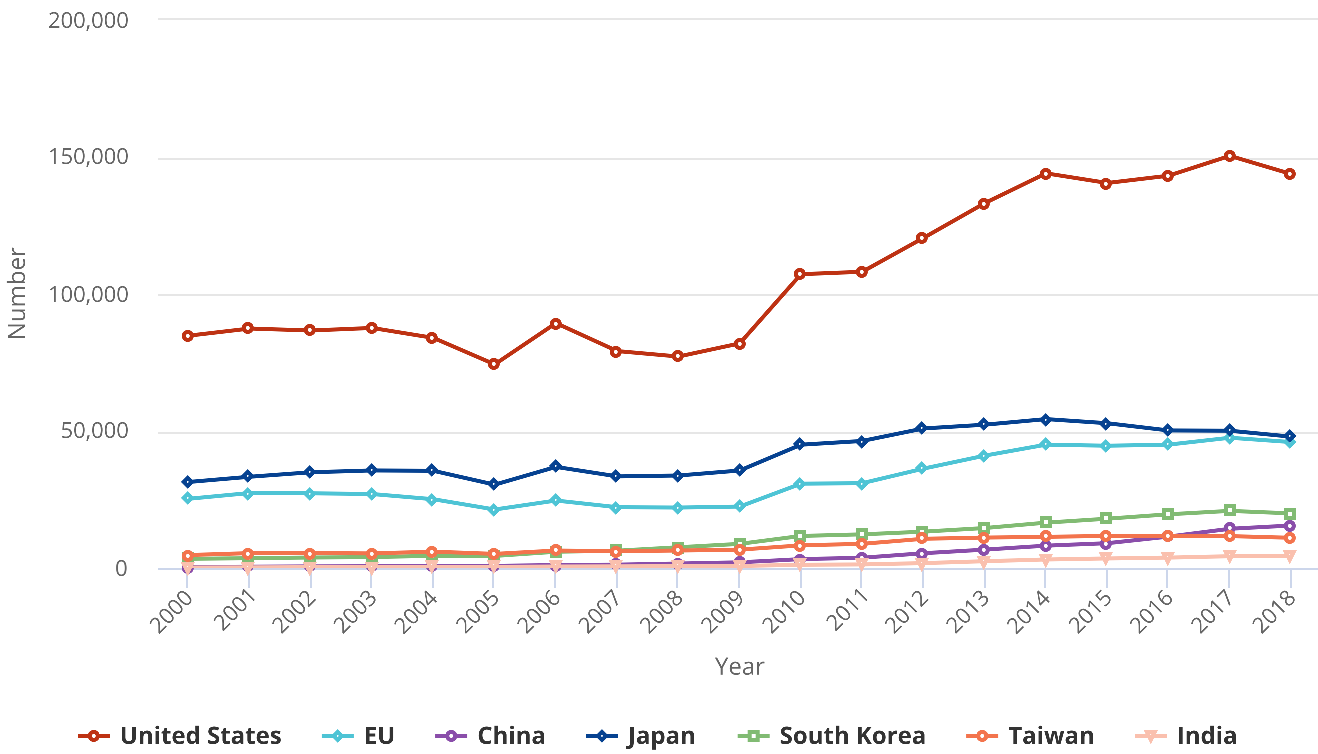
Science and Engineering Indicators

USPTO Patents

USPTO patents provide insight into the activities of inventors who choose to bear the cost of protecting their inventions in the U.S. market. The USPTO grants slightly more than half (53%) of all U.S. patents to foreign inventors, up from 46% in 2000 (Table S8-4). Rising rates of foreign patenting reflect the expansion of commercial activities across international borders as foreign firms seek patent protection in multiple international jurisdictions (Fink, Khan, and Zhou 2015). Large multinational companies, including those based outside of the United States, have increasingly sought patent protection beyond their domestic borders. The EU and Japan continue to account for the largest numbers of foreign USPTO patent grantees, followed by South Korea (**Figure 8-10**). Although inventors from China account for a relatively small number of USPTO patents, over a decade, they have seen almost a 10-fold rise in the number of USPTO patents granted (from 1,600 in 2008 to 15,500 in 2018) (**Figure 8-10**). Patents related to electrical engineering accounted for the majority (63%) of USPTO patents granted to inventors from China (**Figure 8-11**).

FIGURE 8-10

USPTO utility patents granted, by selected region, country, or economy: 2000–18



EU = European Union; USPTO = U.S. 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. The EU includes 28 member countries. China includes Hong Kong.

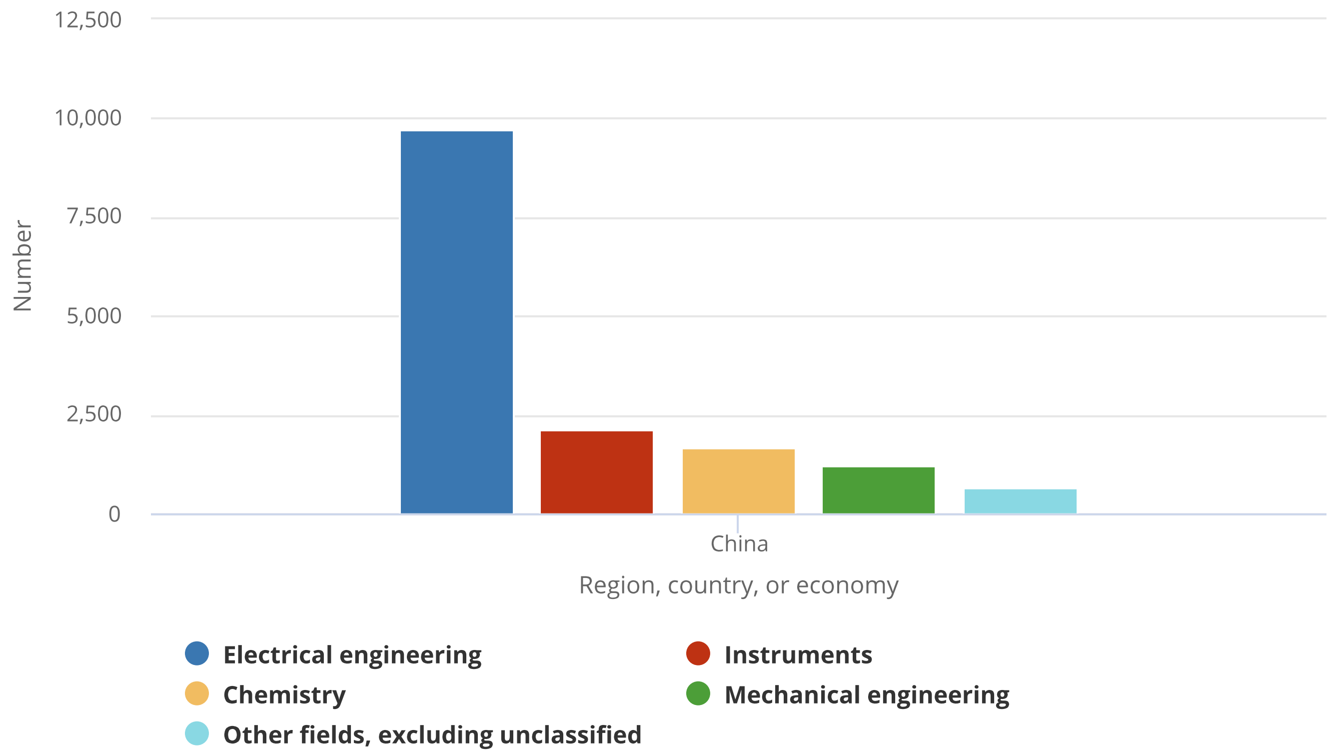
Source(s)

National Center for Science and Engineering Statistics, National Science Foundation; Science-Metrix; PatentsView, USPTO, accessed June 2019. See Table S8-4.

Science and Engineering Indicators

FIGURE 8-11

USPTO patents granted to inventors from China, by broad technology area: 2018



IT = information technology; USPTO = U.S. Patent and Trademark Office.

Note(s)

Civil engineering is included in Other fields. Patents are allocated geographically according to patent inventorship information. They are classified technologically under the World Intellectual Property Organization (WIPO) classification that is made up of 35 International Patent Classification (IPC) technical fields. Fractional counts of patents to each technological field assign the weight of a patent to the corresponding technological fields. For instance, a patent that is classified under five different technological fields will contribute 0.2 patent counts to each of its technological fields. Data across technical fields also sum up to the total number of USPTO-granted patents.

Source(s)

National Center for Science and Engineering Statistics, National Science Foundation; Science-Metrix; PatentsView, USPTO, accessed June 2019. See Table S8-5 through Table S8-39.

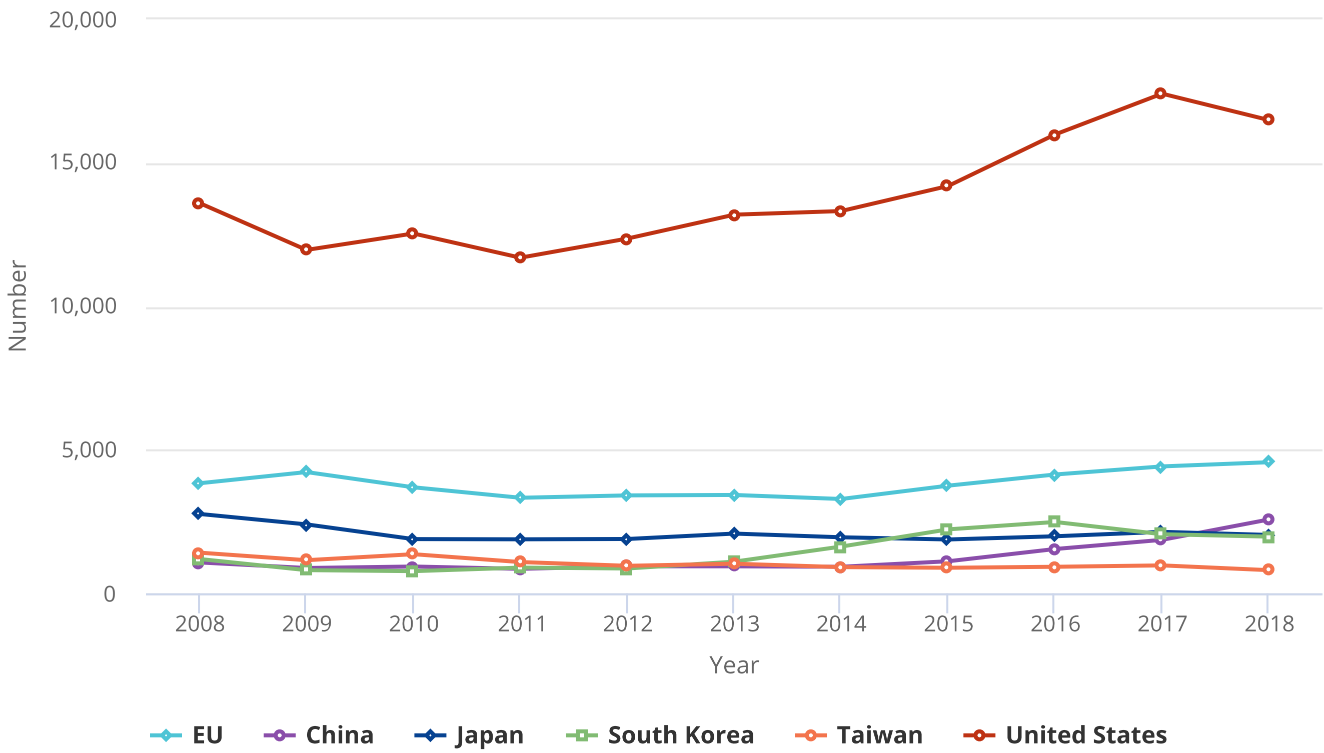
Science and Engineering Indicators

USPTO Design Patents

Patenting of designs is a very important intellectual property protection strategy for about one in six U.S. R&D-funding or -performing firms (NCSES 2018). In 2018, the USPTO awarded over 16,000 design patents to U.S. inventors or designers (**Figure 8-12**). The USPTO granted an additional 14,000 design patents in 2018 to inventors from outside of the United States (Table S8-43).[3] The EU accounts for about 4,600 of these (**Figure 8-12**). Since 2014, China has rapidly increased its design patenting in the United States and now patents on a scale comparable to Japan and South Korea (**Figure 8-12**).[4]

FIGURE 8-12

USPTO design patents granted, by selected region, country, or economy: 2008–18



EU = European Union; USPTO = U.S. Patent and Trademark Office.

Note(s)

Design 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. The EU includes 28 member countries. China includes Hong Kong.

Source(s)

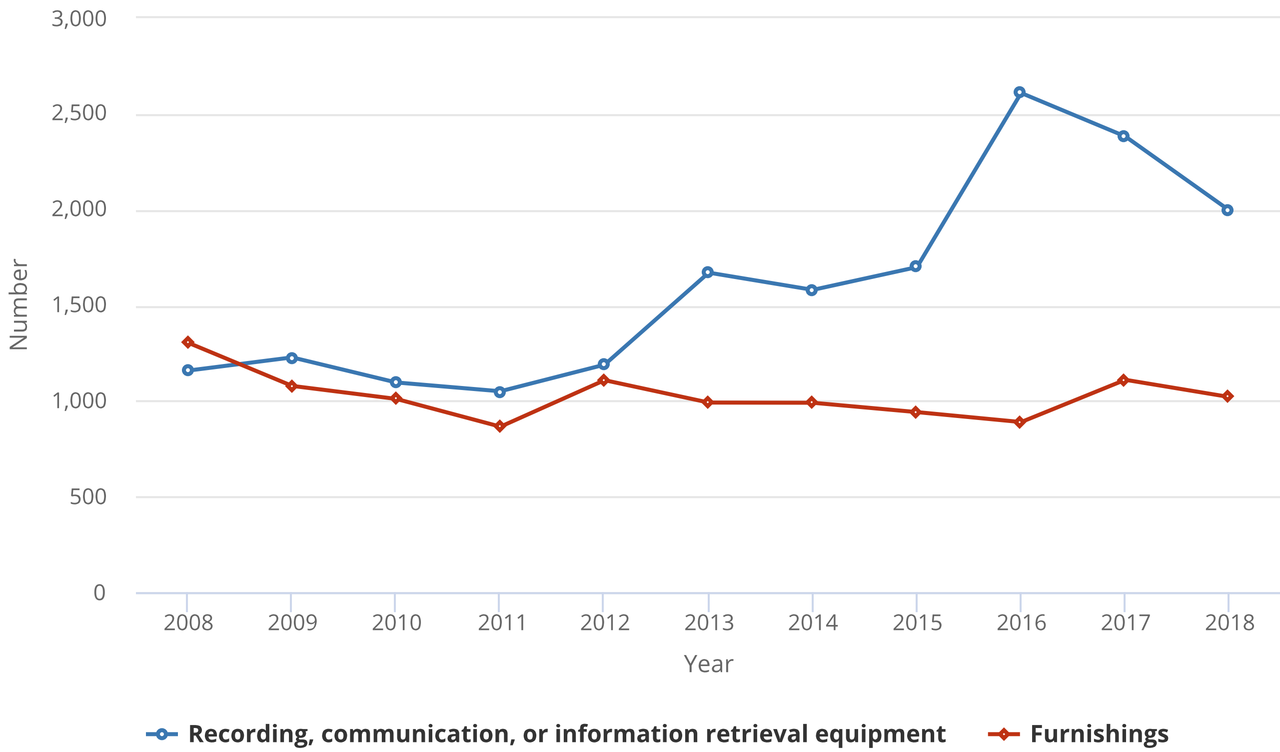
National Center for Science and Engineering Statistics, National Science Foundation; Science-Metrix; PatentsView, USPTO, accessed June 2019. See Table S8-43.

Science and Engineering Indicators

By product area, 10 years ago, the largest number of design patents were granted for furnishings (Table S8-44). The focus has shifted over the last decade to recording, communication, or information retrieval equipment—the category that includes items like smart phones, keyboards, and computer icons has grown rapidly to become the largest category of design patenting. **Figure 8-13** shows the trend growth for U.S. design patents in this category and in furnishings.

FIGURE 8-13

USPTO design patents granted to U.S. inventors in recording, communication, or information retrieval equipment and in furnishings: 2008–18



USPTO = U.S. Patent and Trademark Office.

Note(s)

Design patents are allocated according to patent inventorship information. Patents are classified under the USPTO classification of design patents, which classifies USPTO design patents under 35 design classes. Fractional counts of patents were assigned to each design class on patents to assign the proper weight of a patent to the corresponding design class under the classification.

Source(s)

National Center for Science and Engineering Statistics, National Science Foundation; Science-Metrix; PatentsView, USPTO, accessed June 2019. See Table S8-44.

Science and Engineering Indicators

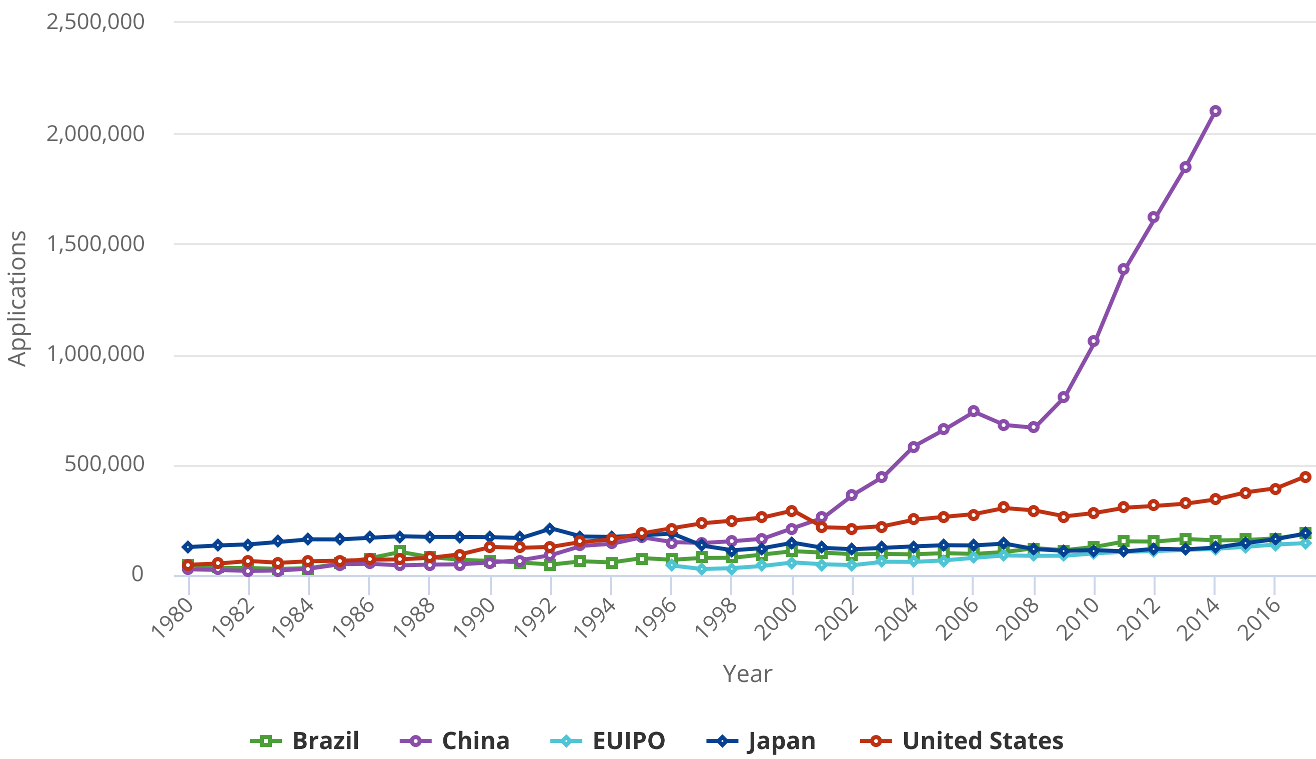
Beyond Patents: Trademarks and Plant Varieties

The registration of commercially used symbols, images, and names through trademarking can signal the creation of new products and services. Advances in ICT and digitization drive the development of new products, contributing to the growth in trademark applications (see Gao and Hitt [2012]). For companies in the United States that either perform or fund R&D, trademarks are considered as important as utility patents as an intellectual property protection strategy (NCSES 2018).

In the 20th century, intellectual property protection through registration of trademarks was primarily an activity of the United States, Europe, and Japan. This has changed. Trademark applications worldwide have increased rapidly in recent years, more than doubling from 5.5 million in 2008 to over 12 million a year in 2017 (WIPO 2019). Middle-income countries Brazil and China make up much of this growth; in 2017, Brazil's trademark applications met or surpassed those of Japan and the European Union Intellectual Property Office (**Figure 8-14**). As with global patenting, China has registered a rapidly increasing number of trademarks (**Figure 8-14**).

FIGURE 8-14

Total trademark applications, by top five filing offices: 1980–2017



EUIPO = European Union Intellectual Property Office.

Source(s)

World Intellectual Property Organization Statistics Database, Total trademark applications (direct and via the Madrid system), accessed 27 September 2019.

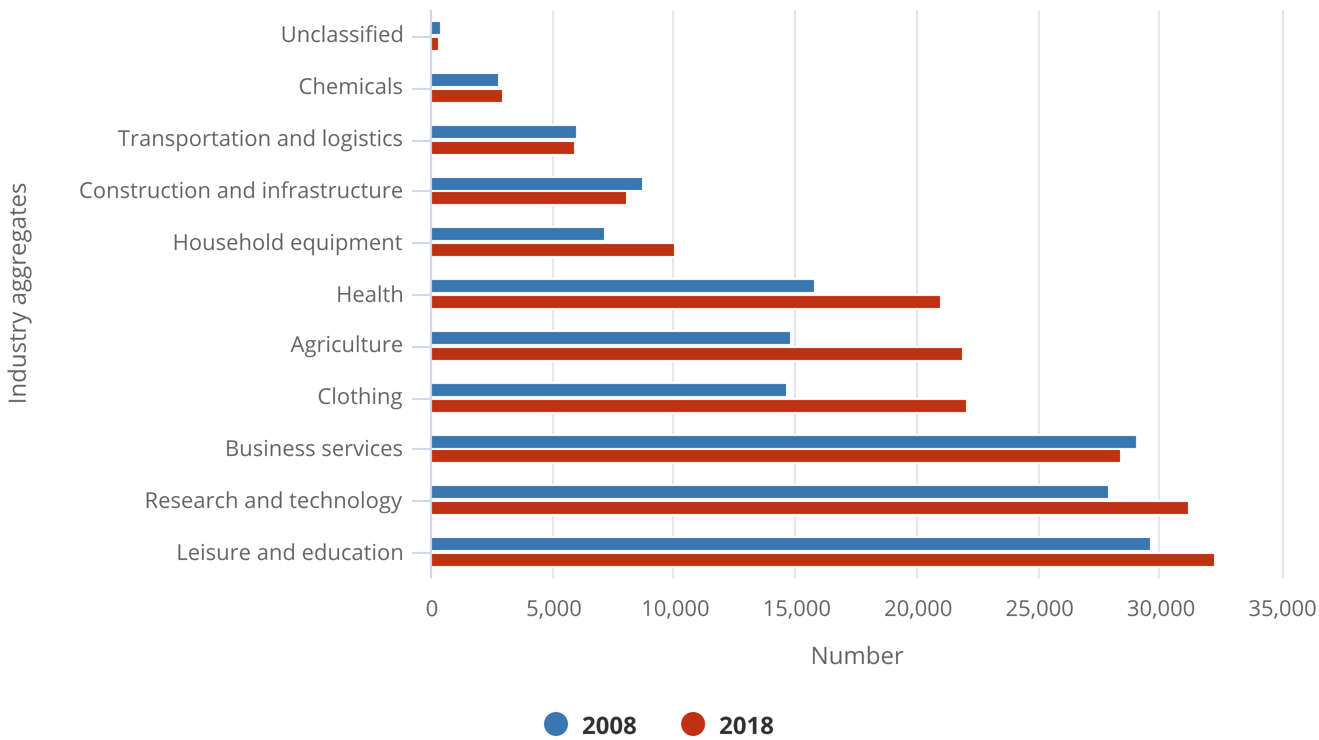
Science and Engineering Indicators

USPTO Trademarks

The USPTO registered 273,000 trademarks in 2018, including 184,000 to U.S. assignees (Table S8-45). While the three broad categories that make up about half of these trademarks have not changed (**Figure 8-15**), similar to USPTO patents, the internationalization of commerce has led to an increasing share of USPTO trademarks registered to foreign assignees. Over the last decade, the number of foreign-registered USPTO trademarks has grown 137%, compared with 17% growth in the number of USPTO trademarks registered to U.S. assignees (**Figure 8-16**).

FIGURE 8-15

Number of U.S.-registered USPTO trademarks, by 10 aggregates (Nice classification): 2008 and 2018



USPTO = U.S. 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.

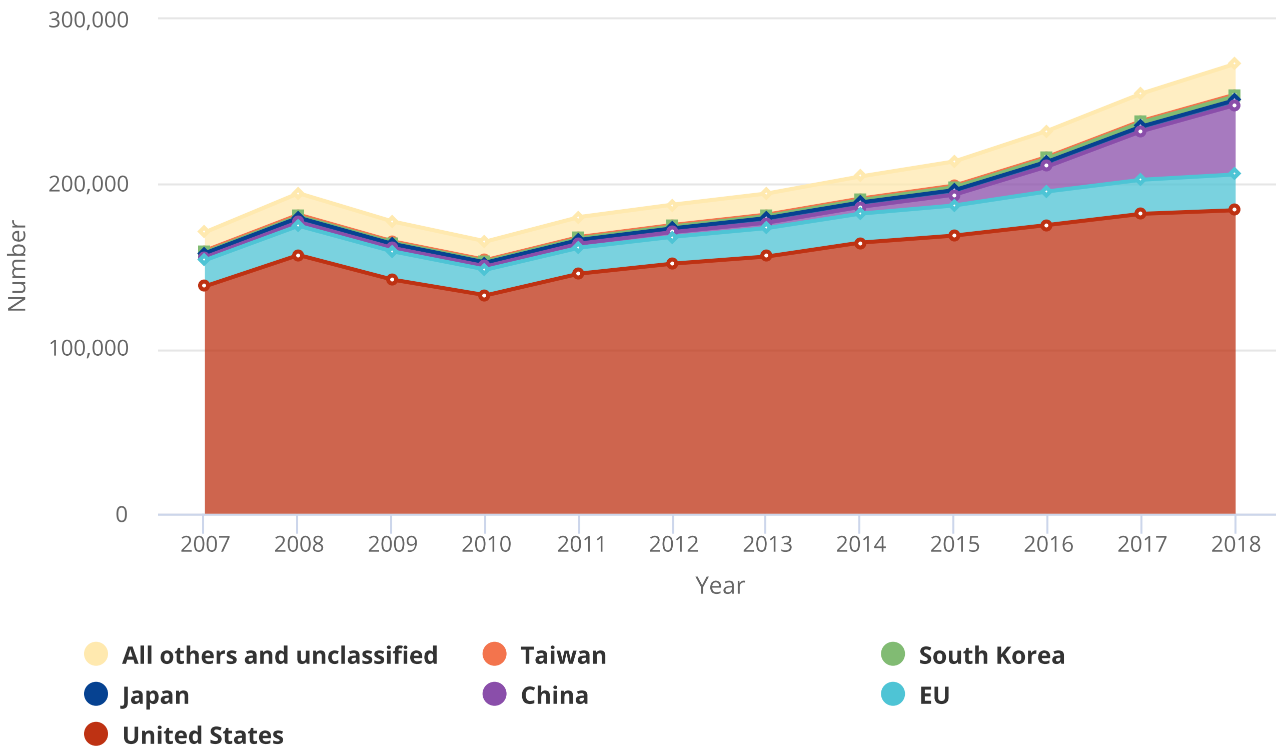
Source(s)

National Center for Science and Engineering Statistics, National Science Foundation; Science-Metrix; USPTO data hosted by Reed Tech (LexisNexis), accessed April 2019. See Table S8-48 through Table S8-58.

Science and Engineering Indicators

FIGURE 8-16

Number of registered USPTO trademarks, by selected region, country, or economy: 2007–18



EU = European Union; USPTO = U.S. 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. The EU includes 28 member countries. China includes Hong Kong. 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.

Source(s)

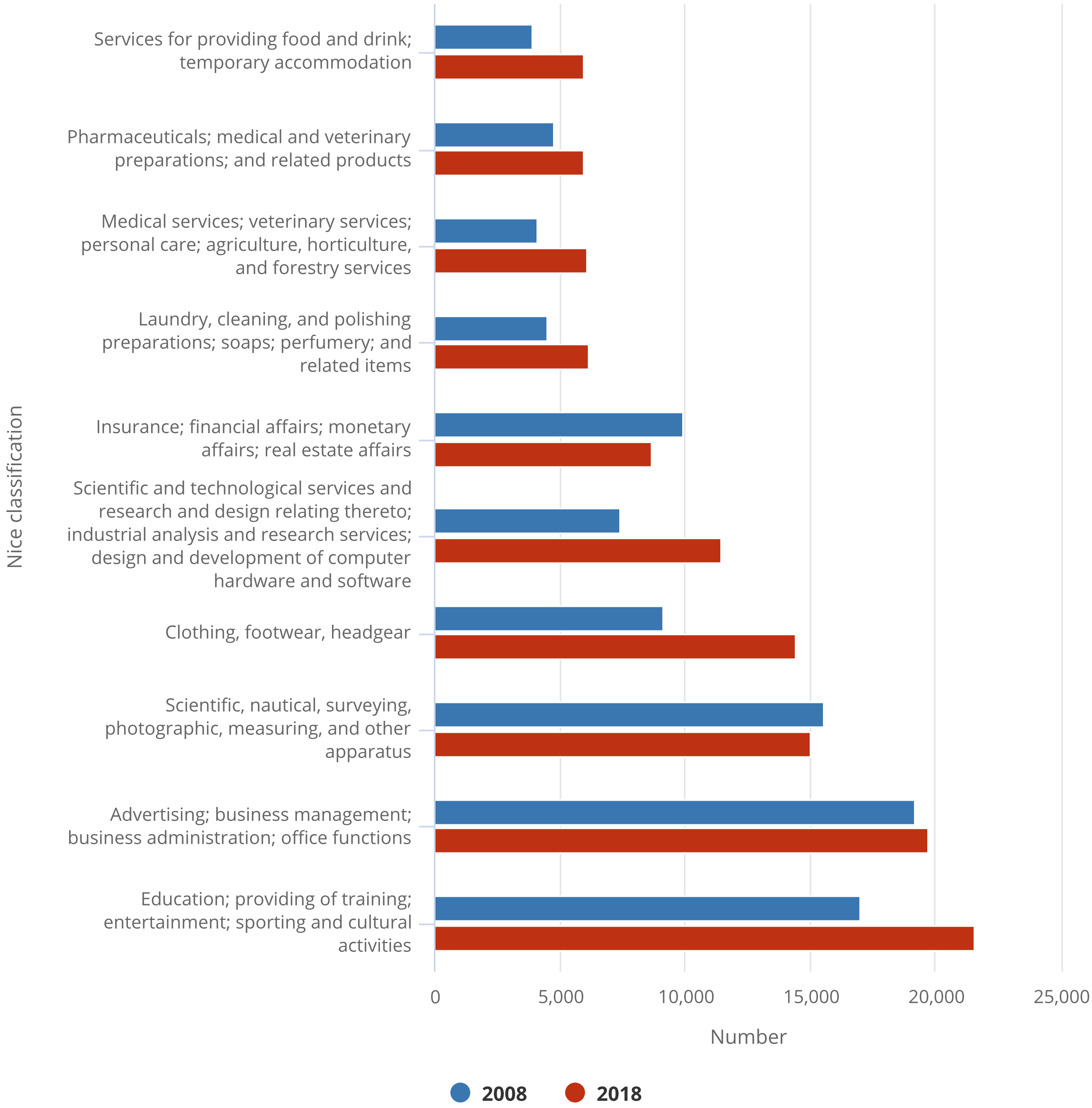
National Center for Science and Engineering Statistics, National Science Foundation; Science-Metrix; USPTO data hosted by Reed Tech (LexisNexis), accessed April 2019. See Table S8-45.

Science and Engineering Indicators

For U.S.-registered USPTO trademarks, education, business services, and scientific apparatus were the largest product categories in 2018 (**Figure 8-17**).

FIGURE 8-17

Number of U.S.-registered USPTO trademarks, by selected Nice classification: 2008 and 2018



USPTO = U.S. 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.

Source(s)

National Center for Science and Engineering Statistics, National Science Foundation; Science-Metrix; USPTO data hosted by Reed Tech (LexisNexis), accessed April 2019. See Table S8-46 and Table S8-47.

Science and Engineering Indicators

Trademarks from China grew nearly 20-fold, and those from the EU maintained a steady presence. One quarter of this growth from China comes in the broad science-linked category of research and technology (Table S8-56). Trademark data by detailed category are provided in Table S8-45 through Table S8-58.

Plant Varieties

Plant varieties are another kind of invention protected as intellectual property across national offices and within the EU. WIPO collects and shares data on these protections in its annual report (WIPO 2019). Plant variety protection covers nonhybridized plants; these plants must be created by seeds and tubers. Like patenting, this protection grants exclusive rights to produce the plant for sale for an extended number of years. In 2017, national offices issued over 15,000 plant variety protections worldwide, compared with 10,500 in 2008 (Table S8-59). The EU alone issued more than half of the plant variety protections in 2017, of which the Netherlands received nearly 3,700 (Table S8-59). China issued over 1,500 varieties, and Russia issued almost 500 (Table S8-59). The United States issued just over 1,700 varieties in 2017 (Table S8-59). Hybridized plants can be patented by the USPTO as plant patents; the European Patent Office does not allow this.

Knowledge Transfer

Knowledge transfer makes it possible for technology or knowledge developed for one purpose to be applied and used elsewhere or used for a different purpose. For invention and innovation, the sources of knowledge include direct outputs of R&D as well as the human capital gained by scientists, engineers, and inventors as they create and develop new and useful products and processes. Scientific discoveries and inventions suit many uses, and scientists and engineers add to the stock of knowledge through their discoveries. As knowledge and human capital accumulate and disseminate widely, new discoveries and innovations build on those that came before. Significant feedback mechanisms (often complex and numerous) may magnify the ultimate impact of innovation activities.

However, for knowledge to flow into innovation, invention and patenting are not enough; knowledge transfer is critical. Knowledge transfer takes place through the systematic activities of individual researchers as they collaborate, through the organized activities of institutions and governments, and through market activities.[5] This section presents several knowledge transfer indicators. First, the section presents two measures based on S&E publication output: (1) coauthoring of peer-reviewed S&E publications between business-affiliated and academic authors, and (2) the citation of peer-reviewed publications within patent documents. Both indicate the sharing of S&E research knowledge across sectors of the economy.

Next, the section presents indicators related to technology transfer as reported by federal agencies and academic institutions, including technology licensing activities, collaborative agreements, and support for startups. Within the federal government, the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs provide support for startups. As primary producers of research, academic institutions and federal labs have active technology transfer programs to provide potentially useful research to businesses and others. The section ends with a market-based measure of technology transfer: global flows of licensing receipts.

Business Collaboration in Peer-Reviewed Publications

Coauthorship on research publications indicates knowledge flow through collaboration between researchers and institutions. This form of collaboration can represent a range of activities from coauthoring the content to sharing data or research tools. This collaboration is observable when both collaborators have their names on the publication (Katz and Martin 1997). Business collaborations with universities have outsized impacts compared with other coauthoring combinations. A study of publications from 12 high-ranking private universities between 2012 and 2016 found that publications from research collaborations with businesses had the highest citation impacts (Shneiderman 2018).

The vast majority (84% or 44,053) of U.S. business-sector publications in 2018 have multiple authors (**Table 8-1**). Of these, more than half were coauthored with U.S. academic researchers (26,896). Government-coauthored publications accounted for another 14% (7,113) of business publications. Reflecting the importance of international knowledge flows, 37% (19,430) of the business-sector publications included coauthors from institutions in more than one country (**Table 8-1**). For more information on scientific publications, see *Indicators 2020* report "Publications Output: U.S. Trends and International Comparisons."

TABLE 8-1

U.S. business-sector publications with other U.S. sectors and foreign institutions: 2008 and 2018

(Number and percent)

Business-sector publications	Number (2008)	Percent (2008)	Number (2018)	Percent (2018)
All publications	56,793	100.0	52,384	100.0
Total coauthored	43,296	76.2	44,053	84.1

TABLE 8-1

U.S. business-sector publications with other U.S. sectors and foreign institutions: 2008 and 2018

(Number and percent)

Business-sector publications	Number (2008)	Percent (2008)	Number (2018)	Percent (2018)
Total coauthored with another U.S. sector (excluding business sector) and/ or foreign institution	36,973	65.1	39,949	76.3
Coauthored with another institution from business sector	9,836	17.3	8,471	16.2
Coauthored with another U.S. sector	28,874	50.8	30,276	57.8
Coauthored with academic sector	24,847	43.8	26,896	51.3
Coauthored with nonacademic sector	9,306	16.4	10,596	20.2
Coauthored with government	3,248	5.7	7,113	13.6
Coauthored with private nonprofits and other	14,187	25.0	4,448	8.5
Coauthored with foreign institution	6,625	11.7	19,430	37.1

Note(s)

Publications are classified by their publication and are assigned to a sector based on the institutional address(es) listed within. Each publication is credited to a sector based on the institution type. Each collaborating institution is credited as co-authoring in this table 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, National Science Foundation; Science-Metrix; U.S. Patent and Trademark Office; Elsevier, Scopus abstract and citation database, accessed June 2019.

Science and Engineering Indicators

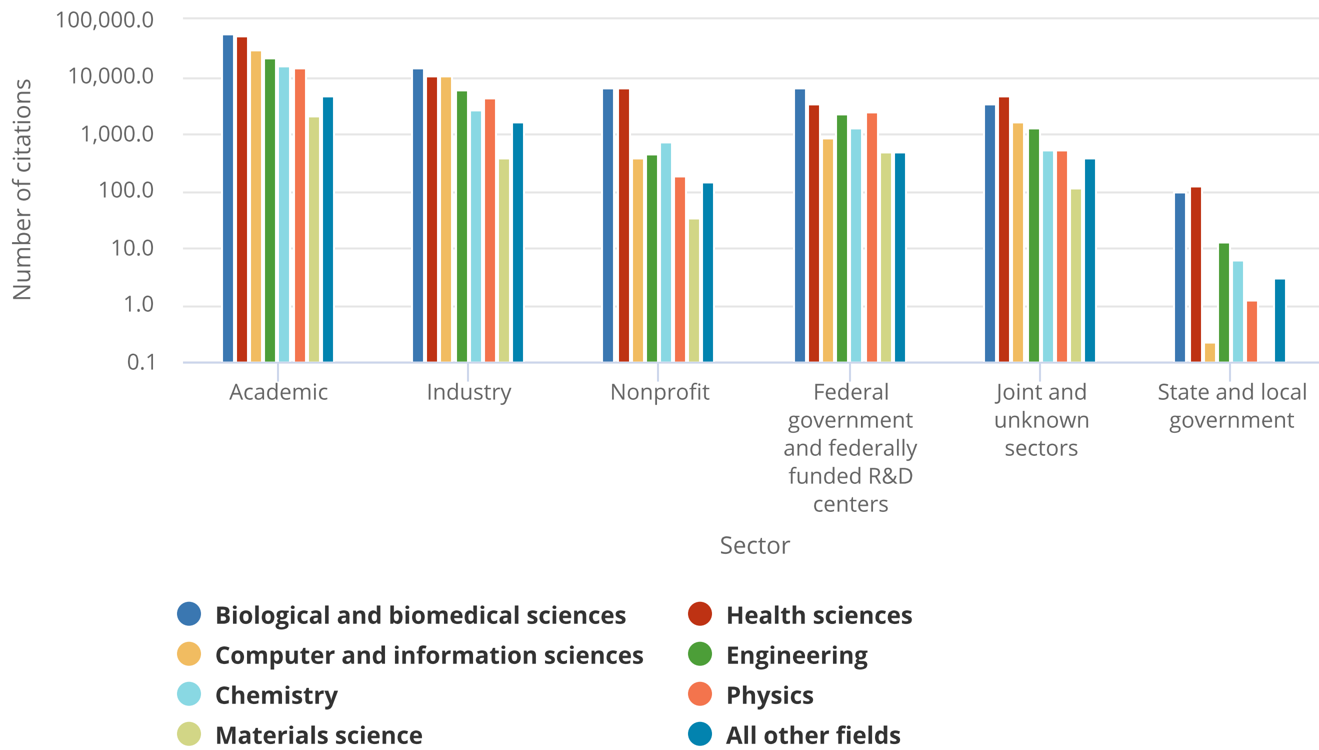
Citations of Peer-Reviewed Research in Patents

Patent documents filed with the USPTO include citations to prior art, which refers to published patents and patent applications as well as to peer-reviewed research and other published documents (nonpatent literature). Citations of S&E articles in patent documents provide another indicator of knowledge as an input to invention. (See Table S8-60 for detailed data on the number of citations to S&E publications in USPTO patents by author's sector and cited field of science.)

About 45% (290,483) of the citations in USPTO utility patents to peer-reviewed literature in 2018 were to U.S. S&E articles, and two-thirds (196,003) of these were to articles from the U.S. academic sector (Table S8-60). U.S. S&E articles in biological and biomedical sciences, along with articles in health sciences, account for more than half of academic citations in patents (**Figure 8-18**, shown on a log scale).

FIGURE 8-18

Log scale of citations of U.S. S&E articles in USPTO utility patents, by selected sector and S&E field: 2018



Note(s)

A log scale value of less than 1 represents a citation fractional count of less than 1. This can happen when a paper is coauthored and credit is divided among the authors.

Source(s)

National Center for Science and Engineering Statistics, National Science Foundation; Science-Metrix; PatentsView, USPTO, accessed April 2019; Elsevier, Scopus abstract and citation database, accessed July 2019. See Table S8-60.

Science and Engineering Indicators

Academic institutions and the federal government together perform over a fifth of U.S. R&D (*Indicators 2020* report "Research and Development: U.S. Trends and International Comparisons"). Technology transfer activities help bring knowledge and technology developed in those settings into the hands of those with abilities to apply, further develop, and eventually commercialize the research. These activities include licensing of patents, support for startup companies that use these licenses, cooperative R&D agreements, and other kinds of partnerships.

Alongside patenting and licensing, technology transfer can occur through various other channels, such as scientific dissemination through publications, conference papers, and working papers; exchanges of lab personnel with outside organizations that have R&D needs; and collaborative agreements and activities to find dual uses for technologies and products with both commercial and federal applications.

Technology Transfer by Academic Institutions and Federal Labs

Technology transfer is the way that technology or knowledge developed in one place or for one purpose is applied and used in another place for the same or different purpose. Scientific discoveries and inventions flow into economic activity through freely accessible dissemination (e.g., open scientific and technical literature, person-to-person exchanges) and market-based transactions (e.g., patent licensing, formal collaborative R&D relationships that provide intellectual property protections, use of copyrighted materials). Organizations in academia, government, business, and nonprofit sectors all have policies and activities directed at identifying new knowledge and technology and helping transfer them where they can be applied, further developed, and eventually commercialized as new products and processes. Most statistics on technology transfer address university and federal government technology transfer policies, less is known about the technology transfer that happens within the private or nonprofit sectors.

Universities began to collect and share technology transfer metrics in an organized way following the passage of the Bayh-Dole Act of 1980, which provided clear guidance on how universities could control their inventions (Choudry and Ponzio 2019). While patenting is an indicator of invention, the licensing of patented technologies is a key activity for university technology transfer offices. Both patenting and licensing are key components of the regularly reported data for universities, along with startups based on university technology (AUTM 2018).

Inventors with academic affiliations received almost 7,000 patents in 2018; this accounted for about 4% of the USPTO patents granted to U.S. inventors (**Figure 8-1**).[6] Over the last decade, inventions, licensing, and technology-linked startups at academic institutions have grown rapidly, although from a relatively small base, as shown by the data collected by the AUTM (**Table 8-2**).[7] As a cumulative indicator, active licenses from universities exceeded 45,000 in 2017 (**Table 8-2**).

TABLE 8-2

University technology transfer activity indicators: 2007, 2012, and 2017

(Number of activities)

Technology transfer activity	2007	2012	2017
Invention disclosures and patenting			
Inventions disclosed	14,398	19,827	24,998
Patent applications	11,797	14,192	15,335
Patents issued	3,622	5,153	7,459
Licensing			
All licenses, total active in the year	30,351	40,006	45,657
Licenses issued	4,354	5,130	6,283
Startup companies			
Startup companies formed	555	705	1080
Operational startups	3,388	4,002	6,050

Note(s)

AUTM collects data on invention and patent-related activities of its member universities. The number of member universities varies slightly from year to year. There were 161 in 2007, 165 in 2015, and 167 in 2017. The response rate of the survey in 2017 was 61.9% (AUTM 2018). Responding institutions may report for any 12-month period ending in the identified year.

Source(s)

AUTM, AUTM Licensing Survey (various years), accessed 5 May 2019.

Science and Engineering Indicators

Seven federal agencies conduct more than $1 billion of R&D annually and account for most of the annual total of federal technology transfer activities (*Indicators 2020* report “Research and Development: U.S. Trends and International Comparisons”). However, nearly all agencies and their associated federal labs promote the transfer of government-developed inventions with potential for commercial applications. Compared with businesses, patenting occurs less frequently among federal labs. Of the 153,000 patents granted to U.S. assignees in 2018, just over 1,300 patents had government assignees (**Figure 8-1**). Similar to university technology transfer metrics, federal labs use patenting and licensing statistics as technology transfer metrics; thus, this report presents these activities in this section.

However, technology transfer activities differ in emphasis across agencies (**Table 8-3**). The Department of Energy, the National Aeronautics and Space Administration (NASA), and Health and Human Services exhibit particularly intensive licensing activity. The Departments of Commerce and Defense participate in relatively large numbers of cooperative R&D agreements, while the Department of Agriculture has by far the most other collaborative R&D relationships.

TABLE 8-3

Federal laboratory technology transfer activity indicators, by selected agencies: FYs 2006, 2009, 2012, and 2016

(Number of activities)

Fiscal year and technology transfer activity	All federal laboratories	DOD	HHS	DOE	NASA	USDA	DOC	DHS
2006								
Invention disclosures and patenting								
Inventions disclosed	5,193	1,056	442	1,694	1,749	105	14	NA
Patent applications	1,912	691	166	726	142	83	5	NA
Patents issued	1,284	472	164	438	85	39	7	NA
Licensing								
All licenses, total active in the fiscal year	10,186	444	1,535	5,916	2,856	332	111	NA
Invention licenses	4,163	438	1,213	1,420	308	332	111	NA
New invention licenses in the fiscal year	711	56	253	203	47	25	83	NA
Collaborative relationships for R&D								
CRADAs, total active in the fiscal year	7,268	2,999	164	631	1	195	3,008	NA
Traditional CRADAs	3,666	2,424	92	631	1	163	149	NA
Other collaborative R&D relationships	9,738	0	0	0	4,275	3,477	2,114	NA
2009								
Invention disclosures and patenting								
Inventions disclosed	4,450	831	353	1,439	1,412	178	40	32
Patent applications	2,085	690	284	775	141	123	20	2
Patents issued	1,402	404	480	363	93	24	7	2
Licensing								
All licenses, total active in the fiscal year	12,598	432	1,584	5,742	4,181	330	40	63
Invention licenses	3,854	386	1,304	1,452	146	302	40	0
New invention licenses in the fiscal year	492	57	198	139	49	22	11	0
Collaborative relationships for R&D								
CRADAs, total active in the fiscal year	7,740	2,870	457	744	1	243	2,397	23
Traditional CRADAs	4,264	2,247	284	744	1	201	101	22
Other collaborative R&D relationships	17,647	1	0	0	4,507	10,306	2,828	5
2012								
Invention disclosures and patenting								
Inventions disclosed	5,347	1,078	352	1,661	1,656	160	60	40
Patent applications	2,576	1,013	233	933	130	122	27	10
Patents issued	2,325	1,048	335	676	131	69	13	0
Licensing								
All licenses, total active in the fiscal year	8,351	520	1,465	5,328	346	384	41	0
Invention licenses	3,893	432	1,090	1,428	296	341	41	0
New invention licenses in the fiscal year	501	44	192	192	28	28	6	0
Collaborative relationships for R&D								
CRADAs, total active in the fiscal year	8,307	2,400	377	742	0	274	2,410	94
Traditional CRADAs	4,293	1,328	245	742	0	211	154	89
Other collaborative R&D relationships	19,537	0	0	0	1,756	14,691	2,782	11
2016								
Invention disclosures and patenting								
Inventions disclosed	5,086	874	320	1,760	1,554	244	64	17
Patent applications	2,596	941	269	999	129	109	25	15
Patents issued	2,341	665	579	856	103	60	16	3
Licensing								
All licenses, total active in the fiscal year	8,950	515	1,750	5,410	452	441	57	5
Invention licenses	4,156	358	1,721	943	387	370	57	5
New invention licenses in the fiscal year	572	57	221	145	97	27	15	1
Collaborative relationships for R&D								
CRADAs, total active in the fiscal year	11,644	3,125	590	739	12	238	2,940	343

TABLE 8-3

Federal laboratory technology transfer activity indicators, by selected agencies: FYs 2006, 2009, 2012, and 2016

(Number of activities)

Fiscal year and technology transfer activity	All federal laboratories	DOD	HHS	DOE	NASA	USDA	DOC	DHS
Traditional CRADAs	6,720	2,297	391	739	12	161	335	272
Other collaborative R&D relationships	18,472	452	147	0	2,204	11,854	3,273	71

NA = not available.

DOD = Department of Defense; HHS = Department of Health and Human Services; DOE = Department of Energy; NASA = National Aeronautics and Space Administration; USDA = Department of Agriculture; DOC = Department of Commerce; DHS = Department of Homeland Security; CRADA = Cooperative R&D Agreement.

Note(s)

The table includes seven federal departments and agencies that reported R&D obligations at or above $1 billion in FY 2014. (The National Science Foundation was also in this group, but its corresponding data were not available.) Other federal agencies not listed but included in the All federal laboratories totals are the Department of the Interior, the Department of Transportation, the Department of Veterans Affairs, and the Environmental Protection Agency. Invention licenses refer to inventions that are patented or could be patented. CRADAs refers to all agreements executed under CRADA authority (15 U.S.C. 3710a). Traditional CRADAs are collaborative R&D partnerships between a federal laboratory and one or more nonfederal organizations. Federal agencies have varying authorities for other kinds of collaborative R&D relationships.

Source(s)

National Institute of Standards and Technology (NIST), U.S. Department of Commerce, *Federal Laboratory Technology Transfer, Fiscal Year 2016: Summary Report to the President and the Congress* (2019), *Federal Laboratory Technology Transfer, Fiscal Year 2013. Summary Report to the President and the Congress* (2015), and *Federal Laboratory Technology Transfer, Fiscal Year 2010. Summary Report to the President and the Congress* (2012); National Institute of Standards and Technology (NIST), U.S. Department of Commerce, Federal Lab Technology Transfer Database v.2015. Accessed 10 January 2020.

Beyond invention licensing, NASA has made the release and licensing of NASA-developed software an emphasis of its technology transfer activities. In addition to the statistics shown in **Table 8-3**, NASA releases its own statistics on software. In FY 2016, NASA executed over 2,600 new software usage agreements, more than double the amount executed in 2011, and it released 550 software products into the public domain (National Institute of Standards and Technology [NIST] 2019). NIST's annual reports provide more detail about agency-level focus in technology transfer.

Federal Policies and Programs to Reduce Barriers to Innovation

Over the last 30 years, many national policies and related programs have aimed to support businesses in exploiting new technologies for commercial applications and implementing innovations, without requiring the government to make decisions better left to the competitive marketplace. The government has recognized that structural and market barriers—often termed technological and commercial "valleys of death"—may create difficult-to-bridge gaps for the innovation process and for otherwise promising new technologies (Branscomb and Auerswald 2002). The government has launched several federal-wide programs intended to strengthen the development and flow of early-stage technologies into the commercial marketplace. Other policy initiatives have focused on accelerating the commercial exploitation of academic R&D and encouraging R&D ideas and technologies with commercial potential by small or minority-owned businesses.

SBIR and STTR

By budget authority, the most substantial federal programs are the longstanding SBIR and STTR programs. These two programs provide competitively awarded funding to small businesses for stimulating technological innovation, addressing federal R&D needs, increasing private-sector commercialization of innovations flowing from federal R&D, and fostering technology transfer through cooperative R&D between small businesses and research institutions.

The U.S. Small Business Administration (SBA) provides overall coordination for both programs, with implementation by the federal agencies that participate (SBA 2015). Agencies contribute based on their R&D budgets, and both programs provide awards to firms with fewer than 500 employees. Awardees use the funding to assess the scientific and technical feasibility of ideas that may have commercial potential. Beginning in 1983 with 785 awards, the SBIR program conferred over 4,800 awards in 2018, accounting for almost $3 billion in funding in that year (**Table 8-4**).

TABLE 8-4

SBIR and STTR awards funding, by type of award: Selected years, FYs 1983–2018

(Number of awards and funding in millions of dollars)

	SBIR		STTR	
	Number of awards	Funding ($ millions)	Number of awards	Funding ($ millions)
Fiscal year	Total	Total	Total	Total
1983	785	37.9	na	na
1985	1,821	192.4	na	na
1990	3,189	447.6	na	na
1995	4,321	948.0	1	0.1
2000	5,217	1,047.0	404	63.2
2005	6,325	1,862.5	825	236.6
2010	6,306	2,304.9	903	298.7
2011	5,498	2,134.9	709	266.8
2012	5,003	2,047.7	637	222.5
2013	4,486	1,932.4	643	225.5
2014	4,570	2,050.9	703	290.2
2015	4,455	2,210.1	722	285.2
2016	4,610	2,310.7	800	311.5
2017	5,152	2,623.4	847	317.1
2018	4,817	2,727.1	793	382.8

na = not applicable.

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

Note(s)
The first SBIR program awards were made in FY 1983. The first STTR program award was made in FY 1995. Funding data are awarded amount through FY 2014; obligated amount in FY 2015 and later.

Source(s)
Small Business Administration, SBIR/STTR official website, accessed 5 June 2019.

Science and Engineering Indicators

Established a decade after the SBIR program, the STTR program facilitates cooperative R&D by small businesses, universities, and nonprofit research organizations and encourages the transfer of technology developed through such research by entrepreneurial small businesses. The STTR program had 404 awards in 2000, and in 2018, there were 793 awards with a total funding of $383 million (**Table 8-4**).

Other Federal Programs

Other federal programs typically have objectives that closely reflect specific agency missions and draw resources at levels well below SBIR and STTR. **Table 8-5** briefly describes several of the larger programs currently run by federal R&D-performing agencies. Table S8-61 provides greater detail on such federal agency policies and programs.

TABLE 8-5

Examples of federal policies and programs supporting early-stage technology development and innovation

(Summary of program goals and activities for selected federal agencies)

Agency, office, and program
Department of Agriculture
Under Secretary for Research, Education, and Economics
Agricultural Research Service (ARS)
Program name: Agricultural Research Partnerships (ARP) Network
Program goals: The ARS founded the ARP Network to expand the impact of ARS research and provide resources to help ARS commercial partners grow.
Program activities: The ARP Network matches business needs with ARS innovations and research capabilities and provides business assistance services to help companies and startups solve agricultural problems, develop products, and create new jobs. The ARP Network assists ARS in creating new partnerships and in supporting existing partnerships to advance ARS R&D efforts and subsequent utilization, including commercialization. Some of the ARP Network activities include matching industry needs with ARS patents and researchers for partnering; providing access to ARS research expertise, facilities, and equipment; and assisting in identifying sources of funding. The ARP Network is composed of organizations interested in agriculture-based economic development.
Department of Defense
Department wide
Program name: Manufacturing Technology (ManTech) Program
Program goals: The Defense-Wide ManTech Program was established to address crosscutting, game-changing initiatives that are beyond the scope of any one military department or defense agency.
Program activities: ManTech seeks to address defense manufacturing needs, transition manufacturing R&D processes into production applications, attack manufacturing issues, and explore new opportunities.
Department of Health and Human Services
National Institutes of Health (NIH)
National Center for Advancing Translational Sciences
Program name: Therapeutics for Rare and Neglected Diseases (TRND)
Program goals: The TRND program supports pre-clinical development of therapeutic candidates intended to treat rare or neglected disorders, with the goal of enabling an Investigational New Drug (IND) application to the Food and Drug Administration.
Program activities: The TRND program encourages and speeds the development of new treatments for diseases with high unmet medical needs. The program advances the entire field of therapeutic development by encouraging scientific and technological innovations to improve success rates in the crucial preclinical stage of development. TRND stimulates therapeutic development research collaborations among NIH and academic scientists, nonprofit organizations, and pharmaceutical and biotechnology companies working on rare and neglected illnesses. The program provides NIH's rare and neglected disease drug development capabilities, expertise, clinical resources, and regulatory expertise to research partners to optimize promising therapeutics and move them through preclinical testing, with the goal to generate sufficient-quality data to support successful IND applications and first-in-human studies in limited circumstances.
Department of Transportation
Federal Highway Administration
Office of Innovative Program Delivery
Program name: State Transportation Innovation Council (STIC) Incentive Program
Program goals: The STIC Incentive Program offers technical assistance and resources to support the standardization of innovative practices among state transportation agencies and other public-sector stakeholders.
Program activities: The STIC Incentive Program provides up to $100,000 per state per federal fiscal year to STICs to support or offset the costs of standardizing innovative practices in a state transportation agency or other public-sector STIC stakeholder. STIC Incentive Program funding may be used to conduct internal assessments; build capacity; develop guidance, standards, and specifications; implement system process changes; organize peer exchanges; offset implementation costs; or conduct other activities the STIC identifies to address Technology and Innovation Deployment Program goals.
National Aeronautics and Space Administration (NASA)
Human Exploration and Operations Mission Directorate
Advanced Exploration Systems Division
Program name: Next Space Technologies for Exploration Partnerships (NextSTEP)
Program goals: The NextSTEP program is a public-private partnership model that encourages commercial development of deep space exploration capabilities to support more extensive human spaceflight missions in the proving ground around and beyond cislunar space—the space near Earth that extends just beyond the moon.
Program activities: NextSTEP stimulates the commercial space industry to help NASA achieve its strategic goals and objectives for expanding the frontiers of knowledge, capability, and opportunities in space. The NextSTEP partnership model provides an opportunity for NASA and industry to partner to develop capabilities that meet NASA human space exploration objectives while also supporting industry commercialization plans. Through these public-private partnerships, NextSTEP partners provide advanced concept studies and technology development projects in the areas of advanced propulsion, habitation systems, and small satellites.

TABLE 8-5

Examples of federal policies and programs supporting early-stage technology development and innovation

(Summary of program goals and activities for selected federal agencies)

Agency, office, and program
National Science Foundation (NSF)
Directorate for Engineering
Division of Industrial Innovation and Partnerships
Program name: Innovation Corps (I-Corps™) program (NSF, NIH, the Department of Defense, the Department of Energy, and the U.S. Department of Agriculture all have I-Corps programs.)
Program goals: The I-Corps program aims to foster entrepreneurship that will lead to the commercialization of technology that has been supported previously by NSF-funded research. The program provides entrepreneurial education for federally funded scientists and engineers, pairing them with business mentors for an intensive curriculum focused on discovering a demand-driven path from their lab work to a marketable product.
Program activities: There are three distinct components of I-Corps: Teams, Nodes, and Sites. I-Corps Teams include NSF-funded researchers who will receive additional support—in the form of mentoring and funding—to accelerate innovation that can attract subsequent third-party funding. Nodes serve as hubs for education, infrastructure, and research that engage academic scientists and engineers in innovation; they also deliver the I-Corps Curriculum to I-Corps Teams. I-Corps Sites are academic institutions that catalyze the engagement of multiple, local teams in technology transition and strengthen local innovation.

Note(s)

The table summarizes examples of policy and program information collected during the spring and fall of 2017 from federal staff for a selected set of U.S. agencies with major R&D and technology development activities. The table reflects agency responses. For a more comprehensive list of federal policies and programs see Table S8-61.

Source(s)

National Center for Science and Engineering Statistics, National Science Foundation; SRI International, special tabulations of federal program information (2017). See Table S8-61.

Science and Engineering Indicators

Global Flows of Payments for Intellectual Property: Trade in Licensing and Fees

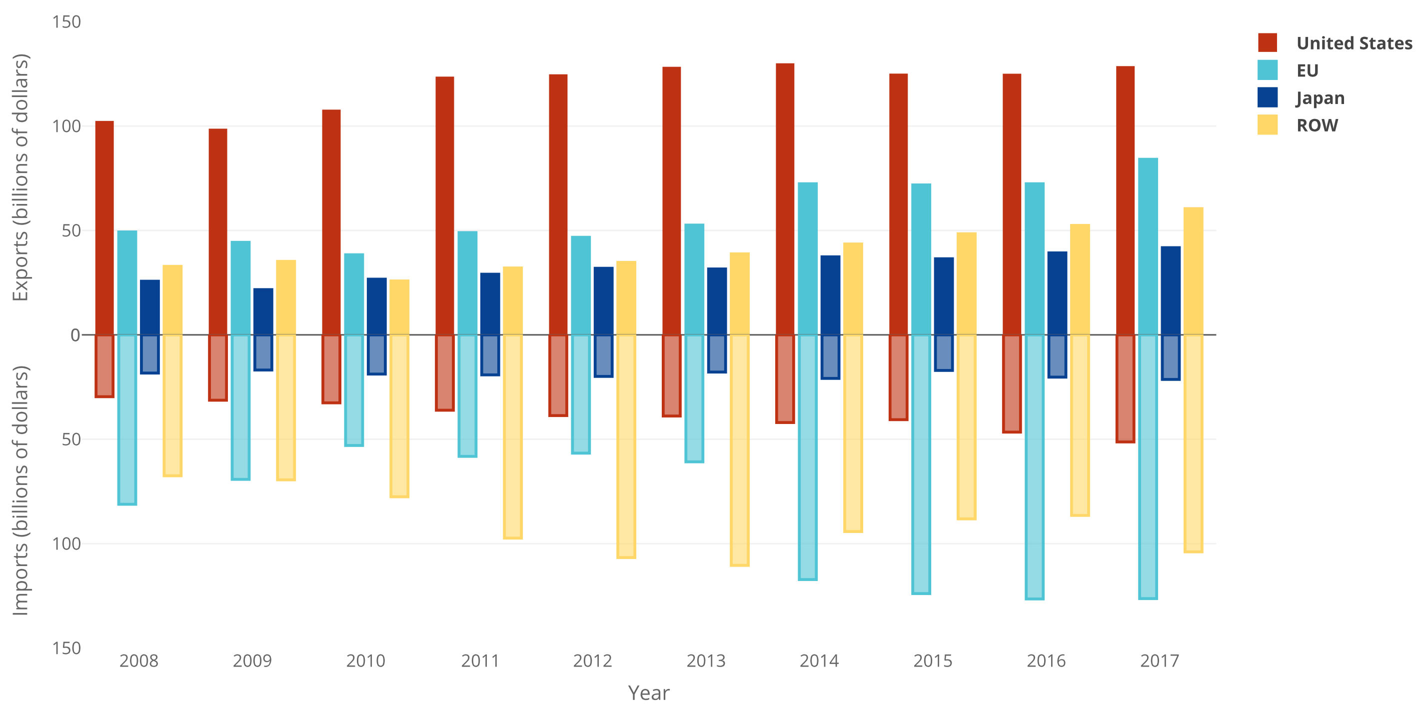
Licensing allows intellectual property developed within firms to be used externally; globally active businesses transfer their intellectual property across national boundaries, exploiting opportunities in external markets. This intellectual property includes the use of proprietary rights—patents, trademarks, copyrights, industrial processes, and designs—and licenses to reproduce or distribute intellectual property embodied in produced originals, prototypes, live performances, and televised broadcasts (World Trade Organization 2016).

Income from outside the country that U.S. firms receive for the use of their intellectual property is a component of global exports of services; thus, it plays an important role in understanding the global balance of trade. (*Indicators 2020* report "Production and Trade of Knowledge- and Technology-Intensive Industries" covers goods trade in R&D-intensive exports and knowledge-intensive services.) The export revenues from these types of transactions, known as "charges for the use of intellectual property," provide a broad indicator of technology flows across the global economy and the value of an economy's intellectual property in the international marketplace.

Global export revenues (receipts for the use of intellectual property) totaled $315 billion in 2017 according to the World Trade Organization, the organization that collects these data from national offices and compiles them internationally (**Figure 8-19**). Unlike patenting, which increasingly takes place in middle-income countries, licensing income for intellectual property continues to be mainly a high-income country source of revenue. The United States is the world's largest exporter of these services; exports increased from $102 billion in 2008 to $128 billion in 2017 (**Figure 8-19**). U.S. imports also expanded, but the United States maintains a surplus between exports and imports for this category. The EU, the world's second-largest exporter, imports more than it exports, resulting in a substantial deficit. Japan, the third-largest exporter of intellectual property services, has a substantial trade surplus. Japan's global export share remained stable between 2008 and 2017 (**Figure 8-19**). Outside of high-income countries, receipts for the use of intellectual property are lower; however, as with USPTO patenting, the U.S. global share of export receipts fell—in this case from 49% in 2008 to 41% in 2017 (**Figure 8-19**).

FIGURE 8-19

Exports and imports of intellectual property (charges for their use), by selected region, country, or economy: 2008–17



EU = European Union; ROW = rest of the world.

Note(s)

These are payments for the use of proprietary rights (such as patents, trademarks, copyrights, industrial processes and designs including trade secrets, franchises). These rights can arise from research and development, as well as from marketing. These charges also include those for licenses to reproduce or distribute intellectual property embodied in produced originals or prototypes (such as copyrights on books and manuscripts, computer software, cinematographic works, and sound recordings) and related rights (such as for live performances and television, cable, or satellite broadcast). EU exports do not include intra-EU exports. EU imports do not include intra-EU imports.

Source(s)

World Trade Organization, trade and tariff data, accessed 27 September 2019.

Science and Engineering Indicators

Innovation Indicators: United States and Other Major Economies

Inventions and knowledge transfer provide the raw material for new and improved commercially viable products and processes. Despite frequent usage of the term itself, *innovation* is hard to measure. Business innovation is defined as the implementation of a new or improved product or business process that differs significantly from previous products or processes and that has been introduced in the market or brought into use by the firm (OECD/Eurostat 2018).

This section discusses complementary innovation-related indicators that provide information on different aspects of innovation. For example, innovation indicators aim to measure the way inputs create new value in the economy. Examples of such indicators include business investment in intangibles, such as software, R&D, and artistic creations; private funding of innovation; and firm-reported data on the introduction of new and improved products and processes. Innovation also produces broader economic impacts, such as improved living standards, productivity growth, and the creation of new firms and new jobs. Broader societal impacts also include improved health outcomes and life expectancy (Cutler and McClellan 2001; Deaton 2013).

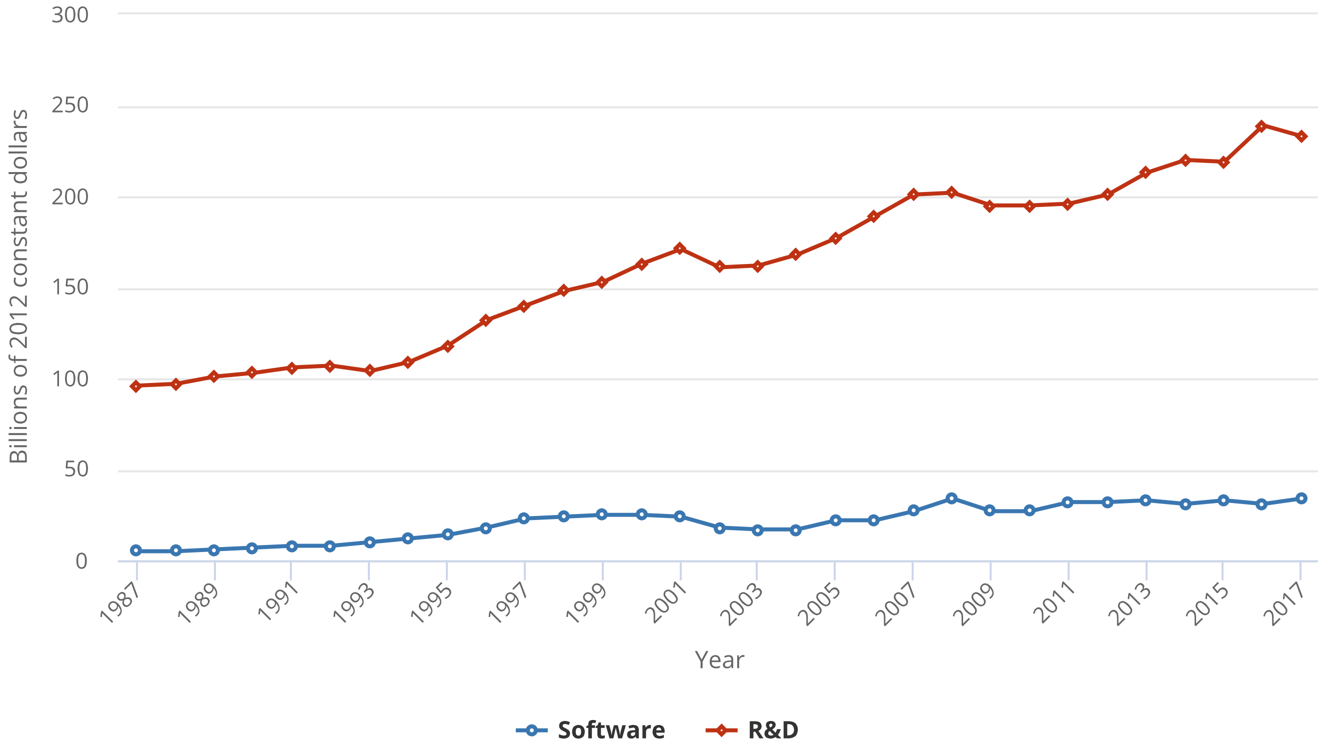
Investment in Intangibles

Intellectual property resulting from knowledge and creative activity includes literary and artistic works as well as symbols, images, and names used in commerce (WIPO 2019). The assets underlying these protections are often intangible assets. Some intangibles create benefits for years to come; examples include, but are not limited to, computer software, R&D activity, and designs and artistic creations. Digitization allows the simultaneous use of many types of intangibles in more than one location, adding a dimension of use that tangibles, such as machine tools and buildings, do not possess. Transmitting these intangibles digitally across networks multiplies potential impact. U.S. investment in computer software and R&D have risen rapidly in the last two decades.

Between 2007 and 2017, U.S. businesses increased their annual investment in these three intangible assets, computer software, R&D, and artistic originals, by almost 50% to $796 billion. By broad sector, manufacturing and nonmanufacturing, this intangible investment was $267 and $528 billion (inflation adjusted), respectively (**Figure 8-20** and **Figure 8-21**).[8] Patents, copyrights, and trade secrets are different forms of intellectual property protection that secure intangible asset owners with the rights of exclusive use.

FIGURE 8-20

U.S. private investment in intangibles, by type, for the manufacturing sector: 1987–2017



Note(s)

Investment in artistic originals is not estimated for manufacturing.

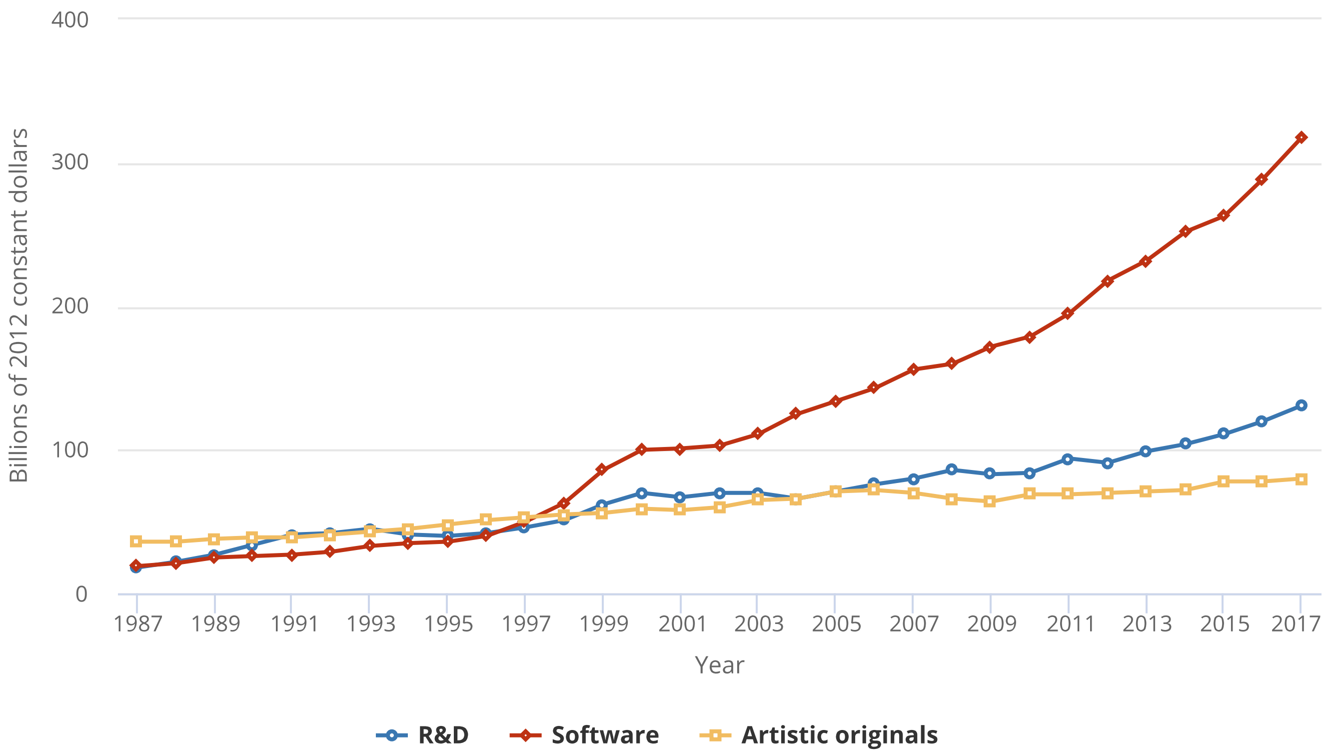
Source(s)

Bureau of Labor Statistics, Intellectual Property Products, Private Business Sector, accessed 30 April 2019.

Science and Engineering Indicators

FIGURE 8-21

U.S. private investment in intangibles, by type, for the nonmanufacturing sector: 1987–2017



Note(s)

Measured in 2012 constant dollars; farm sector is not included in these measures. Artistic originals include expenditures for the development and production of theatrical movies, long-lived television programs, books, music, and other artistic originals.

Source(s)

Bureau of Labor Statistics, Intellectual Property Products, Private Business Sector, accessed 30 April 2019.

Science and Engineering Indicators

As a share of total investment in intangibles, manufacturing invested more in R&D than nonmanufacturing, and nonmanufacturing invested more in software relative to the manufacturing sector (**Figure 8-20** and **Figure 8-21**). In addition, there was $80 billion in investment in artistic originals in 2017, all outside of manufacturing (**Figure 8-21**). Digitization and networking have enabled the transformation of these originals into downloadable and streaming services; users increasingly consume such services using personal devices such as laptops, tablets, and cell phones. GDP statistics for many countries, including the United States, include investment measures for computer software and databases, R&D expenditures, and artistic originals.

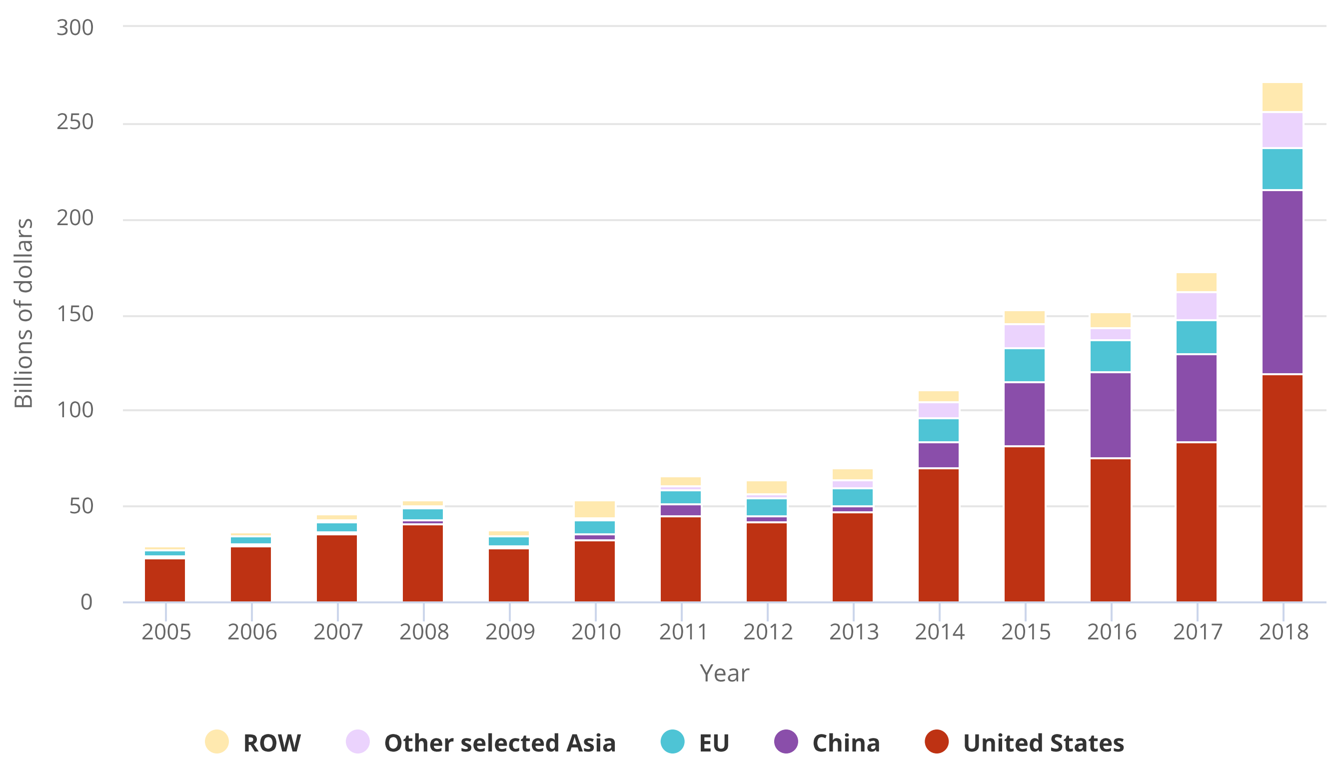
Venture Capital

Access to financing is an essential component of the translation of inventions to innovations, both for new and growing firms. The difficulty of entrepreneurs obtaining financing contributes to the "valley of death," the inability of new and nascent firms to obtain financing to commercialize their inventions and technology. New entrepreneurs and startups rely on their own funds as well as funds from friends and family, bank loans, venture capital, angel investment, or government support (OECD 2014:174). Venture capital investment also supports product development and marketing, company expansion, and acquisition financing.

Global venture capital investment, measured in current dollars, reached a historic high of $271 billion in 2018, more than a 50% increase over the 2017 total and nearly four times as high as its level 5 years ago (**Figure 8-22**). Over the last decade, the venture capital market has shifted from a U.S.-centric structure toward a more globalized market with the Asian region, primarily China, as a rapidly growing recipient of investment. As the leading recipient country of venture capital investment in 2018, the United States received 44% ($119 billion) of total global venture capital funds (**Figure 8-22**). China, the second-largest recipient, received $97 billion in venture capital funds representing a global share of 36% (**Figure 8-22**). The third-largest recipient, the EU nations, collectively received an 8% share (**Figure 8-22**). Five Asian countries—India, Indonesia, Japan, Singapore, and South Korea—collectively received 7% of global venture capital (Table S8-62). ICT-producing industries and health care industries were the largest recipients of these investments in the United States over the last several years, according to private-sector data (PitchBook and National Venture Capital Association [NVCA] 2019).

FIGURE 8-22

Global venture capital investment, by selected country or economy: 2005–18



EU = European Union; ROW = rest of the world.

Note(s)
China includes Hong Kong. Other selected Asia includes India, Indonesia, Japan, Singapore, and South Korea.

Source(s)
PitchBook, venture capital and private equity database, accessed 21 September 2019. See Table S8-62.

Science and Engineering Indicators

Venture Capital Investment in the United States

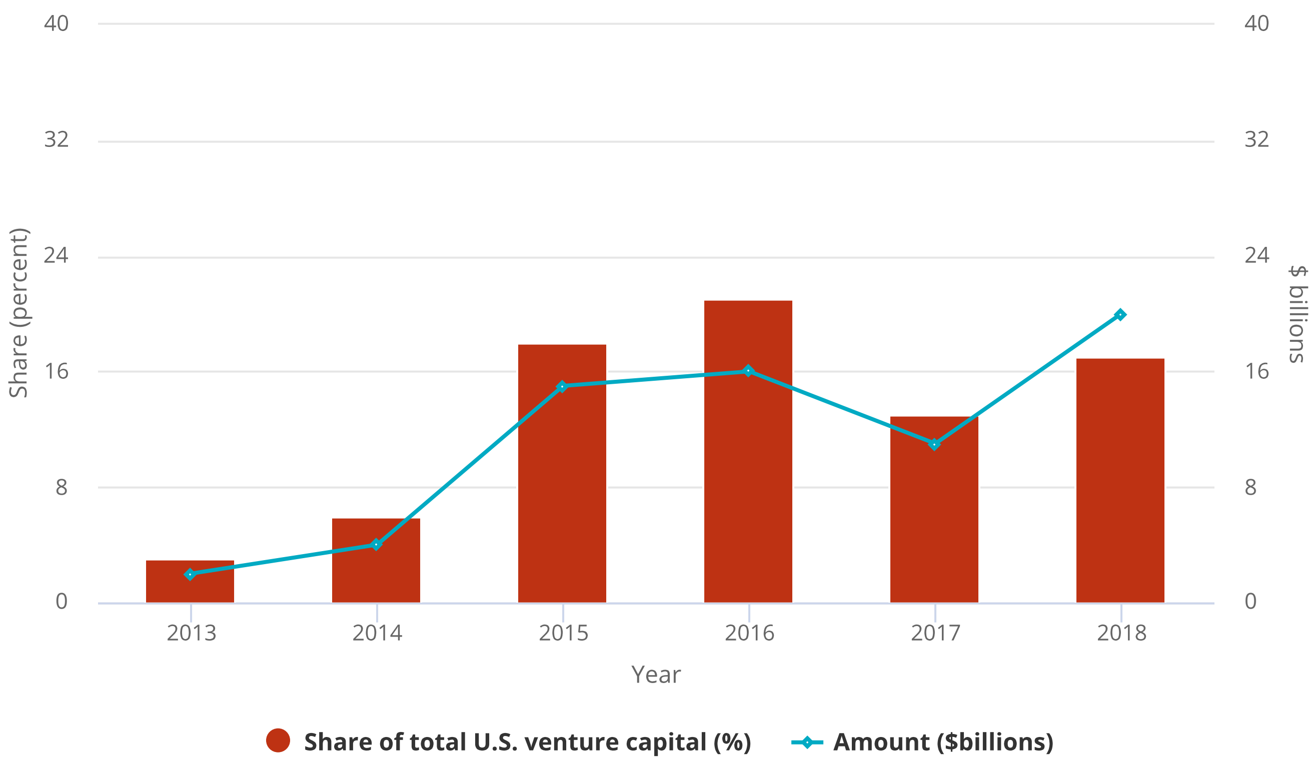
Venture capital in the United States has risen overall in the past 5 years. Since 2014, investment in the United States has surpassed the previous high of $51 billion set during the run-up in venture capital associated with the dot-com bubble in 2000 (Table S8-62). However, during this recent period of robust global investment growth, the U.S. global share dropped from 68% in 2013 to 44% in 2018; faster growth in the funds received by Asian economies including China, India, Indonesia, and South Korea accounted for the shift (Table S8-62).

The U.S. corporate sector and Chinese investors have been two important drivers of U.S. venture capital investment over the last several years. The U.S. corporate share of U.S. venture financing increased from 32% to 51% between 2013 and 2018 (PitchBook and NVCA 2019). U.S. corporations, particularly large Internet and software companies—Alphabet, Amazon, Facebook, and Microsoft—have made major investments in startups. For example, Alphabet's venture arm, GV, has at least $2.4 billion in assets under management and aims to invest $500 million in startups per year (PitchBook and NVCA 2019).

Investors from China have also contributed to the recent growth of U.S. venture capital, financing 17% of U.S. venture capital investment in 2018 compared with 3% in 2013 (**Figure 8-23**). China's growing wealth and its government's push to develop and commercialize technologies, such as artificial intelligence, have prompted increased Chinese investment in U.S. startups (Dwoskin 2016).

FIGURE 8-23

Chinese investment in U.S. venture capital: 2013–18



Note(s)

China includes Hong Kong. China venture capital investment is defined as investors that have a headquarters in China and participate in venture capital deals to finance U.S.-based companies.

Source(s)

PitchBook, venture capital and private equity database, accessed 21 September 2019.

Science and Engineering Indicators

Two industry sectors—information and communication, and health care—received the majority of investments over the last several years. In 2018, investment in these two sectors was a combined $77 billion, accounting for 65% of total U.S. venture capital investment (**Table 8-6** and Table S8-62). Within the information and communication industry sector, the software industry received $39.8 billion, the largest of any industry (**Table 8-6**). In the health care sector, the pharmaceutical and biotechnology industry received the greatest investment at $18.7 billion (**Table 8-6**).

TABLE 8-6

U.S. venture capital investment in health care, ICT, and transportation industries: 2013 and 2018

(Millions of dollars)

Industry	2013	2018
Health care	13,271	31,785
Health care devices and supplies	4,917	5,723
Health care technology systems	1,239	4,855
Pharmaceuticals and biotechnology	5,953	18,662
Other health care	1,161	2,545
ICT	20,703	45,697
Communications and networking	1,021	750
Computer hardware	1,054	1,334
Media	1,495	2,198
Software	16,082	39,764
Other ICT	1,050	1,652
Transportation	648	6,645

ICT = information and communications technology.

Note(s)

Other ICT consists of communications and networking, IT services, semiconductors, and other. Other healthcare consists of healthcare devices and supplies, healthcare services, healthcare technology systems, and other.

Source(s)

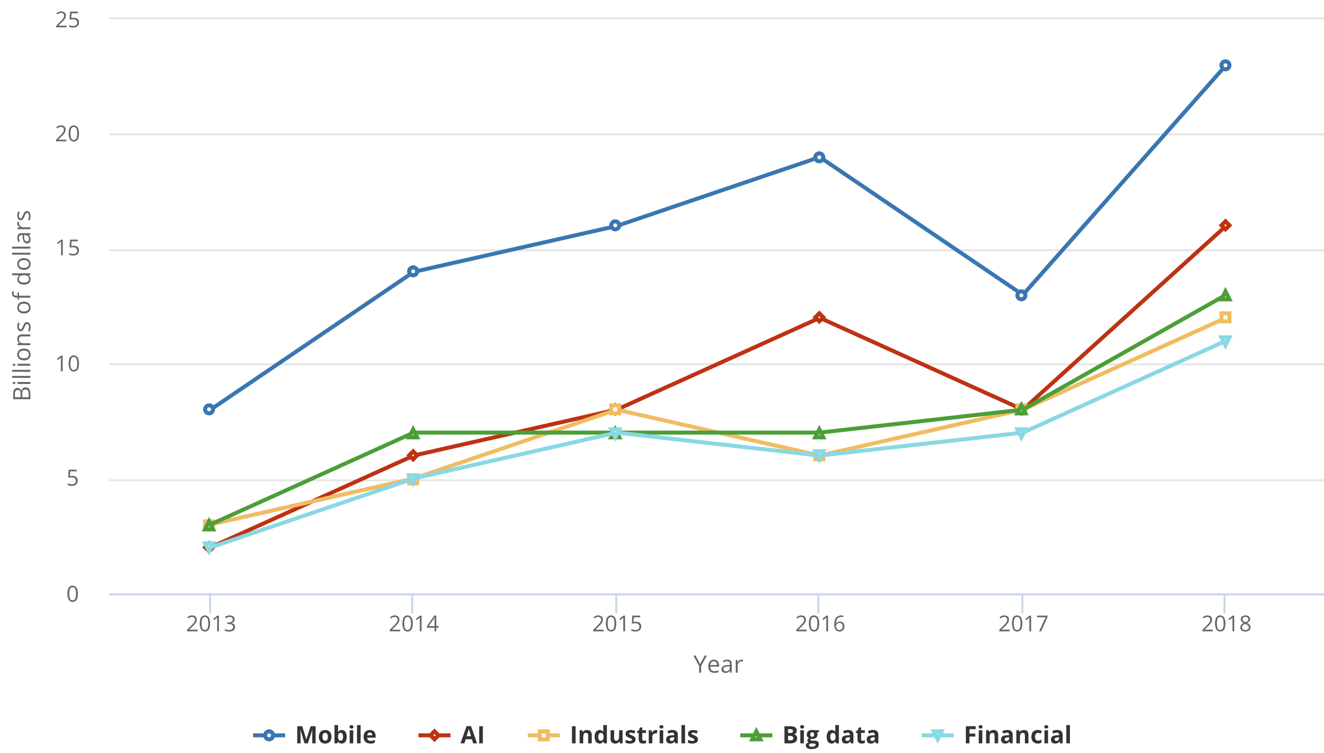
PitchBook, venture capital and private equity database, accessed 21 September 2019. See Table S8-64.

Science and Engineering Indicators

According to PitchBook's market and technology classification, technology areas with significant and rising levels of U.S. investment included mobile, artificial intelligence, industrials, big data, and financial technology (**Figure 8-24** and Table S8-65).[9] These five technology areas comprised 63% of total U.S. venture capital investment in 2018 compared with 39% in 2013 (**Figure 8-24** and Table S8-62). These technology areas rely on software, the industry that has attracted the largest amount of investment of any U.S. industry. Artificial intelligence had the fastest growth rate among these technologies, rising sevenfold to reach $16 billion in 2018 (**Figure 8-24**). Large Internet corporations, including Alphabet, Facebook, and Microsoft, heavily invest in R&D and venture capital in artificial intelligence startups.

FIGURE 8-24

U.S. venture capital investment, by selected industry vertical or technology: 2013–18



AI = artificial intelligence.

Note(s)

Industry verticals are groups of firms focused on a technology area. These areas can overlap, thus the sum of investment of these verticals can exceed total venture capital investment.

Source(s)

PitchBook, venture capital and private equity database, accessed 21 September 2019. See Table S8-65.

Science and Engineering Indicators

Venture Capital Investment in China

Venture capital investment in China has increased rapidly, reaching $97 billion in 2018 (**Figure 8-22**). Both domestic and international investors provide venture capital investment in China. In 2018, U.S. investors financed $53 billion of China's venture capital, up from $2 billion in 2013 (**Figure 8-25**).

FIGURE 8-25

U.S. investment in Chinese venture capital: 2013–18

Note(s)

China includes Hong Kong. U.S. venture capital investment is defined as investors that have a headquarters in the United States and participate in venture capital deals to finance Chinese-based companies.

Source(s)

PitchBook, venture capital and private equity database, accessed 21 September 2019.

Science and Engineering Indicators

According to PitchBook's primary industry classification, the ICT industry sector was the largest recipient of venture capital investment in China in 2018 ($54.5 billion), accounting for slightly more than half of total investment (**Table 8-7** and Table S8-64). Software received by far the most investment ($45.5 billion) among the seven ICT industries (**Table 8-7**). The transportation industry received $13.5 billion (14% of total investment), up from less than $200 million in 2013 (**Table 8-7** and Table S8-64). The health care sector received $6.2 billion, a far smaller share (6%) of China's investment compared with that of the United States (27%) (**Table 8-6**, **Table 8-7**, and Table S8-64).

TABLE 8-7

China venture capital investment in health care, ICT, and transportation industries: 2013 and 2018

(Millions of dollars)

Industry	2013	2018
Healthcare	290	6,184
Pharmaceuticals and biotechnology	71	3,206
Other	219	2,978
ICT	1,130	54,489
Computer hardware	2	984
Software	851	45,512

TABLE 8-7

China venture capital investment in health care, ICT, and transportation industries: 2013 and 2018

(Millions of dollars)

Industry	2013	2018
Media	218	4,436
Other ICT	59	3,557
Transportation	144	13,506

ICT = information and communications technology.

Note(s)

Other ICT consists of communications and networking, information technology services, semiconductors, and other. Other health care consists of health care devices and supplies, health care services, healthcare technology systems, and other.

Source(s)

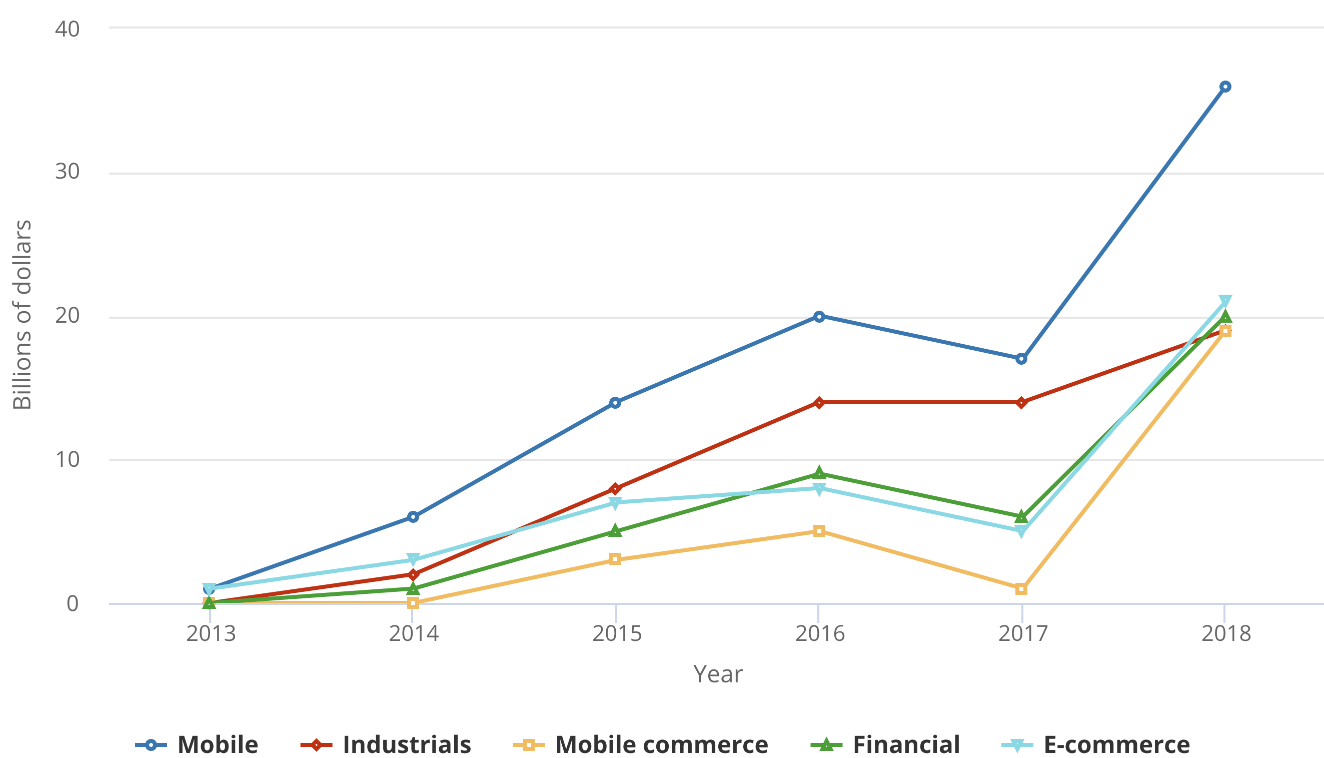
PitchBook, venture capital and private equity database, accessed 21 September 2019. See Table S8-64.

Science and Engineering Indicators

According to PitchBook's industry vertical classification, five technology areas—mobile, industrials, mobile commerce, financial, and e-commerce—were among the top recipients of China's venture capital investment (**Figure 8-26** and Table S8-65). Investment in each of these areas grew from $1 billion or less in 2013 to $19 billion to $36 billion in 2018 (**Figure 8-26** and Table S8-65). Mobile, mobile commerce, financial, and e-commerce all rely on software, which in turn led all industries in attracting venture capital investment (Table S8-64).

FIGURE 8-26

China venture capital investment, by selected industry vertical or technology: 2013–18



Note(s)

Industry verticals are classified by PitchBook and consist of firms operating in diverse industries focused on a technology area. Firms may be classified in multiple industries. The sum of industry verticals exceeds the total amount of venture capital investment.

Source(s)

PitchBook, venture capital and private equity database, accessed 21 September 2019. See Table S8-65.

Science and Engineering Indicators

Innovation Activities by U.S. Businesses

Since 2008, the U.S. Census Bureau and the National Science Foundation have collected comprehensive company-level data on innovation (i.e., counts of new goods and services), as well as counts of improved processes for production and distribution for U.S. companies (with five or more workers). According to these data, 17% of firms (one in six) introduced a new product or process from 2014 to 2016; this incidence rate was higher in manufacturing compared with other industries (**Table 8-8** and **Figure 8-27**). By this measure, a larger number of firms in the nonmanufacturing sector report an innovation than in the manufacturing sector; as a proportion of all firms, however, 15% of nonmanufacturing firms, compared with 33% of manufacturing firms, report an innovation (**Table 8-8** and **Figure 8-27**).

TABLE 8-8

U.S. companies introducing new or significantly improved products or processes, by industry sector: 2014–16

(Number and percent)

Industry	NAICS code	Companies (number)	New or significantly improved products or processes (percent)	New or significantly improved products (percent)	New or significantly improved processes (percent)
All industries	21–23, 31–33, 42–81	1,138,671	16.7	9.5	13.1
Manufacturing industries	31–33	113,066	32.7	22.1	25.5
Nonmanufacturing industries	21–23, 42–81	1,025,605	14.9	8.1	11.7

NAICS = North American Industry Classification System.

Note(s)

New or significantly improved products include goods or services. Statistics for the number of companies are based only on companies in the United States responding "Yes" to at least one of the items on the survey relating to new or significantly improved products regardless of whether the company performed or funded R&D. These statistics do not include an adjustment to the weight to account for unit nonresponse.

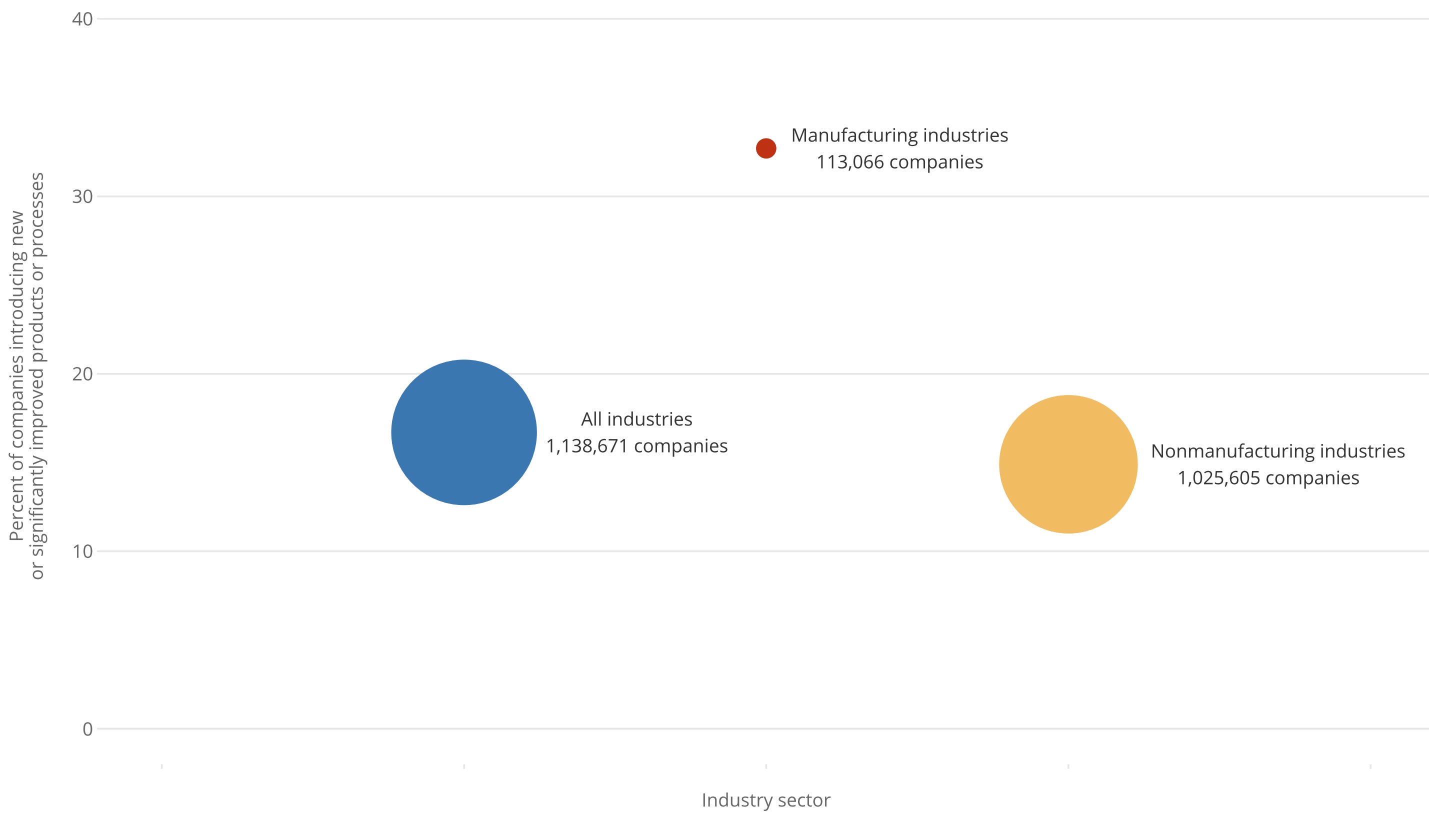
Source(s)

National Center for Science and Engineering Statistics, National Science Foundation, and U.S. Census Bureau, Business R&D and Innovation Survey, 2016, Table 64 and Table 65.

Science and Engineering Indicators

FIGURE 8-27

U.S. companies introducing new or significantly improved products or processes, by industry sector, number of companies, and percentage of companies: 2014–16



Note(s)

Statistics for the number of companies are based only on companies in the United States responding "Yes" to at least one of the items on the survey relating to new or significantly improved products regardless of whether the company performed or funded R&D. These statistics do not include an adjustment to the weight to account for unit nonresponse.

Source(s)

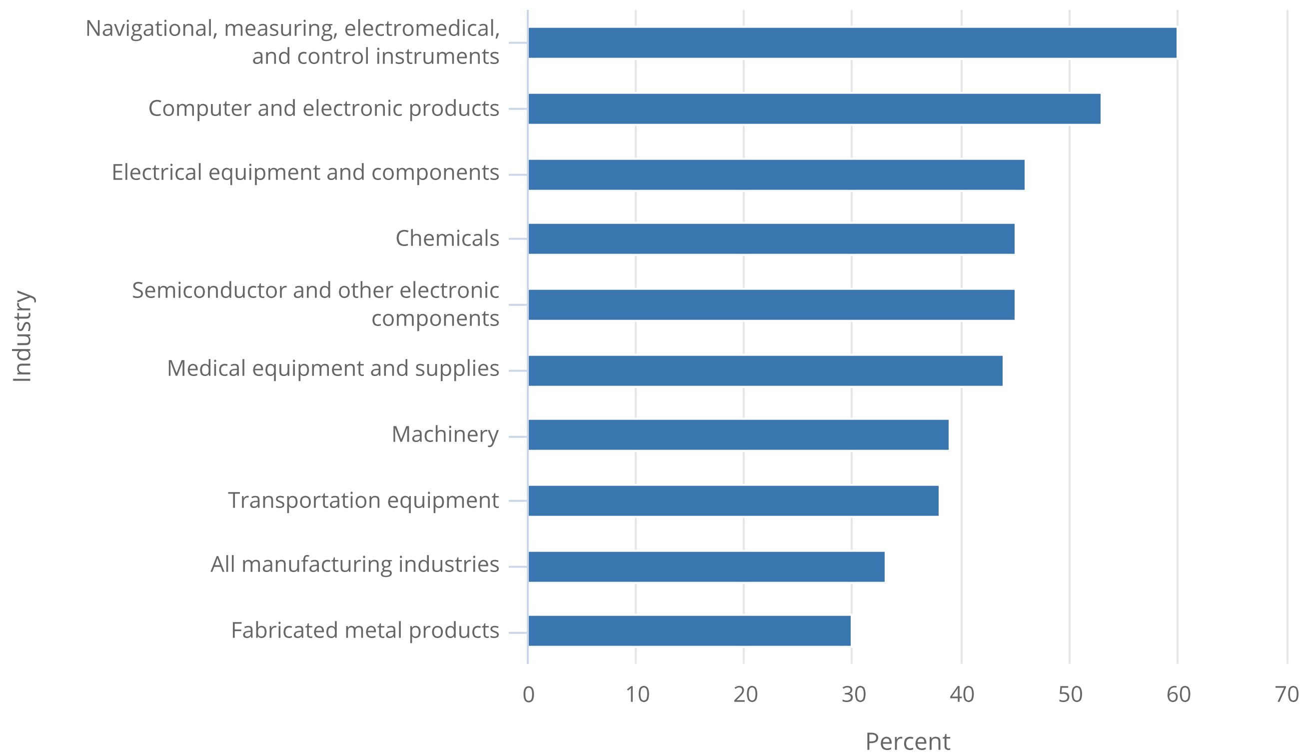
National Center for Science and Engineering Statistics, National Science Foundation, and U.S. Census Bureau, Business R&D and Innovation Survey (BRDIS), 2016, Table 68 and Table 69.

Science and Engineering Indicators

Within the manufacturing sector, the chemicals, transportation equipment, and medical equipment and supplies industries have rates above 35% (**Figure 8-28**). Research-intensive industries that overlap with technology areas with large public investments have high rates of innovation, including pharmaceuticals. The navigational, measuring, electromedical, and control instruments manufacturing industry reports an incidence rate of 60% (**Figure 8-28**). Outside of manufacturing, in addition to the ICT-producing industries discussed earlier, health care services; architectural, engineering, and related services; wholesale trade; and scientific R&D services have incidence rates above the nonmanufacturing average (**Figure 8-29**).

FIGURE 8-28

Share of U.S. manufacturing companies reporting product or process innovation, by selected industry: 2014–16



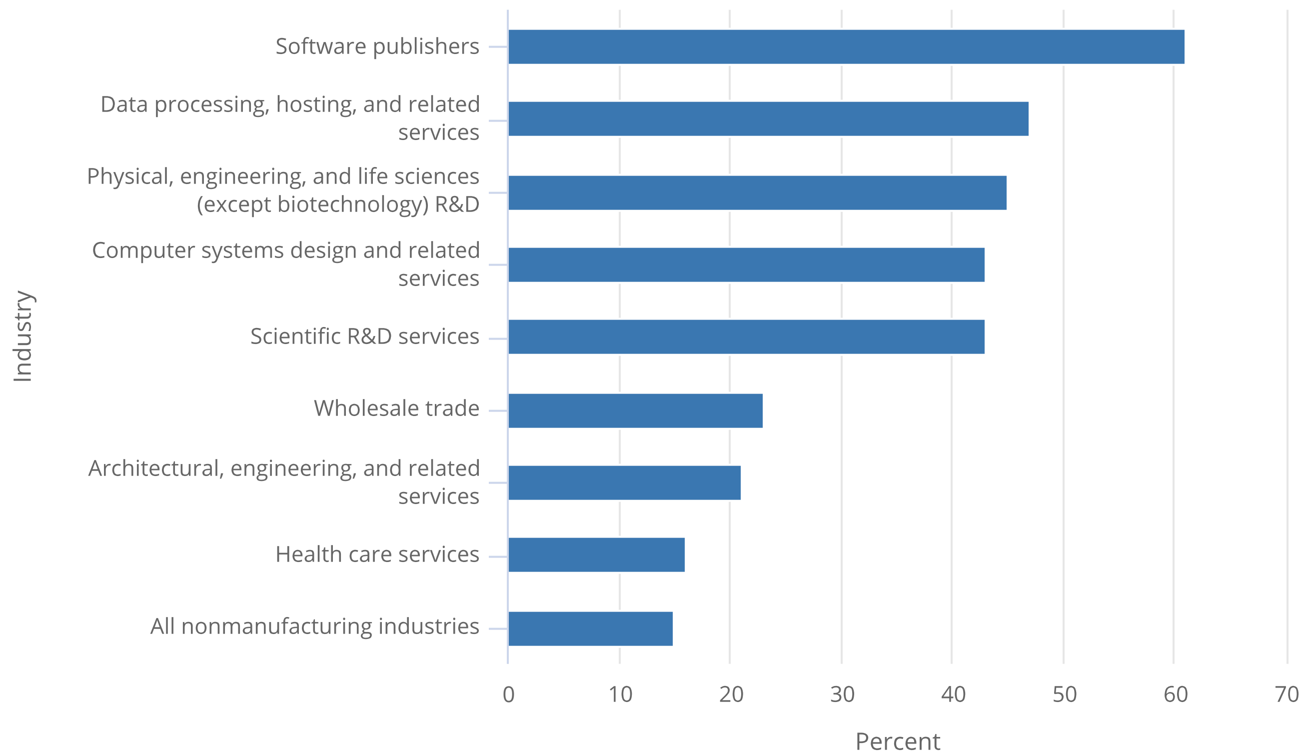
Note(s)
The survey asked companies to identify innovations introduced from 2014 to 2016. Electrical equipment and components includes appliances.

Source(s)
National Center for Science and Engineering Statistics, National Science Foundation, U.S. Census Bureau, Business R&D and Innovation Survey (BRDIS), 2016.

Science and Engineering Indicators

FIGURE 8-29

Share of U.S. nonmanufacturing companies reporting product or process innovation, by selected industry: 2014–16



Note(s)

The survey asked companies to identify innovations introduced from 2014 to 2016. Software publishers includes other publishing.

Source(s)

National Center for Science and Engineering Statistics, National Science Foundation, and U.S. Census Bureau, Business R&D and Innovation Survey (BRDIS), 2015, Table 68.

Science and Engineering Indicators

ICT-producing industries span the manufacturing, information, and service sectors. They cover computer and electronic products manufacturing, software publishing, information and data processing, and computer system design. These ICT industries report among the highest rates of innovation (**Figure 8-28** and **Figure 8-29**).

International Comparisons in Innovation Incidence

Cross-country comparisons of business innovation rates provide a measure distinct from R&D that offers an indication of international competitiveness. These international comparisons are collected under *The Oslo Manual* (OECD/Eurostat 2005) and show differences in rates of firm product and process innovation (**Table 8-9**). Although these statistics exhibit increasing harmonization across methodology and survey concepts, international comparability may be limited due to ongoing survey differences.[10]

Despite differences in how countries measure innovation, broad patterns emerge. Relatively small economies focused on S&T, such as Finland, Israel, and Switzerland, report some of the highest rates of product and process innovation (**Table 8-9**). As measured, the United States, Japan, and the United Kingdom rank lower in reported incidence rates (**Table 8-9**).

TABLE 8-9

International comparison of firm innovation rate of product and process, by country: 2012–14

(Percent of firms)

Country	Product-innovative firms (regardless of any other type of innovation)	Process-innovative firms (regardless of any other type of innovation)
Australia	35.7	31.0
Austria	30.8	32.8
Belgium	31.9	38.8
Brazil	18.5	32.1
Chile	5.1	8.2
China	18.7	20.0
Czechia	25.1	22.4
Denmark	23.2	23.2
Estonia	11.0	13.0
Finland	34.5	32.0
France	27.7	27.1
Germany	34.4	24.1
Greece	23.4	29.6
Hungary	12.0	9.6
Ireland	35.7	37.8
Israel	36.2	34.0
Italy	24.7	24.5
Japan	14.6	19.2
Latvia	8.5	9.7
Lithuania	20.9	31.4
Luxembourg	28.8	25.7
Netherlands	32.5	28.1
New Zealand	18.1	18.9
Norway	32.9	26.9
Poland	9.5	10.9
Portugal	28.4	35.4
Russia	5.3	NA
Slovakia	12.6	12.9
Slovenia	25.2	22.6
South Korea	16.8	17.3
Spain	11.2	14.8
Sweden	31.4	25.8
Switzerland	42.4	26.1
Turkey	22.7	26.8
United Kingdom	26.8	17.9
United States	18.4	19.8

NA = not available.

Note(s)

Where indicated, most recent data are used. The comparison is limited to the sectors and industries that are jointly surveyed, based on the North American Industry Classification System equivalents of International Standard Industrial Classification of All Economic Activities Revision 4. These are: the European Union Core Coverage: B (mining and quarrying); C (manufacturing); D and E (electricity, gas, steam, water supply, sewerage, waste management, remediation); G 46 (wholesale trade, except motor vehicles and motorcycles); H (transport and storage); J 58 (publishing); J 61 (telecommunications); J 62 (computer programming, consultancy, and related activities); J 63 (information services); K (finance and insurance); M 71 (architecture, engineering, technical testing and analysis).

Source(s)

National Center for Science and Engineering Statistics, National Science Foundation, and U.S. Census Bureau, Business R&D and Innovation Survey, 2015; Organisation for Economic Co-operation and Development (OECD), OECD Science, Technology and Industry Scoreboard 2015.

The Diffusion of Innovation: Productivity and Jobs

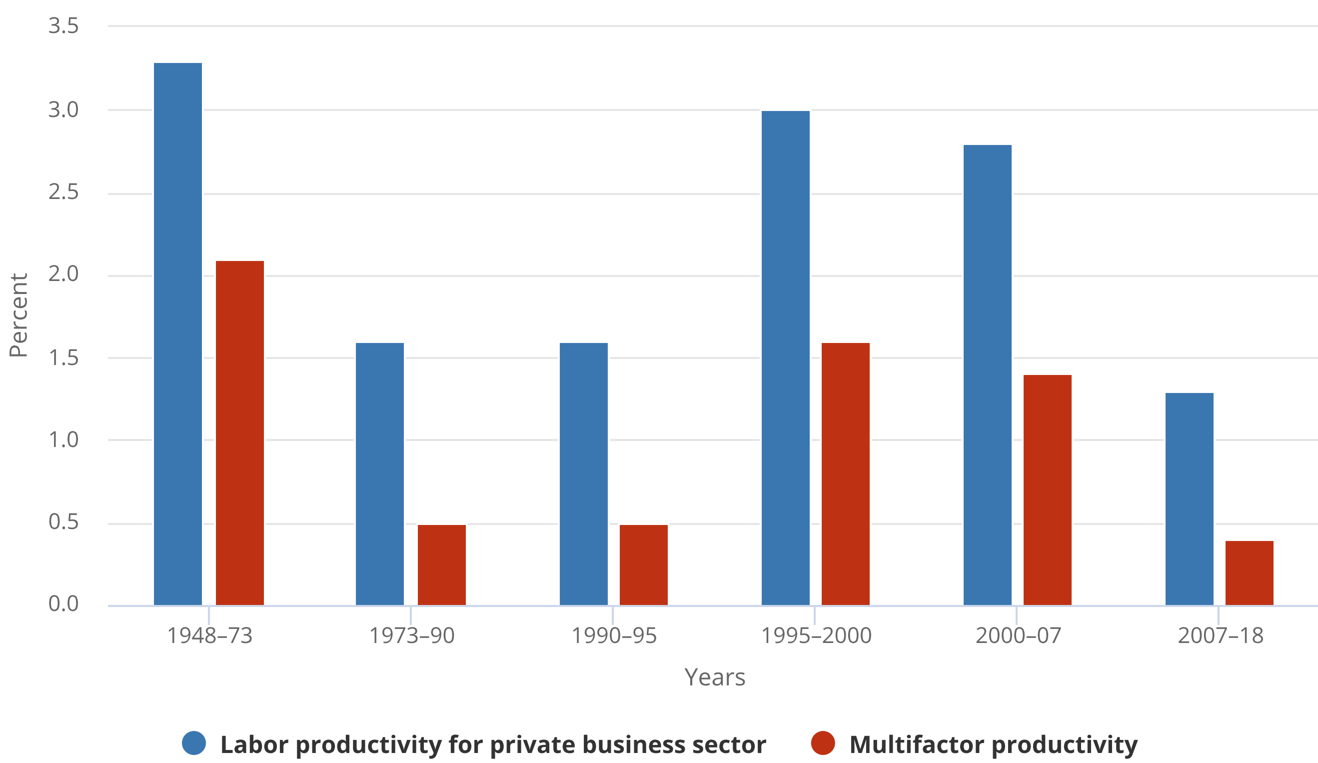
Many countries set the creation of new products and processes through innovation as a key national goal. There is broad consensus that S&T policy and economic policy at the national level should encourage and support innovation; economic growth and advancements in knowledge serve as important justifications for increased investment in S&T (OECD 2016). In addition to products and processes, longer-term impacts of innovation are also often targets of interest. This section closes with two indicators of the translation of technology into the economy: technology-driven productivity growth and the growth of small firms in the United States.

Multifactor Productivity

Multifactor productivity (MFP), an internationally comparable indicator of the impact of innovation and technological change on economic growth, is calculated by dividing output measures by input measures. The source data come from national production accounts, the source of GDP statistics. The data presented in this section show a moderation of MFP across several high-income economies. In the United States, MFP grew faster on average between 1995 and 2007 compared with the first half of the 1990s, and growth has slowed since 2007 (**Figure 8-30**). Labor productivity, which indicates the amount of output for each unit of labor, has also moderated in the United States since 1995 (**Figure 8-30**).

FIGURE 8-30

U.S. labor and multifactor productivity annual growth, multiyear averages, for private business sector: 1948–2018



Note(s)

Growth is calculated by the Bureau of Labor Statistics (BLS) as the average annual rate of growth between the first year and the last year of each period.

Source(s)

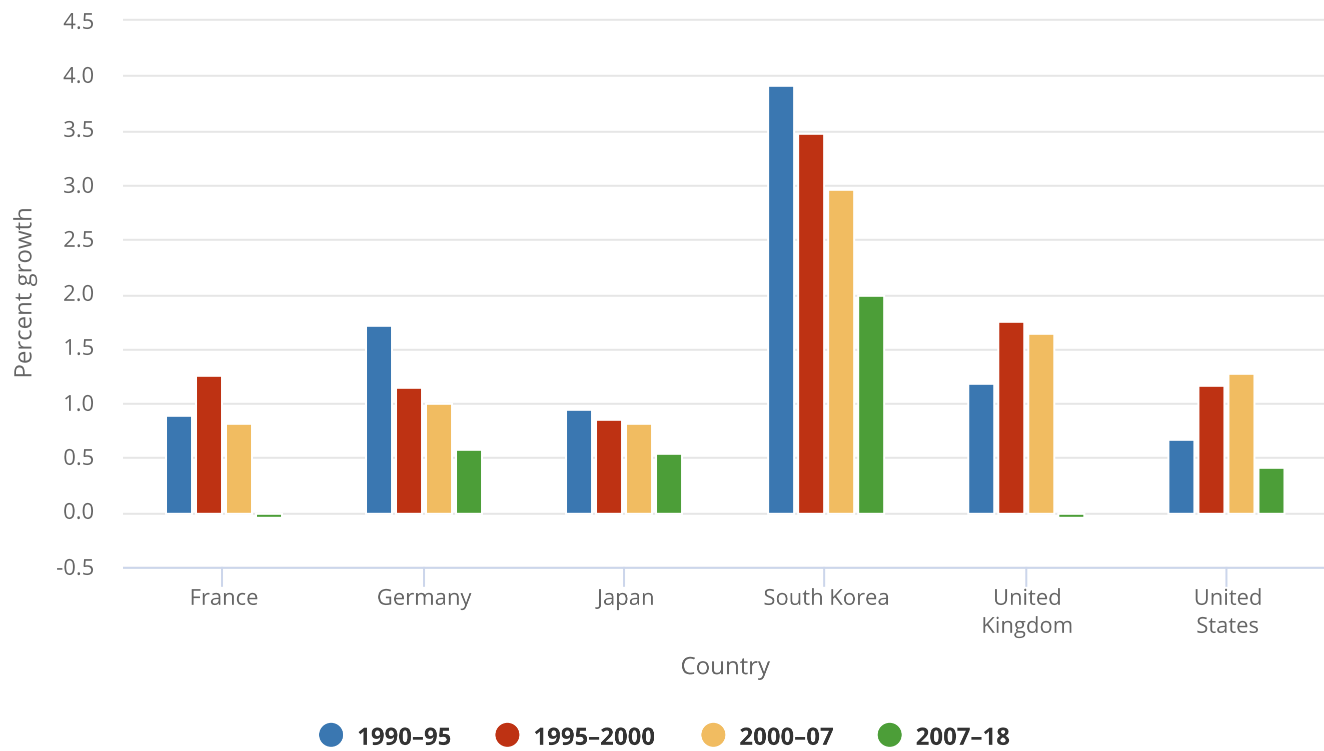
BLS, Productivity Measures (2019), Private Business Sector (Excluding Government Enterprises), accessed 5 May 2019.

Science and Engineering Indicators

This moderation in the MFP growth rate is evident in other high-income economies as well, including France, Germany, Japan, and the United Kingdom (**Figure 8-31**). South Korea has seen some moderation in MFP, yet its average growth rate remains high relative to the rest of OECD (**Figure 8-31**).

FIGURE 8-31

Economy-wide growth in multifactor productivity for selected OECD countries, multiyear averages: 1990–2018



OECD = Organisation for Economic Co-operation and Development.

Note(s)

Growth is calculated by the author as the average annual rate of growth between the first year and the last year of each period. Data for Japan run through 2017.

Source(s)

OECD, Growth in GDP per capita, productivity and ULC, accessed 5 May 2019.

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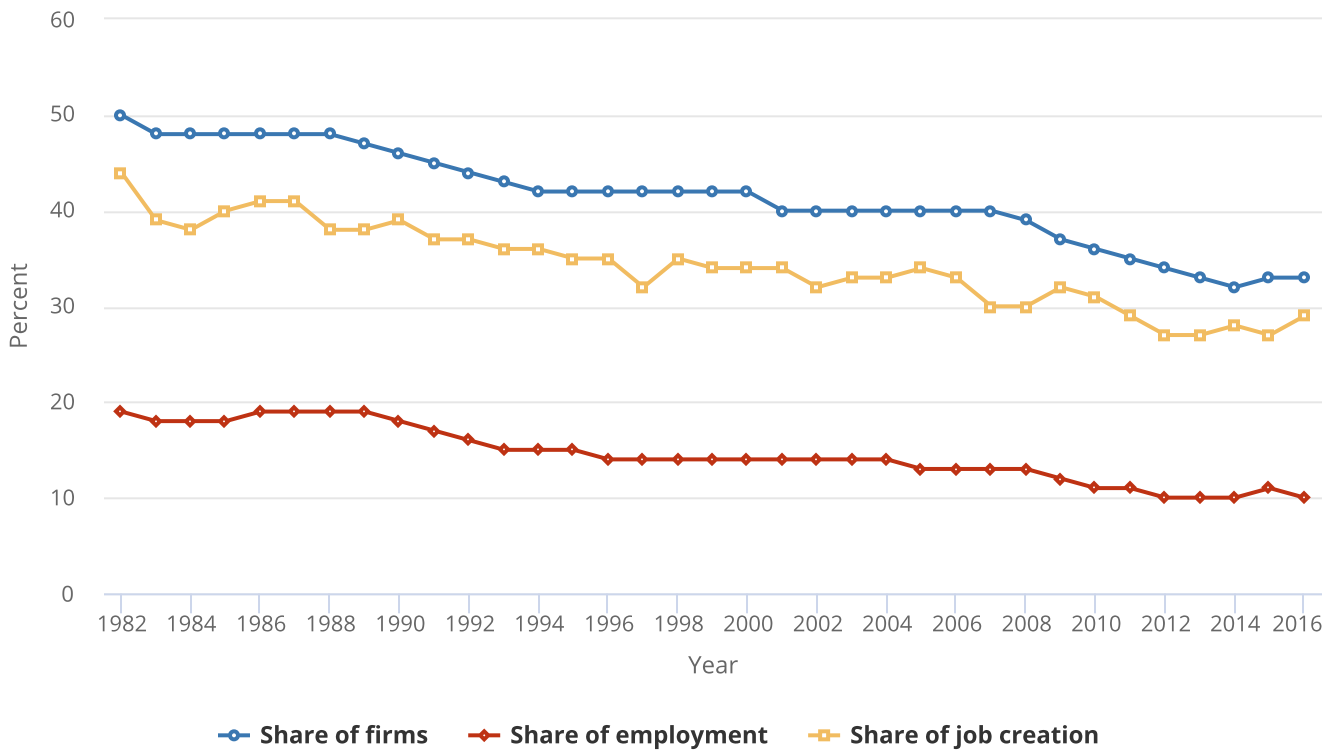
Small, Fast-Growing Firms

Innovation also affects the economy through entrepreneurship and firm creation. Firm-level data from the U.S. Census Bureau's Business Dynamics Statistics provide information on establishments opening and closing, firm startups and shutdowns, and associated employment impacts. Based on U.S. Census Bureau data, half of U.S. firms were 5 years old or younger in 1982; this share has steadily declined, leveling off at about a third between 2012 and 2016 (**Figure 8-32**). Young firms accounted for 19% of employment in 1982 but only 10% in 2016 (**Figure 8-32**).

FIGURE 8-32

Share of firms, job creation, and employment from firms 5 years old or younger: 1982–2016



Source(s)

U.S. Census Bureau, Business Dynamics Statistics, accessed 4 April 2019.

Science and Engineering Indicators

Conclusion

This report focuses on the creation of inventions, knowledge transfer, and innovation through the introduction of new and improved goods and services. This report's indicators address these topics with data from a variety of sources that cover technology areas, industries, and product markets. ICT and related industries, as well as health-related technologies, are prominent across these indicators. On balance, the indicators show the importance of research, output, invention, and innovation in the digital economy, and the strong role of engineering activities.

Intellectual property registration provides a useful set of indicators of invention. Although this activity was once concentrated in upper-income countries, middle-income countries are increasingly participating in intellectual property registration. This results in both collaboration opportunities and competition challenges. The global supply chain is rooted in international S&E capacity, while at the same time growing interconnectedness allows security risks to have widespread impacts. For the digital economy, intellectual property and intangibles play a prominent role. Intellectual property indicators, such as patenting and trademarks, show where new products and processes are emerging. Patent-intensive industries spend higher proportions of their sales on R&D, and both electrical and mechanical engineering-related patents made up about half of all patents granted by the USPTO in 2017. Universities and federal labs transfer knowledge and technology through research collaborations, technology licensing, and support for startups. One in six U.S. firms (with five or more employees) reports having introduced a product or process innovation in recent years. Health-related industries and the digital economy have an outsized impact on innovation rates across the economy, with ICT-producing industries reporting many of the highest rates of innovation. Many of these same industries perform high levels of R&D and compete globally.

Glossary

Definitions

Design patent: Protects the visual ornamental characteristics of an article of manufacture.

European Union (EU): The EU comprises 28 member nations: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom. Unless otherwise noted, data on the EU include all 28 nations.

Federally funded research and development center (FFRDC): R&D-performing organizations that are exclusively or substantially financed by the federal government to meet a particular R&D objective or, in some instances, to provide major facilities at universities for research and associated training purposes. Each FFRDC is administered by an industrial firm, a university, or a nonprofit institution.

Information and communication technologies (ICT): *For economic output data*, OECD includes industries from International Standard Industrial Classification Revision Code 4: 26 Computer, electronic, and optical products; 582 Software publishing; 61 Telecommunications; and 62-63 IT and other information services (OECD 2017a). *For patent data technology classes*, ICT refers to these technology areas: Computer, electrical machinery, apparatus, energy, semiconductors, digital communication, telecommunications, audio-visual technology, basic communication processes, and IT methods for management (Inaba and Squicciarini 2017; OECD 2017b). *For PitchBook venture capital data*, ICT refers to computer hardware, software, media, communications and networking, IT services, and semiconductors industries.

Innovation: The implementation of a new or improved product or business process that differs significantly from previous products or processes and that has been introduced in the market or brought into use by the firm (OECD/Eurostat 2018).

Intangibles: Nonphysical factors that contribute to or are used to produce goods or services or are intended to generate future benefits to the entities that control their use (Blair and Wallman 2001).

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 (WIPO 2019).

International patent family: A group of patents from different national authorities; each member of the family shares a single initial invention. The organization of these families around a single initial invention means that there may be fewer patent families than individual patents.

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

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.

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 S&T statistics for all member and selected nonmember countries.

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.

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

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.

U.S. Patent and Trademark Office (USPTO) patent: A property right granted by the U.S. government to an inventor "to exclude others from making, using, offering for sale, or selling the invention throughout the United States or importing the invention into the United States" for a limited time in exchange for public disclosure of the invention when the patent is granted. (This is the USPTO definition, found on the USPTO website at **https://www.uspto.gov/learning-and-resources/glossary**, accessed 15 June 2017.)

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

Key to Acronyms and Abbreviations

ARPA-E: Advanced Research Projects Agency–Energy

BDS: Business Dynamics Statistics

BEA: Bureau of Economic Analysis

BLS: Bureau of Labor Statistics

BRDIS: Business R&D and Innovation Survey

BRDS: Business Research and Development Survey

CIS: Community Innovation Surveys

CRADA: cooperative R&D agreement

DHS: Department of Homeland Security

DOC: Department of Commerce

DOD: Department of Defense

DOE: Department of Energy

ED: Department of Education

EPO: European Patent Office

EU: European Union

EUIPO: European Union Intellectual Property Office

FFRDC: federally funded research and development center

FY: fiscal year

GDP: gross domestic product

HHS: Department of Health and Human Services

ICT: information and communication technology

INPADOC: International Patent Documentation

IPC: International Patent Classification

IT: information technology

IUCRC: Industry-University Cooperative Research Centers

MEP: Hollings Manufacturing Extension Partnership

MFP: multifactor productivity

NAICS: North American Industry Classification System

NASA: National Aeronautics and Space Administration

NIPA: national income and product accounts

NIST: National Institute of Standards and Technology

NPL: nonpatent literature

NSF: National Science Foundation

OECD: Organisation for Economic Co-operation and Development

PATSTAT: Worldwide Patent Statistical Database

R&D: research and development

ROW: rest of the world

S&E: science and engineering

S&T: science and technology

SBA: U.S. Small Business Administration

SBIR: Small Business Innovation Research

STTR: Small Business Technology Transfer

TFP: total factor productivity

UK: United Kingdom

UPOV: International Union for the Protection of New Varieties of Plants

USDA: U.S. Department of Agriculture

USPTO: U.S. Patent and Trademark Office

WIPO: World Intellectual Property Organization

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Notes

1 Innovation activities are described in the 2018 *Oslo Manual* (OECD/Eurostat 2018).

2 For this report, Table S8-2 lists the 35 WIPO technical fields, Table S8-3 provides the regions, countries, and economies covered by USPTO patent and international patent family patent data, and Table S8-4 through Table S8-42 present utility patent data. The tables cover USPTO patents and international patent family patents from 1998 to 2018. Table S8-2 contains USPTO academic patenting data by the 35 technical fields mentioned above.

3 The design classes that make up design patents registered to U.S. designers are also shown (Table S8-44).

4 Table S8-43 and Table S8-44 show the number of U.S. design patents granted since 2000 and 1998, respectively, by region, country, or economy and by design class.

5 For example, 49% of U.S. manufacturing firms reported that the invention underlying their most recent innovation came from outside the firm (Arora, Cohen, and Walsh 2016).

6 This percentage is calculated from Table S8-1.

7 AUTM collects data on invention and patent-related activities of its member universities. The number of member universities varies slightly from year to year. There were 161 in 2013, 165 in 2015, and 167 in 2017. The response rate of the survey in 2017 was 61.9% (AUTM 2018).

8 These are measured by the Bureau of Economic Analysis (Soloveichik and Wasshausen 2013) and tabulated by the Bureau of Labor Statistics as part of its measurement of productivity.

9 PitchBook classifies venture-backed firms based on their primary industry. See Table S8-63 for a description of PitchBook's industry and technology classification. PitchBook further classifies these industries into technology-focused groups, such as health technology, nanotechnology, and artificial intelligence.

10 *The Oslo Manual* was revised in 2018. The data included in this report, however, were gathered under the guidance of the 2005 *Oslo Manual*.

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