CHAPTER 6

Industry, Technology, and the Global Marketplace

Table of Contents

List of Sidebars

List of Tables

List of Figures

Highlights

Knowledge and Technology Industries in the World Economy

Knowledge- and technology-intensive (KTI) industries are a major part of the global economy.

- Fifteen KTI industries, consisting of five knowledge-intensive services industries, five high-technology manufacturing industries, and five medium-high-technology industries, represented nearly one-third of world gross domestic product (GDP) in 2016.
- The commercial knowledge-intensive services—business, financial, and information—have the highest share of GDP (15%). The public knowledge-intensive services—education and health care—have a 9% share; these are publicly regulated or provided and remain relatively more location bound than the commercial knowledge-intensive services.
- The medium-high-technology manufacturing industries—motor vehicles and parts, electrical machinery, machinery and equipment, chemicals excluding pharmaceuticals, and railroad and other transportation equipment—are the third largest (4%).
- The high-technology manufacturing industries—aircraft and spacecraft; communications and semiconductors; computers; pharmaceuticals; and testing, measuring, and control instruments—account for a 2% share of world GDP.
- The United States has the highest KTI share of GDP (38%) of any large economy closely followed by Japan (36%). The KTI share for the European Union (EU) is considerably lower.
- China has the largest KTI share of any large developing economy (35%), and its KTI share is comparable to those of large, developed economies. The KTI shares in other large developing economies are significantly lower than China's.

Worldwide Distribution of Knowledge- and Technology-Intensive Industries

The United States had the largest global share of commercial KI services in 2016.

- The United States accounted for 31% of global commercial KI services (business, financial, and information), followed by the EU (21%).
- China is the world's third largest provider of commercial KI services (17% global share). Despite a recent slowdown in its rapid pace of growth, China continues to grow far faster than the United States and other large developed economies.
- In high-technology manufacturing, the United States is the largest global producer (31% global share). The U.S. global share has remained stable for the last decade. China is the second largest global producer (24%). Rapid growth of China's industries more than doubled China's global share over the last decade. China surpassed Japan in 2008 and the EU in 2012.
- China is the world's dominant producer in medium-high-technology industries (32% global share). China's global share nearly tripled over the last decade, and it surpassed the United States in the late-2000s and the EU in the early-2010s.

U.S. KTI industries have had a stronger recovery from the global recession than those in the EU and Japan, as evidenced by output data starting in 2011.

- Value-added output of U.S. commercial knowledge-intensive services in 2016 was 26% higher than in 2011. Output in the EU and Japan declined.
- U.S. high-technology manufacturing industries grew 16% between 2011 and 2016. The EU's output grew slightly, and Japan's output was stagnant.
- Value-added output of U.S. medium-high-technology manufacturing industries was 17% higher in 2016 than in 2011. Output in the EU declined and Japan remained flat.

KTI industries play an important role in the U.S. economy and in U.S. business R&D.

- U.S. commercial KI services industries employ 17% of workers in all industries and fund 29% of U.S. business R&D.
- U.S. high-technology manufacturing industries employ 1.8 million workers and fund nearly half of U.S. business R&D.
- U.S. medium-high-technology industries employ 3.0 million workers and fund 11% of U.S. business R&D.
- U.S. KTI industries have had a strong recovery in their output, but gains in employment have been weaker. Employment in commercial KI services in 2016 was 1.2 million higher compared to 2007 prior to the recession. Although growing robustly following the global recession, employment in medium-high technology manufacturing industries remains slightly below its level prior to the global recession. Employment in high-technology manufacturing has remained stagnant and remains below its level prior to the global recession.

The United States is a major exporter of KTI services.

- The EU is the world's largest exporter of commercial KI services, followed by the United States; both have substantial surpluses in this area.
- The EU's commercial KI services exports grew 20% to reach more than $500 billion (33% global share) between 2011 and 2016.
- U.S. exports of commercial KI services grew faster than the EU's over this period, reaching $288 billion (18% global share).
- China and India's KTI exports grew rapidly, resulting in their global export shares reaching 6%–7% in 2016.
- China is the world's largest exporter of high-technology products (24% global share), with a substantial surplus. However, intermediate inputs imported from other countries account for a large share of the value of China's exports. China's exports and trade surplus measured on a value-added basis are considerably lower.
- The EU is the world's second largest exporter of high-technology products (17% global share). The United States is the third largest exporter (12%) closely followed by Taiwan. The United States is the world's largest exporter of aircraft and spacecraft (43% global share).
- The U.S. trade deficit in high-technology goods is largely anchored in products in information and communications technologies—communications, computers, and semiconductors. The United States has a substantial trade surplus in aircraft and spacecraft.

- The EU is the world's largest exporter of medium-high-technology goods (25% global share) and has a substantial surplus. China is the second largest global exporter (20% share) and has a substantial trade surplus, as does third-place Japan (11%).
- The United States is the fourth largest exporter and has a substantial deficit in medium-high-technology goods. The United States has a sizeable deficit in motor vehicles and parts ($98 billion), and deficits of $40–$52 billion in electrical machinery and appliances and machinery and equipment.

Global Trends in Sustainable Energy Research and Technologies

Global private investment in sustainable energy technologies in 2016 was $260 billion, largely in solar and wind. China attracted the most investment of any country.

- Early-stage private investment in sustainable energy technologies, consisting of venture capital and private equity investment, was $7.5 billion in 2016. The United States attracted the most venture capital and private equity of any country ($3.5 billion). China attracted $2.2 billion, a record high, and far higher than in 2015 ($0.5 billion).
- Energy smart and solar are the leading technologies for venture and capital and private equity investment with biofuels and wind receiving far smaller amounts. Energy smart covers a wide range of technologies, from digital energy applications to efficient lighting, electric vehicles, and the smart grid that maximize the energy efficiency of existing energy sources and networks
- Global private investment in later-stage financing—to build utility-scale power plants and installations of solar in residential and commercial buildings—was $252 billion in 2016. Two technologies—wind and solar—dominate investment, each with a share of about 40%.
- China leads the world in attracting later-stage commercial investment in sustainable energy technologies (33% global share), followed by the EU (25%) and the United States (18%).
- Investment in sustainable energy technologies fell 19% in 2016 compared to 2015, the deepest annual decline over the last decade. Investment in China and Japan fell sharply, reflecting, in part, cutbacks in government incentives supporting the deployment of renewable energy and a greater emphasis on utilizing the existing renewable energy capacity in each of these countries more effectively.
- U.S. investment in 2016 ($46 billion) was 8% lower than in 2015. Investment in the United States has fluctuated in a range of $34 billion to $51 billion between 2011 and 2016 because of policy uncertainty. Solar investment has been the main driver of U.S. investment between 2010 and 2015.

The United States was the largest investor ($3.8 billion) in 2014 in public research, development, and demonstration (RD&D) of sustainable energy technologies. The EU is the second largest investor ($3.6 billion), followed by Japan ($2.7 billion).

- Global expenditures on public RD&D of sustainable energy technologies was an estimated $12.0 billion in 2014. Nuclear was the largest area, receiving $3.5 billion. The next two largest areas were energy efficiency ($3.3 billion) and renewables ($3.0 billion).
- Between 2011 and 2014, global expenditures of public RD&D fell from $14 billion to $12 billion, with declines in nuclear, renewables, and carbon capture and storage.

- Despite a decline in U.S. investment between 2011 and 2014, the United States surpassed the EU to become the world's largest investor in 2014. U.S. public RD&D investment in renewables and nuclear declined, while investment in energy efficiency increased.

The number of U.S. Patent and Trade Office patents granted in sustainable energy technologies doubled between 2009 and 2015. Six technologies—solar, hybrid and electric vehicles, smart grid, fuel cell, battery, capture and storage of carbon and other greenhouse gases—have led growth of these patents.

- U.S. inventors received the largest share of sustainable energy patents in 2016 (43%), followed by Japan (20%), and the EU (16%). Patenting by U.S. inventors has been led by four technologies—hybrid and electric vehicles, solar, smart grid, and energy storage.
- Patents granted to South Korea more than quadrupled between 2009 and 2016, led by growth in energy storage, solar, hybrid/electric, and battery technologies.

Introduction

Chapter Overview

Policymakers in many countries increasingly emphasize the central role of knowledge, particularly R&D and other activities that advance science and technology (S&T), in a country's economic growth and competitiveness. This chapter examines the downstream effects of these activities—their embodiment in the production of goods and services—on the performance of the United States and other major economies in the global marketplace.

This chapter covers three main areas. The first is knowledge- and technology-intensive (KTI) industries; the second is trade in KTI products and services; and the third is sustainable energy research and technologies.

KTI industries encompass both service and manufacturing sectors, based on 15 categories of industries formerly classified by the Organisation for Economic Co-operation and Development (OECD 2001, 2007) that have a particularly strong link to S&T (Table 6-1).[1] These include five knowledge-intensive services industries, five high-technology manufacturing industries, and five medium-high-technology industries. The definition of KTI industries has been expanded with the addition of medium-high-technology manufacturing industries for this 2018 edition of *Science and Engineering Indicators* (see sidebar New Definition of KTI Industries). In prior editions KTI consisted of 10 categories of industries—five knowledge-intensive (KI) services industries and five high-technology manufacturing industries.

- Five KI services industries incorporate high technology either in their services or in the delivery of their services. Three of these—financial, business, and information services (including computer software and R&D)—are generally commercially traded. The others—education and health care—are publicly regulated or provided and remain relatively more location bound (Table 6-1). Although they are far less market driven than other KTI industries in the global marketplace, competition in education and health appears to be increasing. Public KI services are also becoming more global; for example, many universities have international campuses.
- Five high-technology manufacturing industries spend a large proportion of their revenues on R&D and make products that contain or embody technologies developed from R&D (Table 6-1). These are aircraft and spacecraft; pharmaceuticals; computers and office machinery; semiconductors and communications equipment (treated separately in the text); and measuring, medical, navigation, optical, and testing instruments.[2] Aircraft and spacecraft and

pharmaceuticals are less market driven than the other three industries because of public funding, procurement, and regulation.[3]

- Five medium-high-technology manufacturing industries spend a relatively large proportion of their revenues on R&D (Table 6-1). These are motor vehicles and parts, chemicals excluding pharmaceuticals, electrical machinery and appliances, machinery and equipment, and railroad and other transportation equipment. Although they spend a relatively lower proportion of their revenue on R&D compared to high-technology manufacturing industries, medium-high-technology manufacturing industries produce many products that incorporate advanced and science-based technologies. For example, cars and trucks contain sophisticated sensors and software to prevent accidents, optimize engine performance, and maximize fuel economy.

TABLE 6-1

Knowledge- and technology-intensive industries, by category

(KTI industries and categories)

Category	Industry
Public KI services	Education
	Primary education
	Secondary education
	Higher education
	Adult education
	Health care
	Counseling
	Hospitals
	Medical and dental practices
	Veterinary
Commercial KI services	Business
	Advertising
	Architectural, engineering, and other technical activities
	Building maintenance and support
	Data processing
	Leasing
	Legal, accounting, and auditing activities
	Market research and public opinion polling
	R&D services
	Financial
	Banking and finance
	Pension
	Insurance
	Commodity, securities, and stock markets
	Information

Category	Industry
	Broadband transmission
	Cable broadcasting
	Cellular transmission
	Computer programming, consultancy and related activities
	Film and video
	Internet
	Software
	Telephone (landline)
	TV broadcasting
High-technology manufacturing	Aircraft and spacecraft
	Communications and semiconductors
	Computers and office machinery
	Pharmaceuticals
	Measuring, medical, navigation, optical, and testing equipment
Medium-high-technology manufacturing	Motor vehicles and parts
	Chemicals excluding pharmaceuticals
	Electrical machinery and appliances
	Machinery and equipment
	Railroad and other transportation equipment

KI = knowledge intensive; KTI = knowledge and technology intensive.

Source(s)

United Nations Statistics Division, International Standard Industrial Classification (ISIC) of All Economic Activities, Rev.3, https://unstats.un.org/UNSD/cr/registry/regcst.asp?Cl=2, accessed 15 August 2017.

Science and Engineering Indicators 2018

Non-KTI industries are also very important in the world economy and therefore receive some attention in this chapter.

The globalization of the world economy involves the rise of new centers of KTI industries.[4] Advances in S&T have enabled companies to spread KTI activity to more locations around the globe and to develop strong interconnections among geographically distant entities. Although the United States and the European Union (EU) continue to be leading global producers in many of these industries, China has become the global leader in many technology-intensive manufacturing industries and is moving from final assembly into higher-value activities, including R&D and manufacture of sophisticated products. Overall, the United States is the largest global producer of high-technology manufacturing industries. However, China is the largest global producer in the information and communication technologies (ICT) manufacturing industries. China is the world's largest global producer in medium-high-technology industries. The U.S. and the EU lead in the production of commercial knowledge-intensive services; China is growing rapidly and is now the third largest producer.

This chapter ends with a discussion of global investment in sustainable energy research and technologies. In recent years, developed and emerging economies have invested in developing improved technologies for generating sustainable energy. Energy has a strong link to S&T and, like ICT, is a key element of infrastructure.

Several themes cross-cut the various indicators examined in the chapter:

- The United States has had robust growth in many KTI industries and trade of KTI goods and services following the global recession, in contrast to tepid or negative growth by the EU and Japan. The United States continues to be the world's largest provider of commercial KI services. China has continued to grow faster than developed countries in many KTI industries and has become the world's largest producer in many technology-intensive manufacturing industries. Although its share is lower in commercial KI services, China is growing far more rapidly overall than developed countries.
- The high-technology and medium-high-technology manufacturing industries are the most globalized among the KTI industries. Two high-technology manufacturing industries—communications and semiconductors and computers—have complex global value chains where manufacturing is located far away from the final markets. Although production is globalized in motor vehicles and parts, a medium-high-technology industry, manufacturing generally occurs near or in the final markets.
- Developed countries continue to dominate in KTI industries despite much more rapid growth by China. Developed countries account for nearly 70% of global production of commercial knowledge-intensive services industries, which are the largest category of KTI industries. However, China is the world's second largest producer in high-technology manufacturing industries, and is the largest producer in medium-high-technology industries.
- Globalization is increasing rapidly in the much larger commercial knowledge-intensive services industries but remains generally lower than in high-technology or medium-high-technology manufacturing. Business services is highly globalized with firms contracting out these services to providers located in developed and developing countries.
- China plays a unique role in global KTI industry production. China's global share in several high-technology- and medium-high-technology industries is comparable with or exceeds that of the United States or the EU.
- Among the KTI industries in developed countries, those in the United States have grown the strongest since the global recession. Growth of KTI industries in the EU and Japan has been weaker than the United States.

Chapter Organization

This chapter focuses on the major players in the global KTI arena, namely the United States, the EU, Japan, China, and other Asian economies. Other major developing countries, including Brazil, India, Indonesia, and Russia, also receive some attention. The time span is from the early 2000s to the present.

This chapter is organized into three sections:

- The first section discusses the prominent role of KTI industries in regional and national economies around the world, describes the global spread of KTI industries, and analyzes regional and national shares of worldwide production. It discusses shares for the KTI industry group as a whole and the knowledge-intensive services and high-technology manufacturing groups. Because advanced technology is increasingly essential for non-high-technology industries, some data on these industries are also presented.

- The second section discusses indicators of increased interconnection of KTI industries in the global economy. It examines patterns and trends in global trade in KTI products and services, with a focus on the links among the United States, the EU, Japan, China, and other Asian countries.
- The last section presents data on sustainable energy research and technologies, which have become a policy focus in many developed and developing nations. These energy technologies, like KTI industries, are closely linked to R&D. Production, investment, and innovation in these energies and technologies are rapidly growing in the United States and other major economies.
- Prior editions of this chapter contained a section on innovation-related indicators, which covered innovation activities of U.S. companies, patenting by the United States and other major economies by technology area, trade in royalties and fees, and venture capital and Small Business Innovation Research investment. For the 2018 edition of *Science and Engineering Indicators*, a new chapter—Chapter 8, Invention, Knowledge Transfer, and Innovation—integrates and extends the innovation-related indicators that have previously been presented in Chapters 4, 5, and 6 of prior editions of *Science and Engineering Indicators*. This new chapter presents a more holistic and comprehensive approach to coverage of innovation and related activities.

Data Sources, Definitions, and Methodology

This chapter uses a variety of data sources. Although several are thematically related, they have different classification systems (see sidebar Industry Data and Terminology. The discussion of regional and country patterns and trends includes an examination of developed and developing countries using the International Monetary Fund's categorization. Countries classified by the International Monetary Fund as advanced are developed countries, whereas those classified as emerging and developing are considered to be developing.

SIDEBAR

Industry Data and Terminology

The data and indicators reported here permit the tracing and analysis of broad patterns and trends that shed light on the spread and shifting distribution of global knowledge- and technology-intensive (KTI) capabilities. The industry data used in this chapter are derived from a proprietary IHS Global Insight database that assembles data from the United Nations (UN) and the Organisation for Economic Co-operation and Development to cover 70 countries consistently. IHS estimates some industry data for developing countries, including China, that are missing or not available on a timely basis.

Firms are classified by their primary activity in the UN's International Standard Industrial Classification of All Economic Activities. Thus, a company that primarily manufactures pharmaceuticals, for example, but also operates a retail business would have all its economic activity counted under pharmaceuticals. Table 6-A describes these classification systems and aims to clarify the differences among them.

Production is measured as value added. Value added is the amount contributed by an economic entity—country, industry, or firm—to the value of a good or service. It excludes purchases of domestic and imported supplies as well as inputs from other countries, industries, or firms.

Value added is measured in current dollars. For countries outside the United States, value added is recorded in the local currency and converted at the prevailing nominal exchange rate. Industry data are reported in current dollar terms because most KTI industries are globally traded and because most international trade and foreign direct investment is dollar denominated. However, current dollars have shortcomings as a measure of economic performance, which the reader should bear in mind. Economic research has found a weak link between nominal exchange rates of countries' currencies that are globally traded and differences in their economic performance (Balke, Ma, and Wohar 2013). In addition, the exchange rates of some countries' currencies are not market determined.

Using value added as a measure of output has disadvantages. It is credited to countries or regions based on the reported location of the activity, which is often uncertain because of companies' use of different reporting and accounting conventions. In addition, the value added of companies that have diversified businesses is assigned to the single industry that accounts for the largest share of the company's business. Moreover, a company classified as manufacturing may include services, and vice versa. For China and other developing countries, industry data may be estimated by IHS Global Insight or may be revised frequently because of rapid economic change or improvements in data collection by national statistical offices.

For all these reasons, the reader should view the value-added trends analyzed here as relatively internally consistent but broad indicators of the changing geographical distribution where economic value is generated. Small differences and fluctuations in the data should be treated with caution.

TABLE 6-A

Data Sources

(Topics and selected data source information)

Topic	Data provider	Variables	Basis of classification	Coverage	Methodology
Knowledge-intensive (KI) services and high-technology (HT) manufacturing industries	IHS Global Insight, World Industry Service database (proprietary)	Production, value added	Industry basis using International Standard Industrial Classification of All Economic Activities	KI services — business, financial, information, health, and education	Uses data from national statistical offices in developed countries and some developing countries and estimates by IHS Global Insight for some developing countries
Information and communications technologies (ICT) spending	IHS Global Insight, Global ICT Navigator (proprietary database)	ICT expenditures, by businesses and consumers	ICT consumer spending of population, by country	Not applicable	Uses data from national statistical offices and other sources and estimates by IHS Global Insight for some developing countries
Trade in commercial KI services	World Trade Organization	Exports and imports	Product basis using Extended Balance of Payments Services classification	KI services — business, financial, information, and royalties and fees	Uses data from national statistical offices, the International Monetary Fund, and other sources
Trade in HT goods	IHS Global Insight, World Trade Service database (proprietary)	Exports and imports	Product basis using Standard International Trade Classification	Aerospace, pharmaceuticals, office and computing equipment, communications equipment, and scientific and measuring instruments	Uses data from national statistical offices and estimates by IHS Global Insight
Globalization of U.S. multinationals	U.S. Bureau of Economic Analysis (BEA)	Value added, employment, and inward and outward direct investment	Industry basis using North American Industrial Classification System (NAICS)	Commercial KI services — business, financial, and information	BEA annual surveys of U.S. multinationals and U.S. subsidiaries of non-U.S. multinationals

Topic	Data provider	Variables	Basis of classification	Coverage	Methodology
U.S. industry innovation activities	National Science Foundation, Business R&D and Innovation Survey	Innovation activities	U.S. businesses with more than five employees	Industries classified on an industry basis using NAICS	Survey of U.S.-based businesses with more than five employees using a nationally representative sample
U.S. Patent and Trademark Office (USPTO) patents	Science-Metrix, SRI International, Scopus, LexisNexis	Patent grants	Inventor country of origin, technology area as classified by the Patent Board	More than 400 U.S. patent classes, inventors classified according to country of origin and technology codes assigned to the grant	Source of data is USPTO
Triadic patent families	Organisation for Economic Co-operation and Development (OECD)	Patent applications	Inventor country of origin and selected technology area as classified by the OECD	Broad technology areas as defined by the OECD, inventors classified according to country of origin	Sources of data are USPTO, European Patent Office, and Japan Patent Office
Venture capital	Dow Jones VentureSource	Investment, technology area, country of investor origin	Technology areas as classified by the Dow Jones classification system	Twenty-seven technology areas, investment classified by venture firms' country location	Data collected by analysts from public and private sources, such as public announcements of venture capital investment deals
Sustainable energy investment	Bloomberg New Energy Finance (BNEF)	Investment, technology area, country	Technology area classified by BNEF	Ten technology areas, investment classified by country receiving investment	Data collected by analysts from public and private sources, such as public announcements of venture capital investment deals
Public research, development, and demonstration (RD&D) in sustainable energy and related technologies	International Energy Agency (IEA)	Type of RD&D, technology area, country	Technology area classified by IEA	Six broad technology areas and numerous subtechnology areas	Data collected by IEA survey of its member countries

Topic	Data provider	Variables	Basis of classification	Coverage	Methodology
Public and private investment in energy infrastructure	IEA	Investment, type of energy source	Energy source classified by IEA	Six broad and numerous fine technology areas	Data collected by IEA survey of its member countries

Science and Engineering Indicators 2018

---

[1] See OECD (2001) for a discussion of classifying economic activities according to their degree of "knowledge intensity." Like all classification schemes, the OECD classification has shortcomings. For example, KTI industries produce some goods or services that are neither knowledge intensive nor technologically advanced. In addition, multiproduct companies that produce a mix of goods and services, only some of which are KTI, are assigned to their largest business segment. Nevertheless, data based on the OECD classification allow researchers and analysts to trace, in broad outline, worldwide trends toward greater interdependence in science and technology and the development of KTI sectors in many of the world's economies.

[2] In designating these high-technology manufacturing industries, the OECD estimated the degree to which different industries used R&D expenditures made directly by firms in these industries and R&D embedded in purchased inputs (indirect R&D) for 13 countries: the United States, Japan, Germany, France, the United Kingdom, Canada, Italy, Spain, Sweden, Denmark, Finland, Norway, and Ireland. Direct R&D intensities were calculated as the ratio of total R&D expenditure to output (production) in 22 industrial sectors. Each sector was weighted according to its share of the total output among the 13 countries, using purchasing power parities as exchange rates. Indirect intensities were calculated using the technical coefficients of industries on the basis of input-output matrices. The OECD then assumed that, for a given type of input and for all groups of products, the proportions of R&D expenditure embodied in value added remained constant. The input-output coefficients were then multiplied by the direct R&D intensities. For further details concerning the methodology used, see OECD (2001). It should be noted that several nonmanufacturing industries have R&D intensities equal to or greater than those of industries designated by the OECD as high-technology manufacturing. For additional perspectives on the OECD's methodology, see Godin (2004).

[3] Aircraft and spacecraft trends are affected by public funding for military aircraft, missiles, and spacecraft, and by different national flight regulations. Public funding and regulation of drug approval, prices, patent protection, and importation of foreign pharmaceuticals can affect pharmaceuticals.

[4] See Mudambi (2008) and Reynolds (2010) for a discussion of the shift to knowledge-based production and geographical dispersion of economic activity.

Patterns and Trends of Knowledge- and Technology-Intensive Industries

This section will examine the importance of KTI industries in the global economy as measured by the KTI share of gross domestic product (GDP) in the global and major economies, and the positions of the United States and other major economies in KTI industries, as measured by their value-added output and shares of global KTI activity (Appendix Table 6-1). (For an explanation of KTI industries, please see section Chapter Overview.)

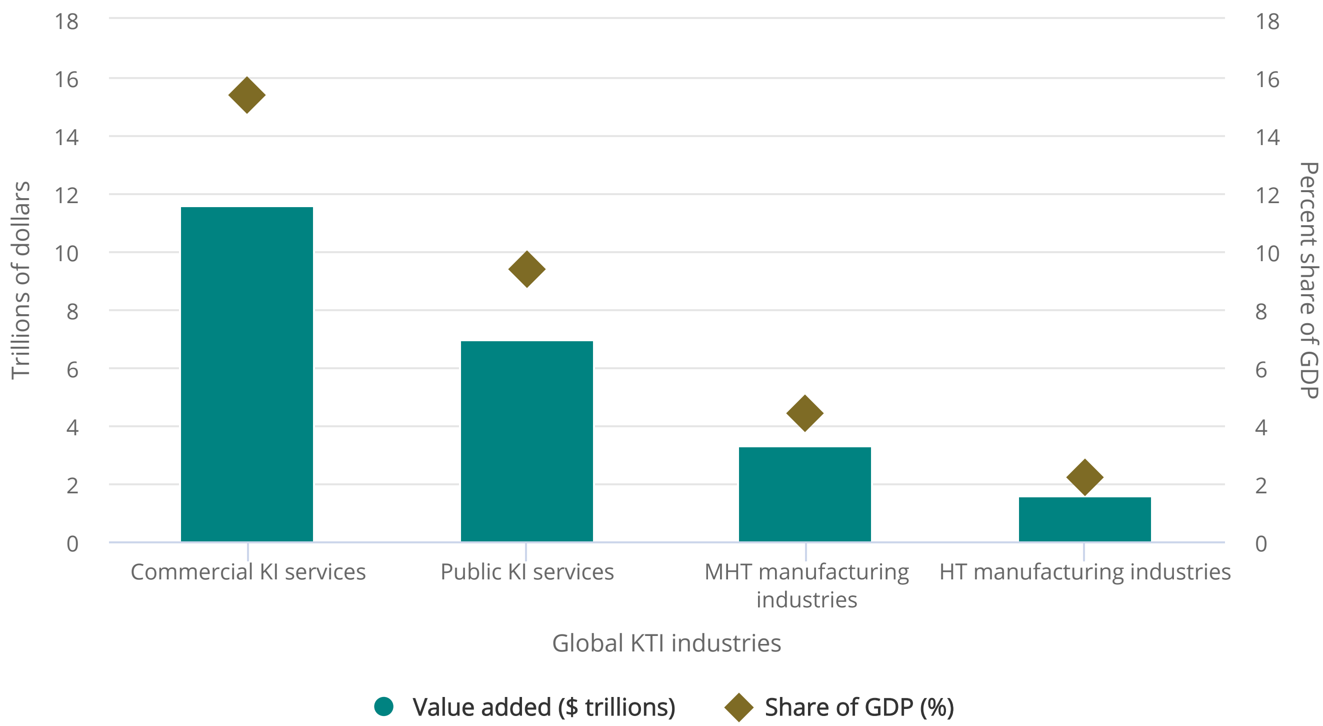
Knowledge- and Technology-Intensive Industries in the Global Economy

KTI industries have a value-added output of $24 trillion, making up nearly one-third of world GDP (Figure 6-1; Appendix Table 6-1, Appendix Table 6-2, and Appendix Table 6-3). This 2018 edition of *Science and Engineering Indicators* includes an expanded definition of KTI industries to add several industries with a value-added output of $3.3 trillion (see sidebar New Definition of KTI Industries).

Among the KTI industries, the commercial knowledge-intensive services—business, financial, and information—have the highest share (15% of GDP) (Figure 6-1; Table 6-1; Appendix Table 6-3 and Appendix Table 6-4). The public knowledge-intensive services—education and health care—have the second largest (9% of GDP) (Figure 6-1; Appendix Table 6-3, Appendix Table 6-5, and Appendix Table 6-6).[1] The newly added KTI industries for the 2018 edition of *Science and Technology Indicators* are medium-high-technology manufacturing industries that consist of motor vehicles and parts, electrical machinery, machinery and equipment, chemicals excluding pharmaceuticals, and railroad and other transportation equipment (see sidebar New Definition of KTI Industries). These industries have the third largest share (4% of GDP) (Figure 6-1; Appendix Table 6-3 and Appendix Table 6-7). The high-technology manufacturing industries—aircraft and spacecraft; communications; computers; pharmaceuticals; semiconductors; and testing, measuring, and control instruments—are smaller, with a 2% share, but use and embody cutting-edge technologies (Figure 6-1; Appendix Table 6-3 and Appendix Table 6-8).

FIGURE 6-1

Global KTI industries, by output and share of GDP: 2016



GDP = gross domestic product; HT = high technology; KI = knowledge intensive; KTI = knowledge and technology intensive; MHT = medium-high technology.

Note(s)

Output of KTI industries is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. KTI industries include KI services, HT manufacturing industries, and MHT manufacturing industries based on a former classification by the Organisation for Economic Co-operation and Development. KI services include business, financial, information, education, and health care. Commercial KI services include business, financial, and information. Public KI services include education and health care. HT manufacturing industries include aircraft and spacecraft; communications and semiconductors; computers; pharmaceuticals; and testing, measuring, and control instruments. MHT manufacturing industries include motor vehicles and parts, electrical machinery, machinery and equipment, chemicals excluding pharmaceuticals, and railroad and other transportation equipment.

Source(s)

IHS Global Insight, World Industry Service database (2016). See Appendix Table 6-3 through Appendix Table 6-8.

Science and Engineering Indicators 2018

SIDEBAR

New Definition of KTI Industries

Previous editions of this chapter defined knowledge- and technology-intensive (KTI) industries based on two categories of industries formerly classified by the Organisation for Economic Co-operation and Development (OECD). Five high-technology manufacturing industries—aircraft and spacecraft; pharmaceuticals; computers and office machinery; semiconductors and communications equipment; and measuring, medical, navigation, optical, and testing instruments—spend a high proportion of their revenues on research and development (Table 6-1).* Five knowledge-intensive services industries—business, education, financial, health care, and information—incorporate high technology either in these services or in the delivery of these services (Table 6-1).† While output data are based on industry categories, trade data are based on products and not industry categories. The National Center for Science and Engineering Statistics classifies trade of KTI products and services by selecting products and services that closely correspond to KTI industries.

Trade of KTI products and services was previously defined as three categories of knowledge-intensive services—telecommunications, computer, and information; finance; and other business—and six categories of high-technology goods—aerospace; communications; computers; pharmaceuticals; semiconductors; and testing, measuring, and control instruments.‡

For this 2018 edition of *Science and Engineering Indicators*, we have expanded our definition of KTI industries to include five medium-high-technology industries in addition to the existing two categories of KTI services and high-technology manufacturing industries (Table 6-1). The five medium-high-technology industries are motor vehicles and parts, chemicals excluding pharmaceuticals, electrical machinery and appliances, machinery and equipment, and railroad and other transportation equipment. These industries as formerly classified by the OECD spend a relatively large proportion of their revenues on R&D and make products to incorporate advanced technologies.* Although they spend a lower proportion of their revenue on R&D compared to high-technology manufacturing industries, medium-high-technology manufacturing industries produce many products that incorporate advanced and science-based technologies. For example, cars and trucks contain sophisticated sensors and software using sensing, measurement, and information and communications technologies to prevent accidents, optimize engine performance, and maximize fuel economy.

Consequently, the definition of KTI products and services has been expanded to make trade data consistent with the new definition of KTI industries. Chemicals excluding pharmaceuticals, motor vehicles and parts, machinery and equipment, electrical machinery and appliances, and railroad and other transportation equipment have been added to the existing three categories of knowledge-intensive services and six categories of medium-high-technology goods.

* In designating these high-technology and medium-high technology manufacturing industries, the OECD estimated the degree to which different industries used R&D expenditures made directly by firms in these industries and R&D embedded in purchased inputs (indirect R&D) for 13 countries: the United States, Japan, Germany, France, the United Kingdom, Canada, Italy, Spain, Sweden, Denmark, Finland, Norway, and Ireland. Direct R&D intensities were calculated as the ratio of total R&D expenditure to output (production) in 22 industrial sectors. Each sector was weighted according to its share of the total output among the 13 countries, using purchasing power parities as exchange rates. Indirect intensities were calculated using the technical coefficients of industries on the basis of input-output matrices. The OECD then assumed that, for a given type of input and for all groups of products, the proportions of R&D expenditure

embodied in value added remained constant. The input-output coefficients were then multiplied by the direct R&D intensities. For further details concerning the methodology used, see OECD (2001) and Godin (2004).

† See OECD (2001) for a discussion of classifying economic activities according to their degree of "knowledge intensity." Like all classification schemes, the OECD classification has shortcomings. For example, KTI industries produce some goods or services that are neither knowledge intensive nor technologically advanced. In addition, multiproduct companies that produce a mix of goods and services, only some of which are KTI, are assigned to their largest business segment. Nevertheless, data based on the OECD classification allow researchers and analysts to trace, in broad outline, worldwide trends toward greater interdependence in science and technology and the development of KTI sectors in many of the world's economies.

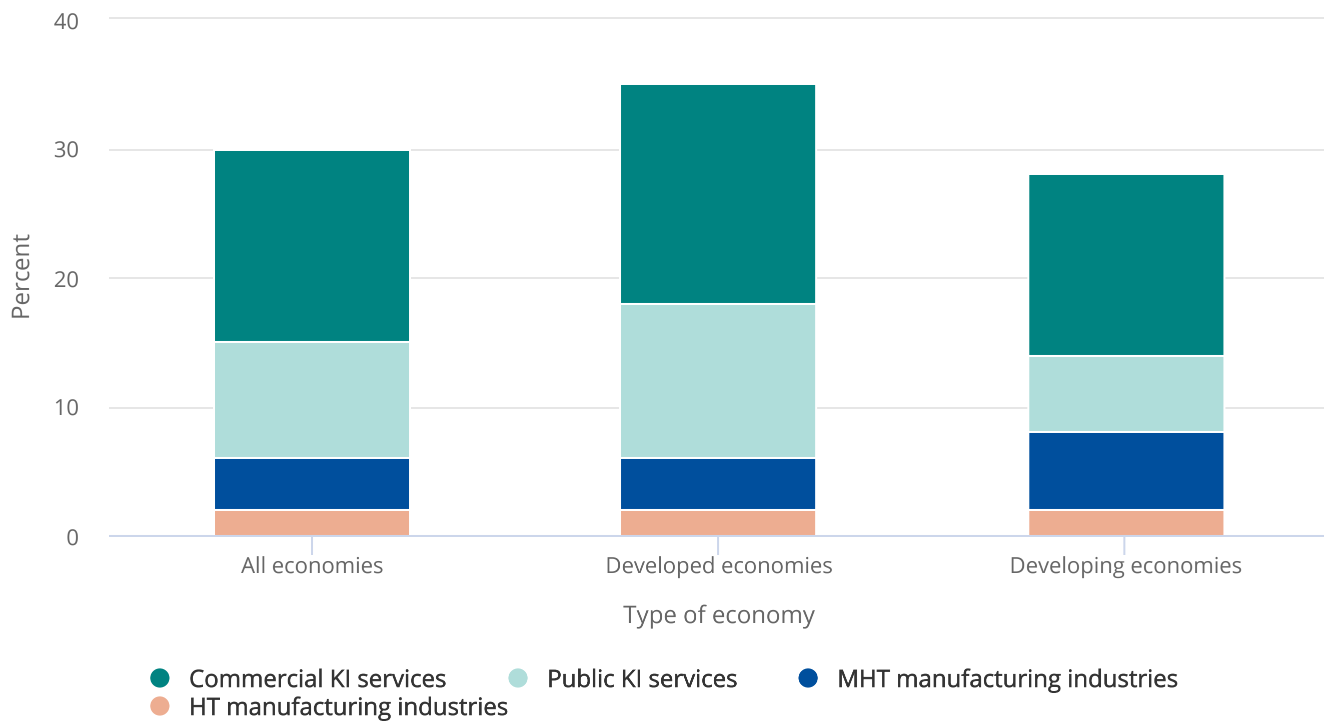
‡ Other business services include trade-related services, operational leasing (rentals), and miscellaneous business, professional, and technical services. These include legal, accounting, management consulting, public relations services, advertising, market research and public opinion polling, research and development services, architectural, engineering, and other technical services, agricultural, mining, and on-site processing (WTO 2016:83).

The KTI share of developed economies is higher than that of developing economies, largely because of their much higher share of knowledge-intensive services (Figure 6-2 and Figure 6-3; Appendix Table 6-2 through Appendix Table 6-6). But KTI shares vary widely, even among developed economies:

- The United States has the highest KTI share of any major developed economy (38%) largely because its share of commercial knowledge-intensive services is higher than the average for developed economies.
- The UK and Japan have the second highest share (36%). The United Kingdom (UK), like the United States, has a higher-than-average share of commercial KI services. In contrast, Japan has a much higher share in medium high-technology manufacturing industries compared to the United States and the UK. Germany also has a relatively high KTI share (35%) with a similar profile to Japan.

FIGURE 6-2

Selected industry category share of GDP of developed and developing economies: 2016



GDP = gross domestic product; HT = high technology; KI = knowledge intensive; MHT = medium-high technology.

Note(s)

Output of knowledge- and technology-intensive (KTI) industries is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. KTI industries include KI services, HT manufacturing industries, and MHT manufacturing industries based on a former classification by the Organisation for Economic Co-operation and Development. KI services include business, financial, information, education, and health care. Commercial KI services include business, financial, and information. Public KI services include education and health care. HT manufacturing industries include aircraft and spacecraft; communications and semiconductors; computers; pharmaceuticals; and testing, measuring, and control instruments. MHT manufacturing industries include motor vehicles and parts, electrical machinery, machinery and equipment, chemicals excluding pharmaceuticals, and railroad and other transportation equipment. Developed economies are those classified as advanced by the International Monetary Fund (IMF). Developing economies are those classified as emerging by IMF.

Source(s)

IHS Global Insight, World Industry Service database (2017). See Appendix Table 6-3 through Appendix Table 6-8.

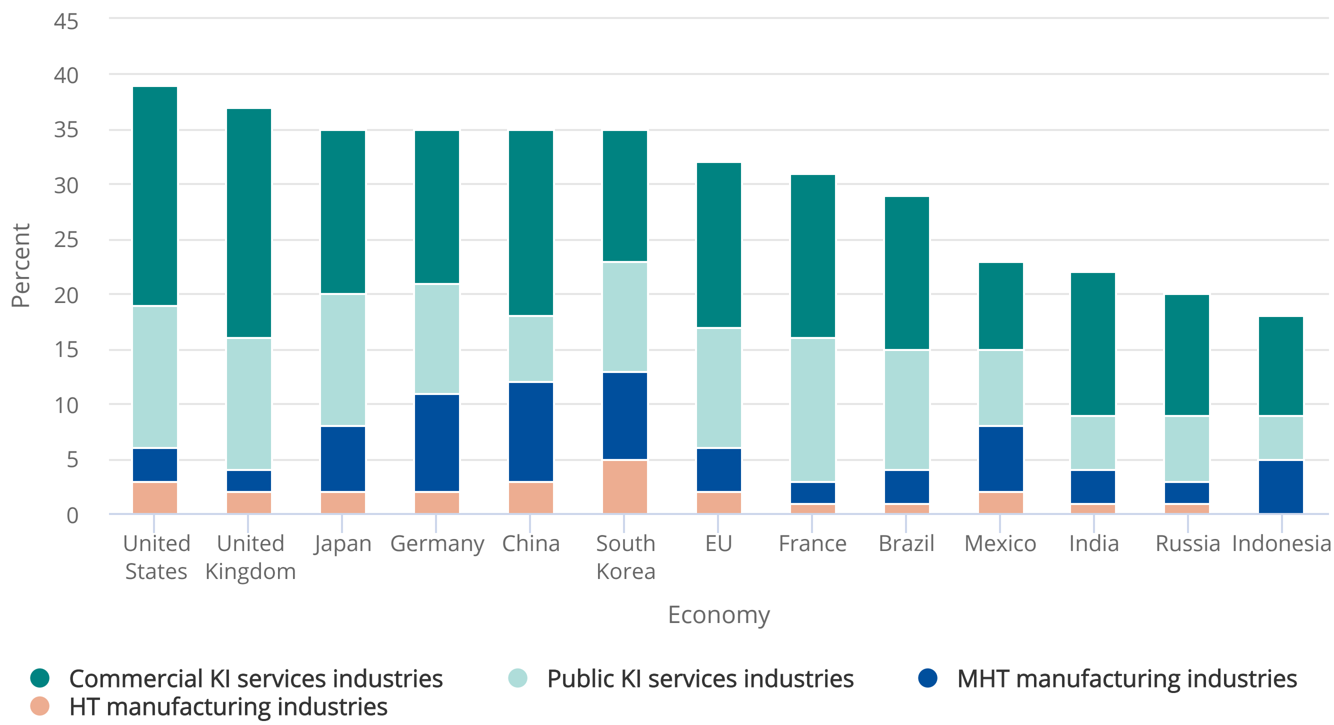
Science and Engineering Indicators 2018

The KTI shares of large developing countries vary widely, in part reflecting differences in their stage of development, level of per capita income, and the size of their high-technology and medium-high-technology industries (Figure 6-3; Appendix Table 6-2 and Appendix Table 6-3).

- China has the largest share of any large developing economy (35%) due to its relatively large shares in medium-high-technology manufacturing industries and commercial KI services industries.
- Mexico, India, Russia, and Indonesia have KTI shares (19%–22%) that are considerably lower than the average for developing economies.

FIGURE 6-3

Output of KTI industries as a share of the GDP of selected countries or economies: 2016



EU = European Union; GDP = gross domestic product; HT = high technology; KI = knowledge intensive; KTI = knowledge and technology intensive; MHT = medium-high technology.

Note(s)

Data are not available for EU members Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Economies classified by the International Monetary Fund as *advanced* are developed countries, whereas those classified as *emerging* and *developing* are considered to be developing. Output of KTI industries is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. KTI industries include KI services, HT manufacturing industries, and MHT manufacturing industries based on a former classification by the Organisation for Economic Co-operation and Development. KI services include business, financial, information, education, and health care. Commercial KI services include business, financial, and information. Public KI services include education and health care. HT manufacturing industries include aircraft and spacecraft; communications and semiconductors; computers; pharmaceuticals; and testing, measuring, and control instruments. MHT manufacturing industries include motor vehicles and parts, electrical machinery, machinery and equipment, chemicals excluding pharmaceuticals, and railroad and other transportation equipment.

Source(s)

IHS Global Insight, World Industry Service database (2017). See Appendix Table 6-3 through Appendix Table 6-8.

Science and Engineering Indicators 2018

ICT Investment in Knowledge- and Technology-Intensive and Other Industries

Investment in ICT plays an important role in the competitiveness and innovation capability of KTI and other industries. In addition, the ICT industries (a subset of KTI industries), consisting of communications, semiconductors, and computers and information services, produce ICT products and services that are used by the entire economy. Many economists regard ICT as a general-purpose platform technology that fundamentally changes how and where economic activity is carried out in today's knowledge-based countries, much as earlier general-purpose technologies (e.g., the steam engine, automatic machinery) propelled growth during the Industrial Revolution.[2] Many KTI and other industries invest heavily in ICT to be successful and compete in global markets. Investment in ICT, particularly by businesses, is also important because it has a substantial impact on a country's living standards, employment, and productivity. The Internet of Things—ICT technologies that sense, measure, and connect devices through the Internet—is rapidly growing and holds the potential to raise consumer and business productivity and raise living standards (see sidebar The Internet of Things).[3]

SIDEBAR

The Internet of Things

The Internet of Things (IoT) has received growing attention by researchers, government, and businesses over the last several years. There are numerous and varying definitions of the IoT. For example, the United Nations defines it "as a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies" (UN Broadband Commission for Sustainable Development 2016:12). The McKinsey Global Institute defines the IoT as "sensors or actuators embedded in physical objects that are linked through wired and wireless networks" (Manyika et al. 2015:17).

Numerous researchers and organizations believe that the IoT is rapidly growing and is already used in a wide variety of products and applications. For example, the Apple Watch monitors a user's activity, sleep time, and heart rate. The data generated from the Apple Watch is transmitted through the user's iPhone and fed to computers that analyze the data to provide feedback on health and fitness. In agriculture, precision farming equipment with wireless links to data collected from remote satellites and ground sensors measure crop conditions and adjust the way each individual part of a field is farmed.

The IoT is projected to have wide-ranging global economic and social impacts, including raising productivity, saving energy, improving health, automating chores and factory production, and optimizing mass-transportation and driverless cars. Manyika et al. (2015) projects that the economic impact of the IoT in 2025 will be equivalent to 4%–11% of global gross domestic product (GDP) Manyika et al. (2015:2). Furthermore, Manyika et al. (2015) projects that the industrial sector will be one of the largest sources of value from adoption of the IoT (1%–4% of GDP) due to improvements including automation of complex production processes, optimizing inventory, energy savings, and improving worker health and safety (Manyika et al. 2015:7).

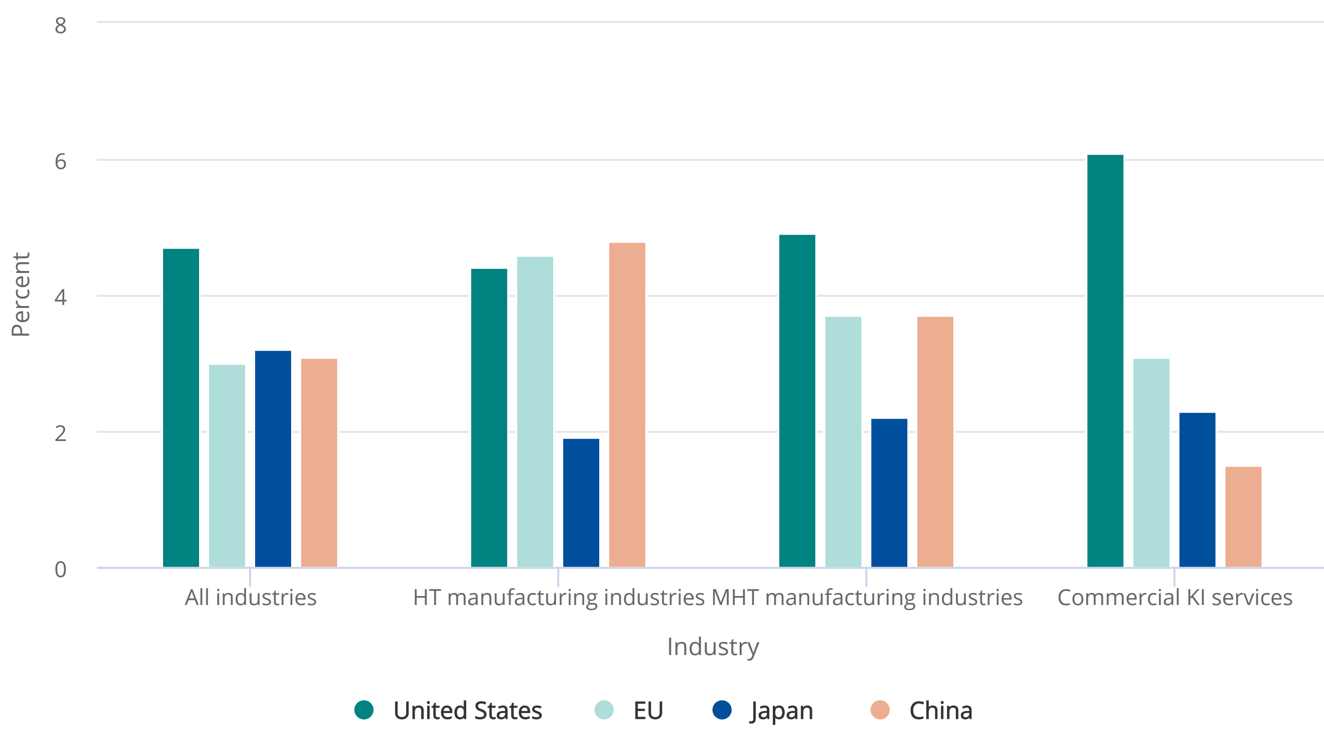
IHS Global Insight, a private economic research and consulting service, forecasts that global shipments of IoT devices will more than triple between 2017 and 2025 to reach 19.4 billion devices. The use of the number of shipments of IoT devices as an indicator has several limitations including the lack of an estimated market value for IoT devices, which vary widely in size and technological sophistication. For example, the value of an Apple Watch would be different from an IoT device used in a factory. In addition, IHS does not forecast objects that are currently unconnected, such as desk chairs and pet collars, which could be a very large part of the market.

According to IHS, the fastest growing sector will be industrial, jumping from 1.3 billion devices to 10.8 billion devices, pushing its share of all IoT devices from 21% to 56%. The rapid deployment of the IoT in this sector is broadly consistent with McKinsey Global's projection of a large economic impact on this sector. Although the number of devices will more than double from 2.1 billion to 4.9 billion, the consumer sector share will drop from 35% to 24%. Despite modest growth in communications devices, its share will drop sharply from 36% to 14%.

The United States has the highest rate of ICT investment in all of its industries (measured as an industry's ICT spending share of value-added output) compared to the other three largest economies—EU, Japan, and China (Figure 6-4). Among the KTI industries, the United States has a considerably higher rate of ICT investment in medium-high-technology manufacturing industries and commercial knowledge-intensive services. The high rate of ICT investment by U.S. commercial knowledge-intensive services coincides with the global dominance of this U.S. industry, particularly business services, a category that contains many advanced industries, such as R&D, architectural, and engineering services (Table 6-1). The rate of ICT investment for the other three economies is far below that of the United States in this industry. In high-technology manufacturing industries, China, the EU, and the United States have the same rate of ICT investment. Japan's share is considerably lower.

FIGURE 6-4

ICT business spending as a share of selected industry categories for selected countries or economies: 2016



EU = European Union; HT = high technology; ICT = information and communications technology; KI = knowledge intensive; MHT = medium-high technology.

Note(s)

Data are not available for EU members Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Output of industries is on value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. KTI industries include KI services, HT manufacturing industries, and MHT manufacturing industries based on a former classification by the Organisation for Economic Co-operation and Development. KI services include business, financial, information, education, and health care. Commercial KI services include business, financial, and information. Public KI services include education and health care. HT manufacturing industries include aircraft and spacecraft; communications and semiconductors; computers; pharmaceuticals; and testing, measuring, and control instruments. MHT manufacturing industries include motor vehicles and parts, electrical machinery, machinery and equipment, chemicals excluding pharmaceuticals, and railroad and other transportation equipment.

Source(s)

National Science Foundation, National Center for Science and Engineering Statistics, IHS Global Insight ICT Global Navigator, accessed 14 August 2017.

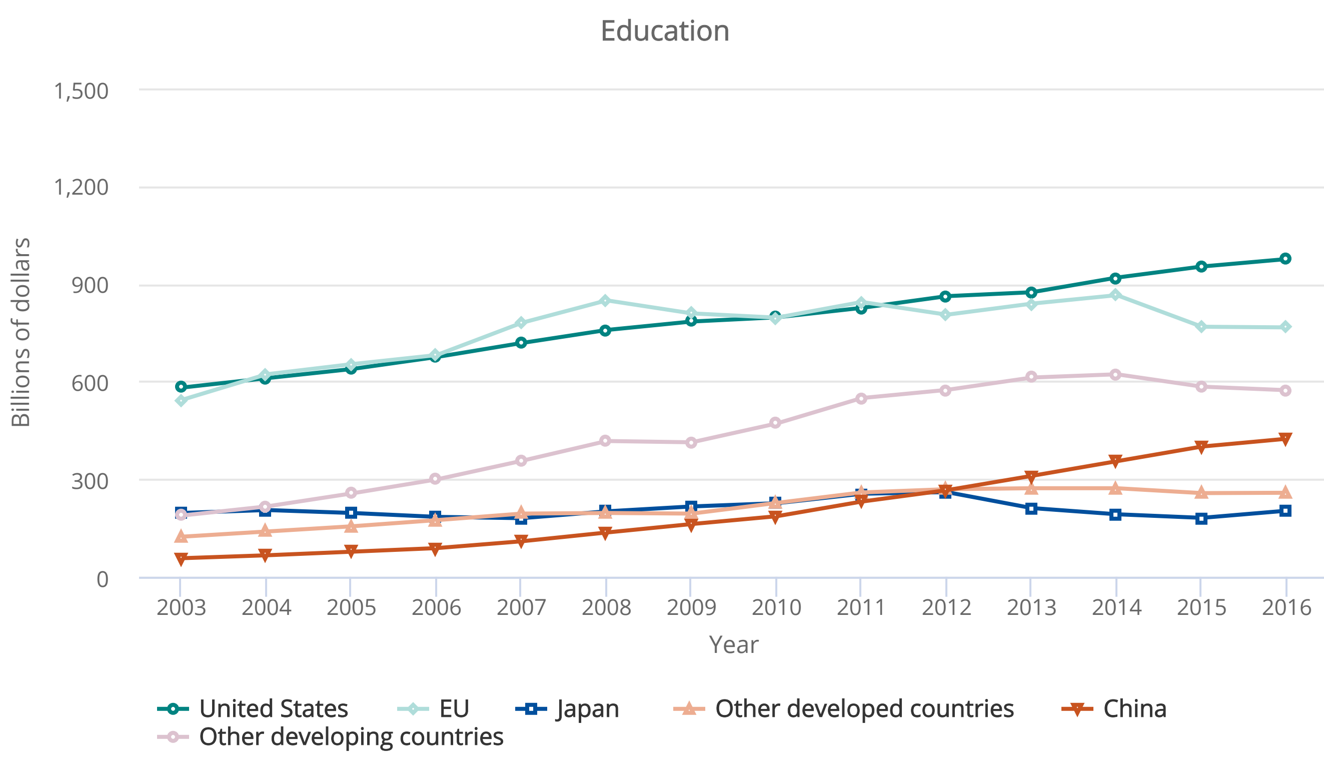
Science and Engineering Indicators 2018

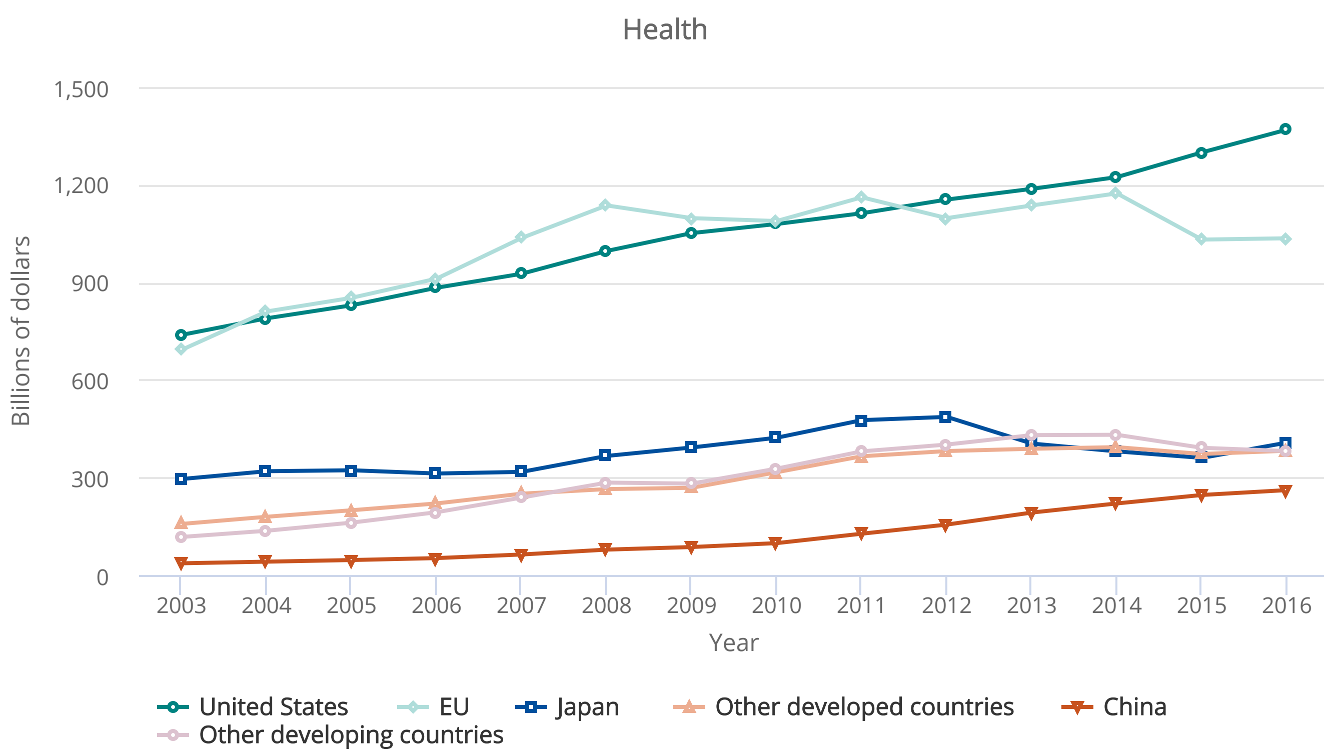
Global Trends in Public Knowledge-Intensive Services Industries

Public knowledge-intensive services—health care and education—account for $7 trillion in global value added (Figure 6-1 and Figure 6-5; Appendix Table 6-5 and Appendix Table 6-6). These sectors are major sources of knowledge and innovation of great benefit to national economies. Although they are far less market driven than other KTI industries in the global marketplace, competition in education and health appears to be increasing.[4] Education trains students for future work in science, technology, and other fields, and research universities are an important source of knowledge and innovation for other economic sectors. Many renowned universities are seeking to establish themselves as global brands. The health sector helps keep the population healthy and productive, trains and employs highly skilled workers, conducts research, and generates innovation. Leading medical centers in many countries are collaborating across borders, and "medical tourism," while modest, is growing.

FIGURE 6-5

Output of education and health care for selected regions, countries, or economies: 2003–16





EU = European Union.

Note(s)

Output of education and health is on a value-added basis. Healthcare includes social assistance. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. Data are not available for EU members Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Developed countries are those classified as advanced by the International Monetary Fund (IMF). Developing countries are those classified as emerging by IMF.

Source(s)

IHS Global Insight, World Industry Service database (2016). See Appendix Table 6-5 and Appendix Table 6-6.

Science and Engineering Indicators 2018

International comparison of both health care and education sectors is complicated by variations in the size and distribution of each country's population, market structure, and the degree of government involvement and regulation. Thus, differences in market-generated value added may not accurately reflect differences in the relative value of these services.

The United States and the EU are the world's largest providers of public and private education services, with global shares of 31% and 24%, respectively (Figure 6-5; Appendix Table 6-5). China is the third largest provider (13%), followed by Japan (6%). The United States and the EU are also the largest providers in health care (Appendix Table 6-6). Japan is the third largest provider followed by China.

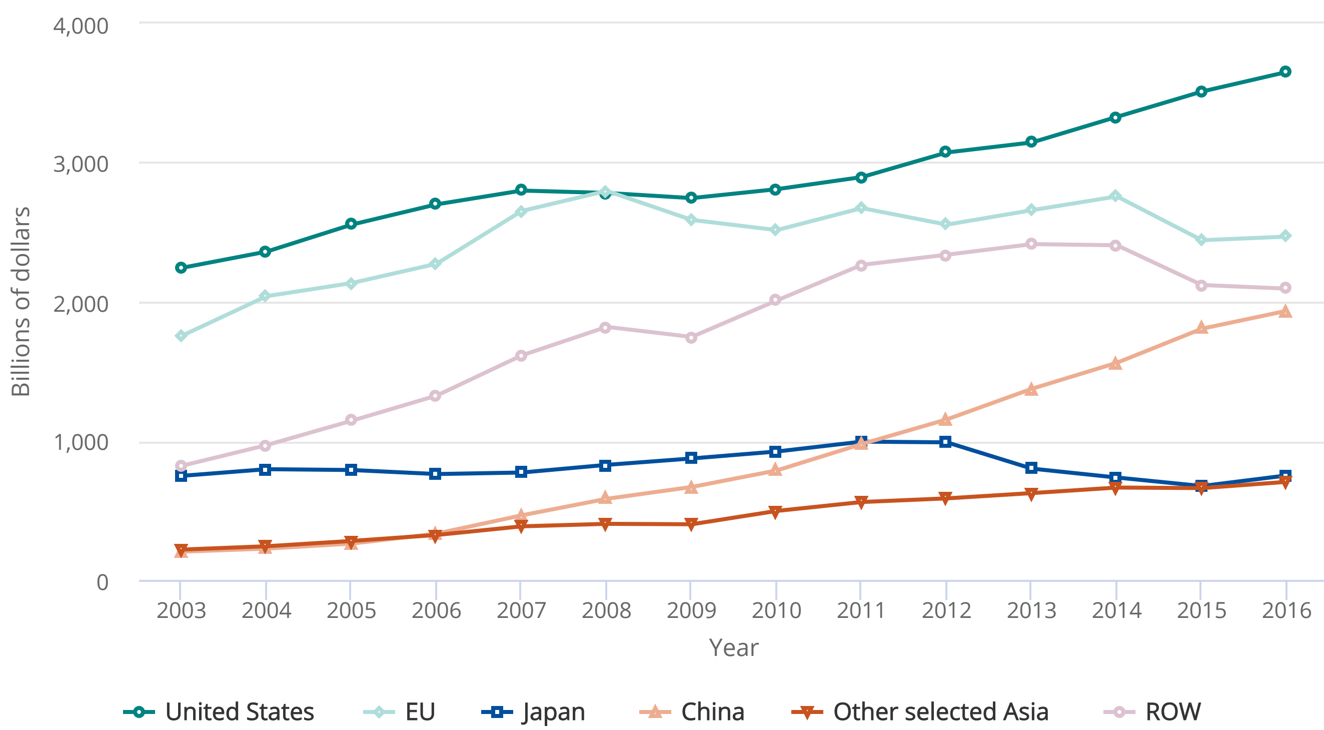
The U.S. global shares of education and health care remained roughly flat over the last decade despite rising in absolute value (Figure 6-5; Appendix Table 6-5 and Appendix Table 6-6). The shares of education and health care for the EU and Japan declined. China's global share of education and health care more than doubled during this period, in line with its rapid economic growth, emphasis on education, and focused efforts to improve the health care system. India and Indonesia also showed expansion. The growth of education in China and India coincided with increases in higher-education degree awards in both countries and, particularly, in doctorates in the natural science and engineering fields (see Chapter 2).

Global Trends in Commercial Knowledge-Intensive Services Industries

The global value added of commercial knowledge-intensive services—business, financial, and information—was $11.6 trillion in 2016 (Figure 6-1 and Figure 6-6; Appendix Table 6-4). Financial services is the largest industry within commercial KI services ($4.6 trillion) (Appendix Table 6-9). The large size of financial services reflects the wide and diverse activities of these industries, including banking, insurance, pension funding, leasing, commodities, securities, and stock markets. Business services, which include the technologically advanced industries of engineering, consulting, and R&D services, is the second largest industry ($4.0 trillion) (Appendix Table 6-10). Many businesses and other organizations purchase various services rather than provide them in-house, particularly in developing countries (Table 6-1). The third largest industry is information services that includes the technologically advanced industries of computer programming and information technology (IT) services ($3.1 trillion) (Appendix Table 6-11 and Appendix Table 6-12).

FIGURE 6-6

Output of commercial KI services for selected regions, countries, or economies: 2003–16



EU = European Union; KI = knowledge intensive; ROW = rest of world.

Note(s)

Output of commercial KI services is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. Commercial KI services are based on a former classification by the Organisation for Economic Co-operation and Development and include business, financial, and information services. Data are not available for EU members Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Other selected Asia includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Vietnam.

Source(s)

IHS Global Insight, World Industry Service database (2017). See Appendix Table 6-4.

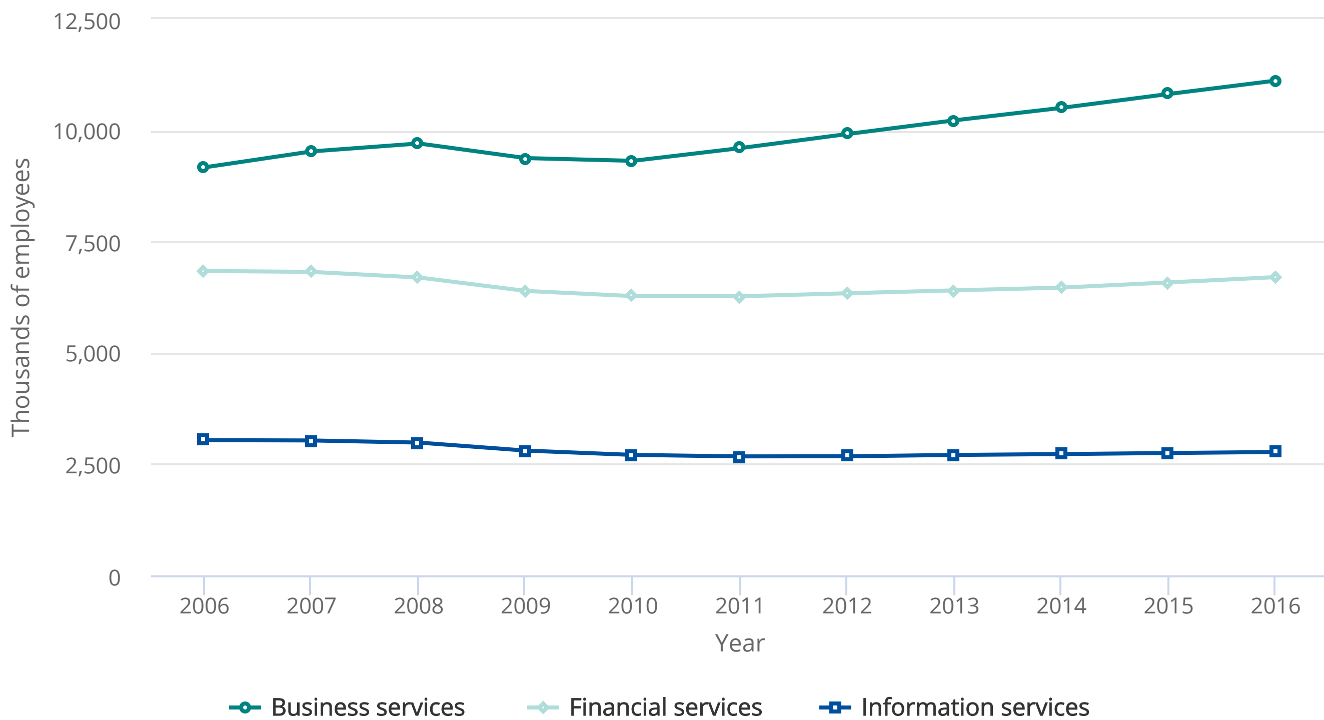
Science and Engineering Indicators 2018

The United States accounted for 31% of global commercial knowledge-intensive services in 2016 (Figure 6-6; Appendix Table 6-4). U.S. commercial knowledge-intensive services industries employ 20.6 million workers, 17% of U.S. private sector employment (Figure 6-7). These industries perform 29% of U.S. industrial R&D, higher than their share of U.S. industrial output (Figure 6-8).

The EU is the second largest global provider (21% share) of commercial knowledge-intensive services (Figure 6-6; Appendix Table 6-4). China is third (17%), and Japan is fourth (6%).

FIGURE 6-7

U.S. employment in commercial KI services: 2006–16



KI = knowledge intensive.

Note(s)

KI services are classified by the Organisation for Economic Co-operation and Development. Commercial KI services include business, financial, and information services. Financial services include finance and insurance and rental and leasing. Business services include professional and technical services and management of companies and enterprises.

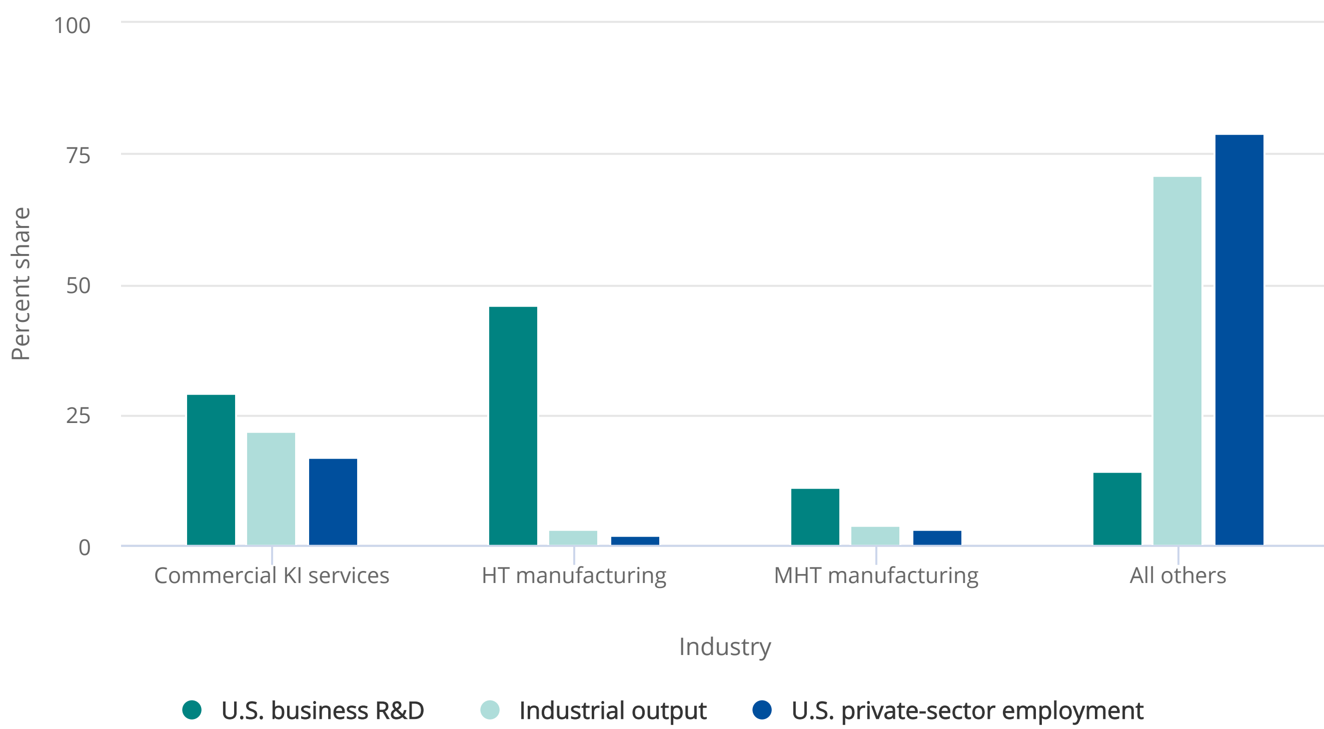
Source(s)

Bureau of Labor Statistics, Current Employment Statistics (2016), https://www.bls.gov/ces/, accessed 9 August 2017.

Science and Engineering Indicators 2018

FIGURE 6-8

U.S. KTI industry share of U.S. business R&D spending, industry output, and industry employment: 2014



HT = high technology; KI = knowledge intensive; KTI = knowledge and technology intensive; MHT = medium-high technology.

Note(s)

Business R&D consists of domestic funding by companies' own internal funds and funds from other sources. HT and MHT manufacturing industries and KI services are formerly classified by the Organisation for Economic Co-operation and Development. HT manufacturing industries include aircraft and spacecraft; communications and semiconductors; computers; pharmaceuticals; and testing, measuring, and control instruments. MHT manufacturing industries include motor vehicles and parts, electrical machinery, machinery and equipment, chemicals excluding pharmaceuticals, and railroad and other transportation equipment. KI services include health, education, business, information, and financial services. Commercial KI services include business, information, and financial services. Business R&D of commercial KI services consists of professional and technical services and information. Coverage of some industries may vary among data sources because of differences in classification of industries.

Source(s)

National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey (BRDIS) (2014) https://www.nsf.gov/statistics/srvyindustry/.

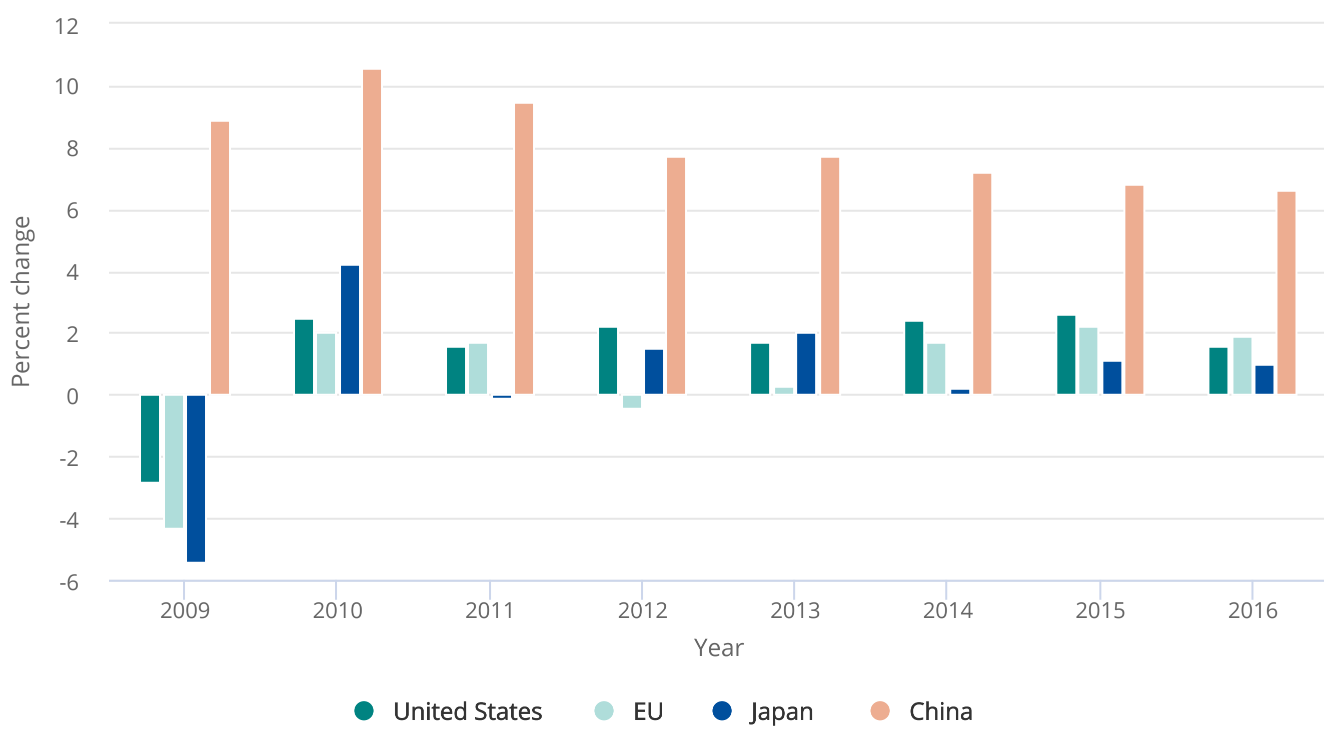
Science and Engineering Indicators 2018

Commercial Knowledge-Intensive Services in the United States

During the post-global recession period of 2011 through 2016, the steady growth of U.S. commercial knowledge-intensive services between 2011 and 2016 contrasts with declines in the EU and Japan, which have had comparatively weaker economic recoveries (Figure 6-6 and Figure 6-9). U.S. value-added output of commercial knowledge-intensive services grew 26% higher during this period, driven by business and financial services (Appendix Table 6-9 and Appendix Table 6-10). However, China grew far faster than the United States with its output nearly doubling.

FIGURE 6-9

Growth in real GDP, by selected region, country, or economy: 2009–16



EU = European Union; GDP = gross domestic product.

Note(s)

GDP is in billions of dollars on 2010 purchasing power parity basis. China includes Hong Kong. The EU consists of 28 current member countries.

Source(s)

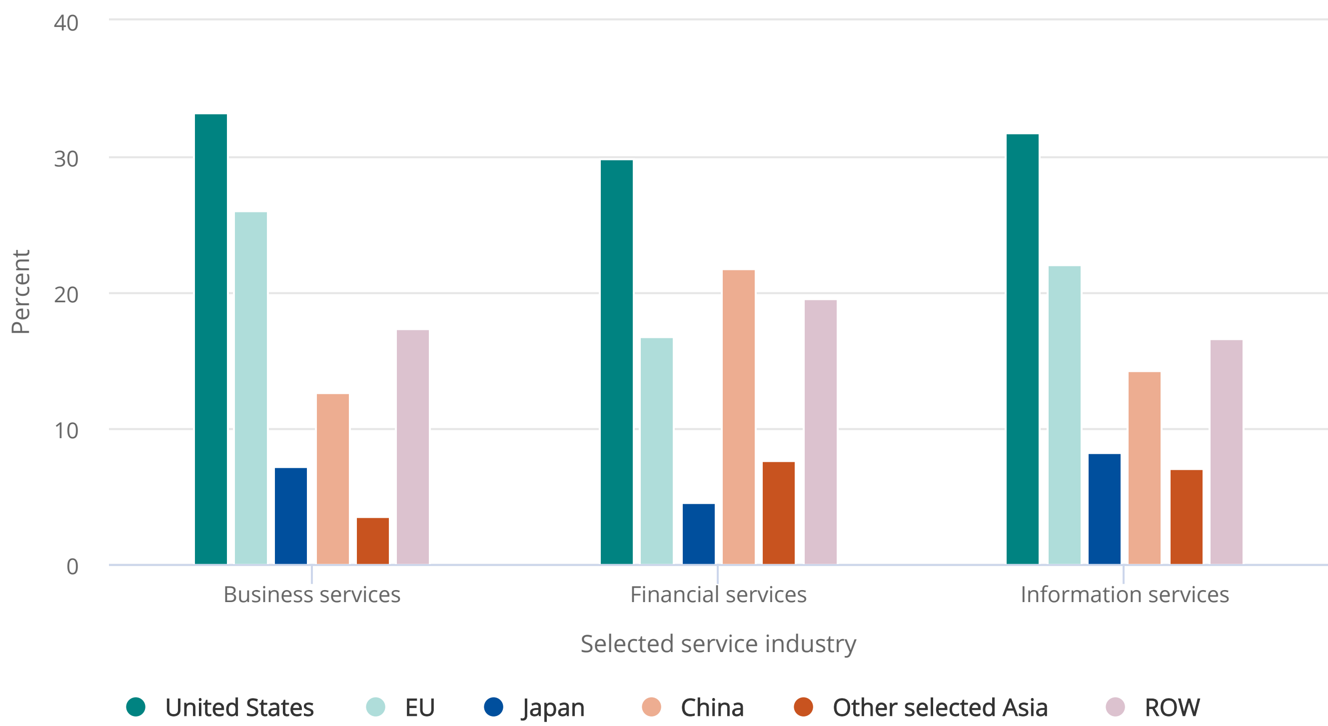
IHS Global Insight, Global Monthly Forecast Update, accessed 17 January 2017.

Science and Engineering Indicators 2018

Since 2006, the U.S. global share of commercial knowledge-intensive services has slightly declined from 35% to 31% (Figure 6-6; Appendix Table 6-4). These changes have been largely due to much faster growth in China. However, the United States continues to be the dominant global provider of commercial knowledge-intensive services. The United States has a strong position in business services (33% global share), a category that includes advanced-technology industries such as engineering, architectural, and R&D services (Figure 6-10; Table 6-1). Business services led the growth of U.S. commercial knowledge-intensive industries over the last decade (Appendix Table 6-10). One source of growth of this U.S. industry has been the infrastructure boom in developing countries, which has employed U.S. firms in areas including architecture, engineering, and consulting.[5]

FIGURE 6-10

Global value-added shares of selected service industries for selected regions, countries, or economies: 2016



EU = European Union; ROW = rest of world.

Note(s)

Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. Business services include computer programming, R&D, and other business services. Financial services include leasing. Data are not available for EU members Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Other selected Asia includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Vietnam.

Source(s)

IHS Global Insight, World Industry Service database (2017). See Appendix Table 6-7 through Appendix Table 6-13.

Science and Engineering Indicators 2018

Employment in U.S. commercial knowledge-intensive services has grown more slowly than value added output in the post-global recession period reaching 20.6 million in 2016, a gain of 2.0 million jobs over 2011 (Figure 6-7).[6] Business and financial services added about 1.5 million and 400,000 jobs, respectively. Employment in information services was stagnant.

The high growth in output of U.S. commercial knowledge-intensive services relative to weak job growth is consistent with historical trends and is largely explained by faster labor productivity growth in these industries relative to non-KTI industries (NSF/NCSES 2014:7).

Commercial Knowledge-Intensive Services in the EU

Output of commercial knowledge-intensive services in the EU fell 8% between 2011 and 2016 (Figure 6-6; Appendix Table 6-4). The slow pace of growth of commercial knowledge-intensive services coincides with the EU's weak and halting economic recovery (Figure 6-9). Over the last decade, the EU's global share has declined from 29% to 21% due to faster growth in the United States and China and other developing countries (Figure 6-6; Appendix Table 6-4). The EU's global share in business services slid from 34% to 26% during this period (Appendix Table 6-10). However, the EU continues to be the second largest global provider in this industry.

The substantial depreciation of the euro relative to the dollar in 2011–16 likely overstated the weakness of the EU's commercial knowledge-intensive services and other KTI industries (see sidebar Currency Exchange Rates of Major Economies).

Commercial Knowledge-Intensive Services in China

China's commercial KI services grew rapidly during the post-global recession period, with output nearly doubling between 2011 and 2016 (Figure 6-6; Appendix Table 6-4). However, toward the end of this period, growth of commercial KI services slowed in 2016, coinciding with the moderation in China's economic growth (Figure 6-9).

Over the last decade, commercial KI services in China has grown at an average annual rate of nearly 20%, resulting in its global share more than quadrupling to reach 17% (Appendix Table 6-4). China surpassed Japan in 2012 to become the world's third largest provider, with its global share in 2016 more than double the size of Japan's. Business services and financial services led the growth of China's commercial KI services (Appendix Table 6-9 and Appendix Table 6-10). China's industry that provides outsourced business services to firms based in other countries has grown rapidly over the last decade.[7]

Commercial Knowledge-Intensive Services in Japan

Output of Japan's commercial knowledge-intensive services shrank 24% in the post-global recession period (Figure 6-6; Appendix Table 6-4), and this trend has coincided with Japan's halting recovery from the global recession (Figure 6-9). In addition, Japan's global position in commercial knowledge-intensive services has weakened over the last decade coinciding with the lengthy stagnation of the Japanese economy (Figure 6-6; Appendix Table 6-3 and Appendix Table 6-4).

The substantial depreciation of the yen relative to the dollar in 2011–16 likely overstated the weakness of Japan's commercial knowledge-intensive services industries and other KTI industries (see sidebar Currency Exchange Rates of Major Economies).

Commercial Knowledge-Intensive Services in Other Countries

Trends were mixed in other large developing economies. India and Indonesia had sizeable gains in commercial knowledge-intensive services over the last decade, with their global shares reaching 3% and 1%, respectively (Appendix Table 6-3 and Appendix Table 6-4). In Brazil and Russia, output of commercial knowledge-intensive services industries was down sharply over the last decade due to their economies entering recession in 2014–16. India had strong gains in business and information services, reflecting, in part, the success of Indian firms providing IT, accounting, legal, and other services to developed countries (Appendix Table 6-10 and Appendix Table 6-11). Indonesia had strong gains in financial services and business services (Appendix Table 6-9 and Appendix Table 6-10).

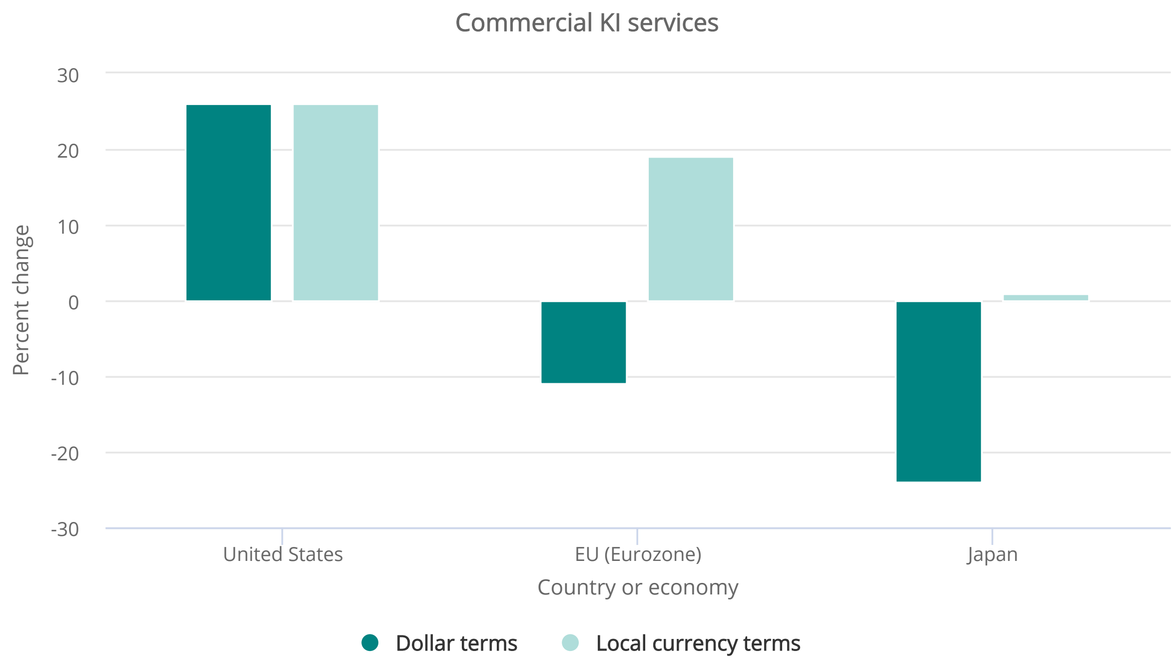
SIDEBAR

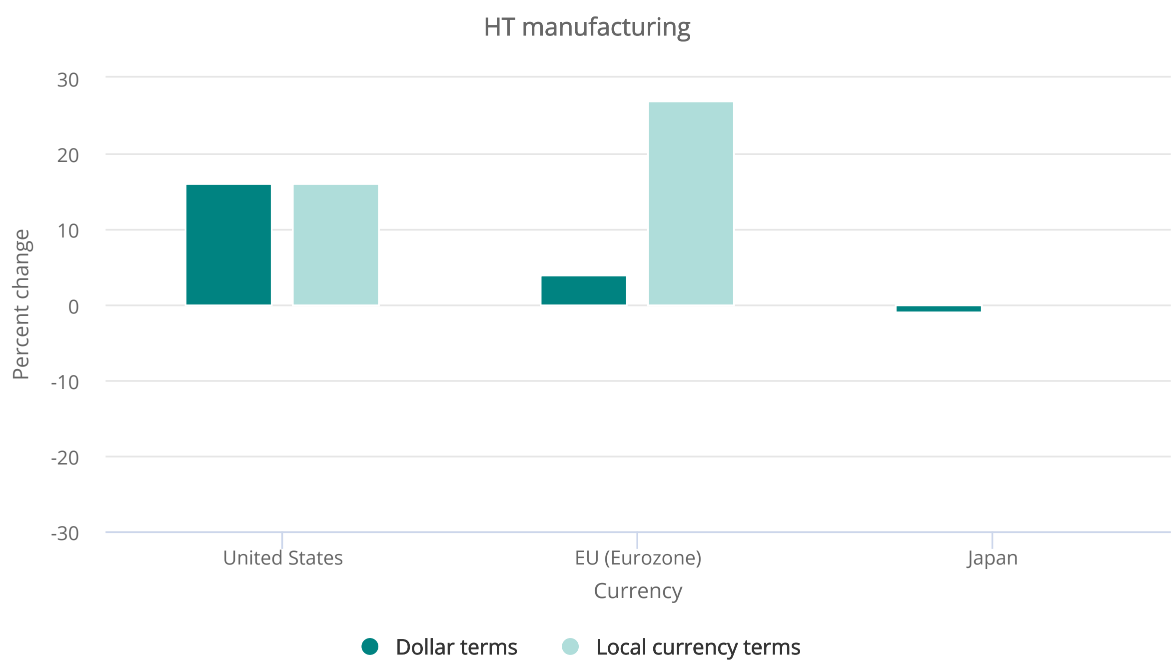
Currency Exchange Rates of Major Economies

The substantial depreciation of the euro and yen against the dollar from 2011 to 2016 reduced the value of the eurozone's and Japan's economic activities in dollar terms relative to their value in local currency terms. Economic activities such as GDP and industry output, denominated in local currencies, had a higher growth rate than these activities denominated in dollars (Figure 6-A).

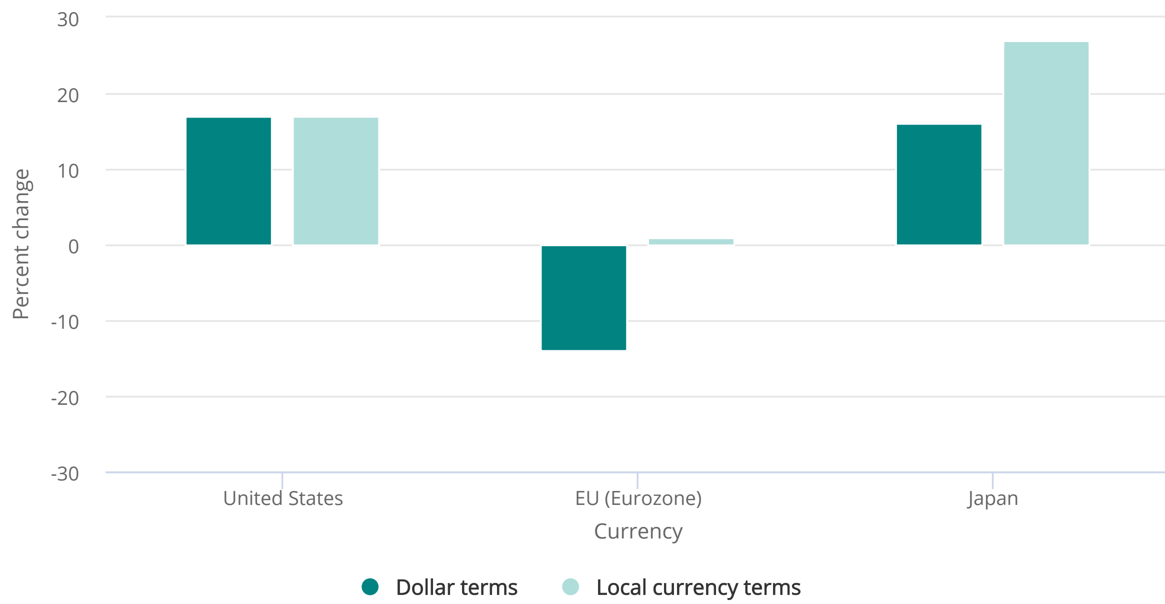
FIGURE 6-A

Growth in output of selected categories of industries, by selected country or economy: 2011–16





MHT manufacturing



EU = European Union; HT = high technology; KI = knowledge intensive; MHT = medium-high technology.

Note(s)

Output of HT manufacturing industries is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. HT manufacturing industries include aerospace; communications; computers; pharmaceuticals; semiconductors; and testing, measuring, and control instruments and are based on a former classification by the Organisation for Economic Co-operation and Development. The EU (Eurozone) consists of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Slovakia, Spain, and Sweden.

Source(s)

Federal Reserve, Economic Research and Data, Foreign Exchange Rates, https://www.federalreserve.gov/releases/h10/current/, accessed 15 August 2017; IHS Global Insight, World Industry Service database (2016). See Appendix Table 6-8.

Science and Engineering Indicators 2018

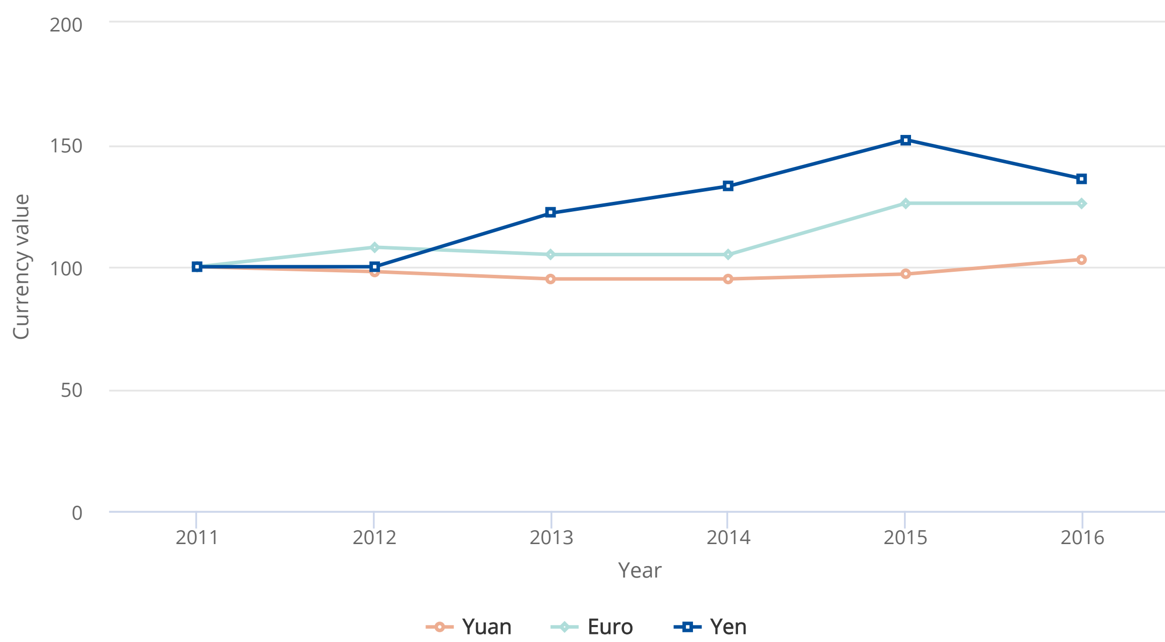
International comparisons of industry, trade, investment, and other global economic activities often use current dollars at market exchange rates. Most global economic activities are dollar denominated, which facilitates comparison. In addition, many economists believe that market exchange rates reflect, at least to some degree, differences in economic performance among various countries (Balke, Ma, and Wohar 2013:2).

However, fluctuations in exchange rates may also reflect factors other than economic performance. Governments influence the level of their exchange rate indirectly through macroeconomic policies and directly through buying and selling currencies. In addition, factors such as political instability or the short-term effects of global financial events on a country's economy can cause currency fluctuations that are unrelated to enduring differences in national economic performance. Comparing economic data from different countries in current dollar terms provides a broadly indicative reflection of a country's relative economic performance.

Between 2011 and 2016, the exchange rates of the world's four largest economies—China, the EU member countries that use the euro (the eurozone), Japan, and the United States—exhibited some fluctuations (Figure 6-B) with substantial depreciation of the euro (26%) and Japanese yen (36%) against the dollar. The yuan's exchange rate, which is controlled by China's government, showed little change against the dollar.

FIGURE 6-B

U.S. dollar exchange rate with selected currencies: 2011–16



Note(s)

Currency value is expressed as an index of 100 in 2011.

Source(s)

Federal Reserve, Economic and Research and Data, Foreign Exchange Rates, https://www.federalreserve.gov/releases/h10/current/, accessed 24 July 2017.

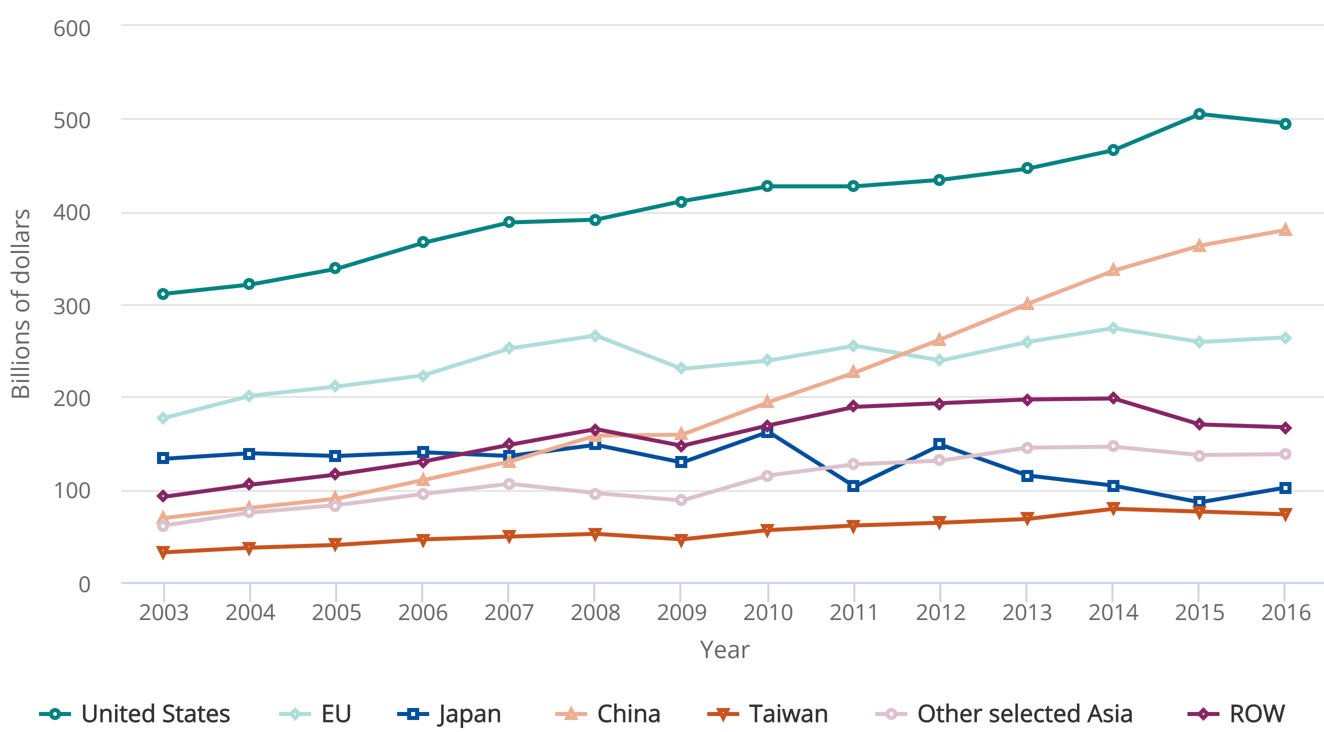
Science and Engineering Indicators 2018

Global Trends in High-Technology Manufacturing Industries

Global value added of high-technology manufacturing was $1.6 trillion in 2016, making up 14% of total manufacturing output (Figure 6-1 and Figure 6-11; Appendix Table 6-8 and Appendix Table 6-13). The three ICT manufacturing industries—semiconductors, computers, and communications—are highly globalized and involve complex value chains in the production process. These ICT industries made up a collective $0.6 trillion in global value added (Appendix Table 6-14, Appendix Table 6-15, and Appendix Table 6-16). Many ICT products such as consumer electronics have short development cycles that require production of large quantities in a short period. The rapid and massive scale-up of production requires a location that can quickly ramp up large-scale production with skilled labor, including engineers and production workers (Donofrio and Whitefoot 2015: 26).

FIGURE 6-11

Output of HT manufacturing industries for selected regions, countries, or economies: 2003–16



EU = European Union; HT = high technology; ROW = rest of world.

Note(s)

Output is measured on a value added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. HT manufacturing industries include aircraft and spacecraft; communications and semiconductors; computers; pharmaceuticals; and testing, measuring, and control instruments. Data are not available for EU members Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Other selected Asia includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Vietnam.

Source(s)

IHS Global Insight, World Industry Service database (2017). See Appendix Table 6-8.

Science and Engineering Indicators 2018

The three remaining high-technology industries are pharmaceuticals ($540 billion); testing, measuring, and control instruments ($280 billion); and aircraft and spacecraft ($190 billion) (Appendix Table 6-17, Appendix Table 6-18, and Appendix Table 6-19). In the aerospace industry, Airbus and Boeing have globalized their production networks in response to rapidly growing markets outside their domestic regions and pressure to reduce labor and other costs, and to comply with requirements by some countries to locally produce components and supplies (Treuner et al. 2014:7). The global networks benefit from more immediate access to raw materials and engineering capacities and low labor cost. The pharmaceuticals industry has two main global value chains. For emerging and complex biologic vaccines and stem cell therapies, pharmaceutical companies generally locate closely with academic and medical R&D laboratories because these innovative products require close integration of R&D, testing, and manufacturing. For existing and mature technologies, such as small molecules and generics, companies do not need to locate near research laboratories because close integration of R&D and manufacturing is not necessary (Donofrio and Whitefoot 2015:25–26).

The United States is the largest global producer (31% global share) of high-technology manufacturing industries (Figure 6-11 and Appendix Table 6-8). U.S. high-technology manufacturing industries account for a small share of the U.S. industrial output and industry employment (Figure 6-8). However, they fund a disproportionately large share of U.S. business R&D. China is the second largest global producer, with a global share of 24%. The EU is the third largest producer (16%). Japan and Taiwan are roughly tied as the fourth largest producers (6% and 5%, respectively) (Figure 6-11; Appendix Table 6-8).

High-Technology Manufacturing Industries in the United States

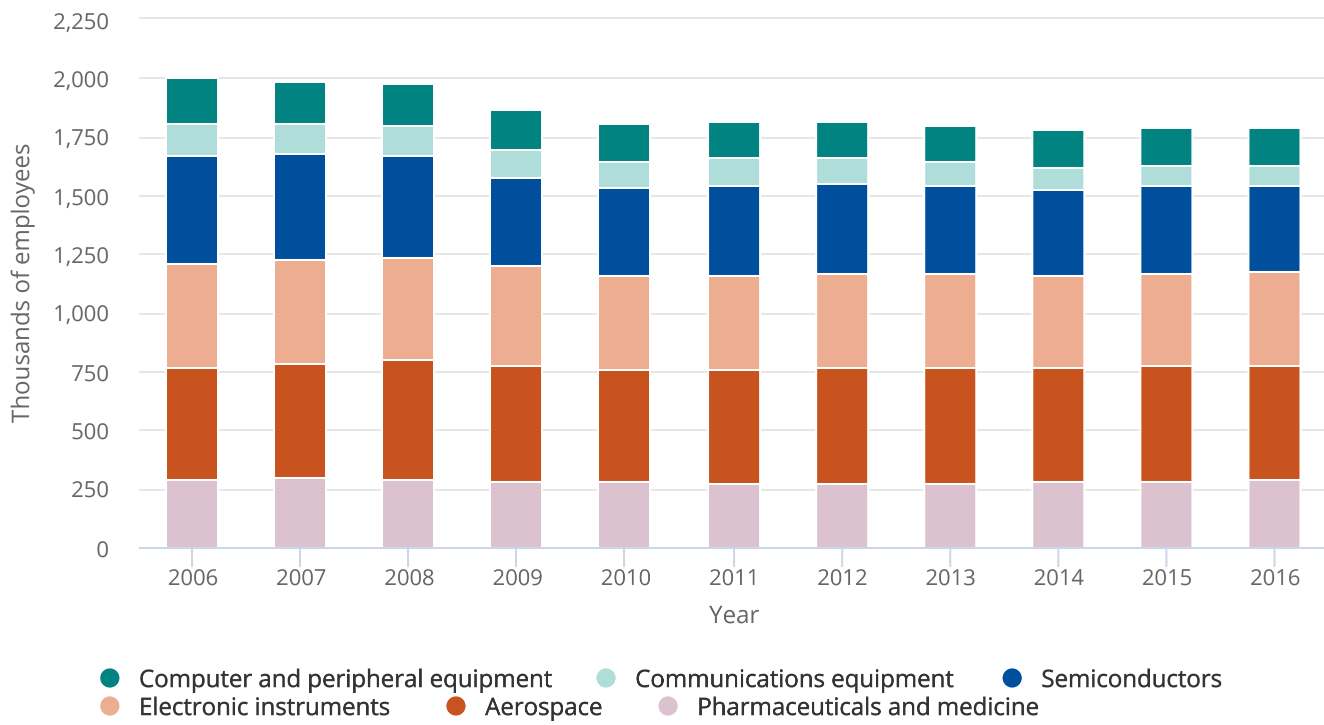
U.S. high-technology manufacturing has grown steadily in the post-global recession period coinciding with its moderate recovery from the global recession (Figure 6-9 and Figure 6-11; Appendix Table 6-8). Between 2011 and 2016, U.S. high-technology manufacturing output grew far faster (16%) compared to the EU and Japan. However, China's output grew far faster (68%) than the United States, resulting in China substantially narrowing its gap with the United States.

Two high-technology manufacturing industries have contributed the most to post-global recession growth: testing, measuring, and control instruments; and pharmaceuticals (Appendix Table 6-17 and Appendix Table 6-18). The United States is the world's largest producer in testing, measuring, and control instruments (44%) and is the second largest global producer in pharmaceuticals closely behind the EU. In the pharmaceuticals industry, production of biologics, vaccines, and stem cell therapies is concentrated in these two economies, where close integration of research, testing, and manufacturing is necessary (Donofrio and Whitefoot 2015:25). The United States is also the dominant global producer in aircraft and spacecraft (53%).

Despite a recovery in output following the global recession, overall U.S. employment in high-technology manufacturing industries has not increased (Figure 6-12). Employment has remained stagnant in the post-global recession period and remains slightly below its level prior to the global recession. The lack of employment growth reflects the relocation of production to China and other countries with lower costs, greater manufacturing scale, or both, as well as the use of robotics and machines in U.S. high-technology manufacturing industries, which have eliminated some jobs, particularly those in routine tasks. Some researchers and policymakers have concluded that the location of high-technology manufacturing and R&D activities may lead to the migration of higher-value activities abroad (Fuchs and Kirchain 2010:2,344).

FIGURE 6-12

U.S. employment in HT manufacturing industries: 2006–16



HT = high technology.

Note(s)

HT manufacturing industries are based on a former classification by the Organisation for Economic Co-operation and Development. HT manufacturing industries include aircraft and spacecraft; communications and semiconductors; computers; pharmaceuticals; and testing, measuring, and control instruments.

Source(s)

Bureau of Labor Statistics, Current Employment Statistics (2016), https://www.bls.gov/ces/, accessed 15 August 2017.

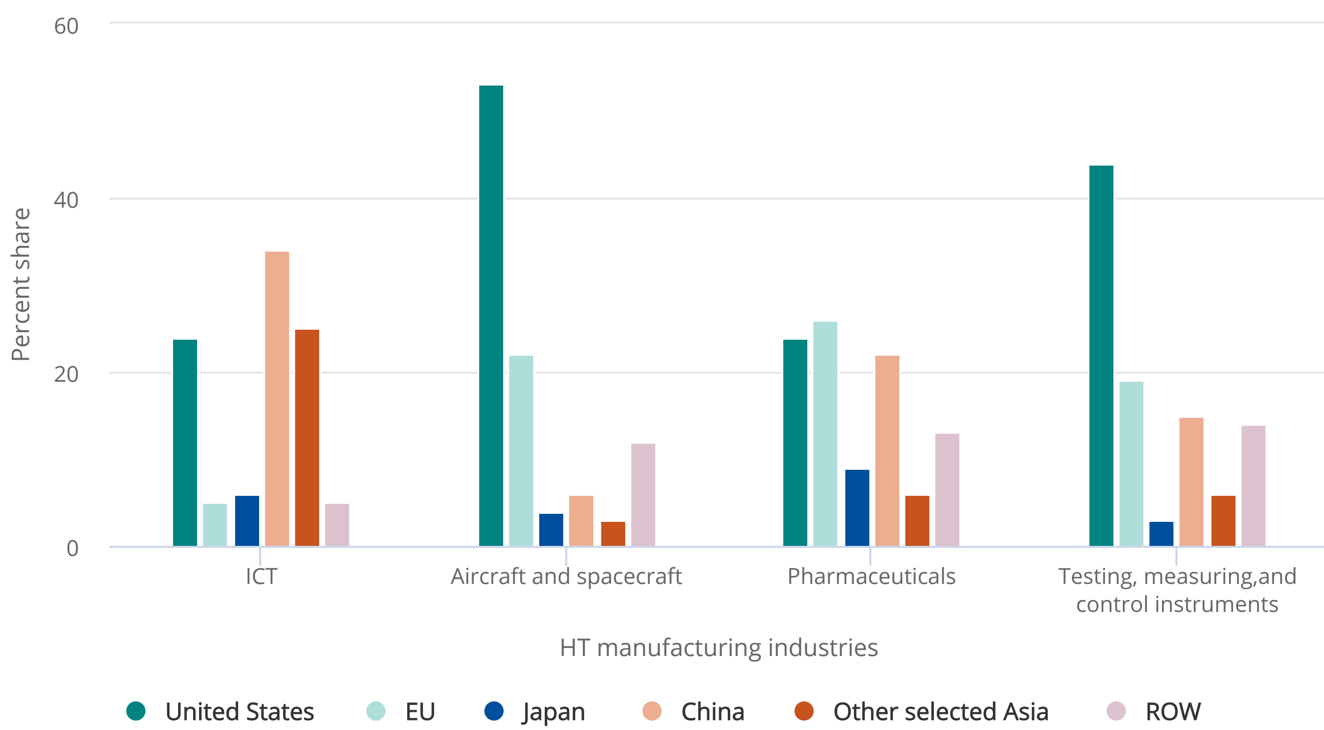
Science and Engineering Indicators 2018

U.S. companies invest a considerable amount of their R&D in three high-technology manufacturing industries—testing, measuring, and control instruments; pharmaceuticals; and aircraft and spacecraft.[8] In addition, manufacturing of aircraft and spacecraft involves a supply chain of other high-technology inputs—navigational instruments, computing machinery, and communications equipment—many of which continue to be provided by U.S. suppliers. Boeing sources about 70% of the parts from U.S.-based companies and 30% from companies outside the United States to produce its advanced 787 airliner and other similar models (Kavilanz 2013). In pharmaceuticals and medical devices (medical devices is part of testing, measuring, and control instruments), production, testing, and treatment are often located close to U.S. academic and medical-center laboratories so that companies can conduct close and continuous research collaboration (Donofrio and Whitefoot 2015:25).

Over the last decade, the U.S. global share of high-technology manufacturing output has remained similar despite a gradual increase in the level of output (Figure 6-11; Appendix Table 6-8). Overall, U.S. high-technology manufacturing output grew by more than 30% over the last decade. Three industries have led growth—testing, measuring, and control instruments; pharmaceuticals; and aerospace (Appendix Table 6-17, Appendix Table 6-18, and Appendix Table 6-19). In contrast, output of the U.S. communication and computer industries has declined coinciding with the rapid rise of China in these industries (Appendix Table 6-15 and Appendix Table 6-16). However, the United States retains a stronger position in the communication and computer industries than the EU or Japan (Figure 6-13), which have had much deeper declines over the last decade.

FIGURE 6-13

HT manufacturing industries of selected regions, countries, or economies: 2016



EU = European Union; HT = high technology; ICT = information and communications technology; ROW = rest of world.

Note(s)

HT manufacturing industries are based on a former classification by the Organisation for Economic Co-operation and Development and include aircraft and spacecraft; communications and semiconductors; computers; pharmaceuticals; and testing, measuring, and control instruments. ICT manufacturing industries consist of computers, communications, and semiconductors. Output is measured on a value added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. Data are not available for EU members Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Other selected Asia includes India, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam.

Source(s)

IHS Global Insight, World Industry Service database (2017). See Appendix Table 6-20 and Appendix Table 6-26 through Appendix Table 6-32.

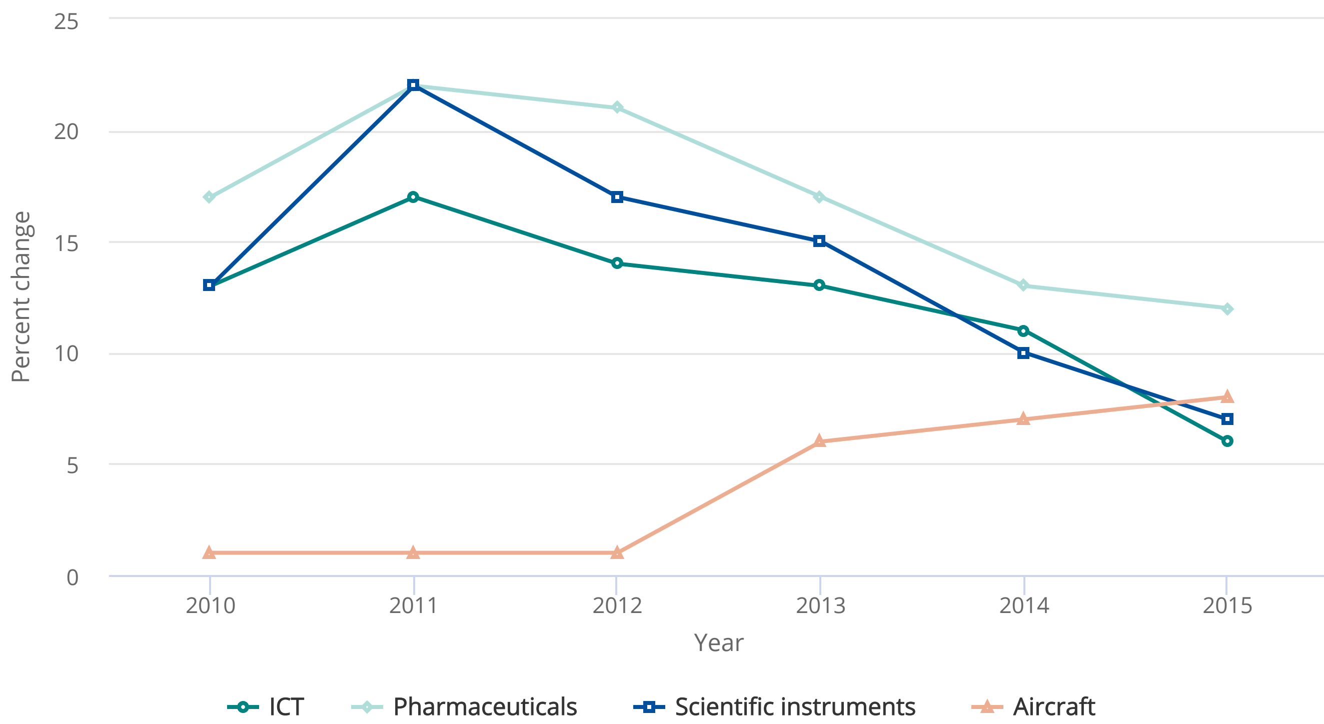
Science and Engineering Indicators 2018

High-Technology Manufacturing Industries in China

China's high-technology manufacturing industries have grown substantially in the post-global recession period, with value-added output growing by 70% between 2011 and 2016, far faster than the United States, EU, or Japan (Figure 6-11; Appendix Table 6-8). However, the growth rate of high-technology industries on a 3-year moving average basis slowed in 2015–16, coinciding with the moderation of China's economic growth (Figure 6-9 and Figure 6-14). The deceleration in growth was most pronounced in the export-oriented ICT manufacturing industries. The pharmaceuticals industry had the slightest decline in growth among the high-technology industries, with its growth rate overtaking the ICT manufacturing industries in 2015 (Figure 6-13; Appendix Table 6-14 through Appendix Table 6-17). Some observers and researchers believe that the slowdown of China's high-technology manufacturing and other export-oriented industries also reflects the economy beginning to shift away from export-led to domestic consumption-led growth (Dizioli, Hunt, and Maliszewski 2016:5; Nie and Palmer 2016:26). China's government adopted the goal of moving the economy from growth based primarily on exports and investment to domestic consumption playing a larger role in supporting its economy in its 12th Five Year Plan for 2011–2016 (Prasad 2015: 4). There is some indication that this policy may be starting to have an impact on the economy. For example, data from the World Bank shows that the private consumption share of GDP increased slightly from 49% to 51% and the share of exports of goods and service fell from 26% to 22% between 2010 and 2015.[9]

FIGURE 6-14

Annual change in value-added output of selected manufacturing industries in China: 2010–15



ICT = information communications technology.

Note(s)

Output is measured on a value added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. Change in value added output is based on a 3-year moving average. For example, output in 2015 is the average for 2014–16.

Source(s)

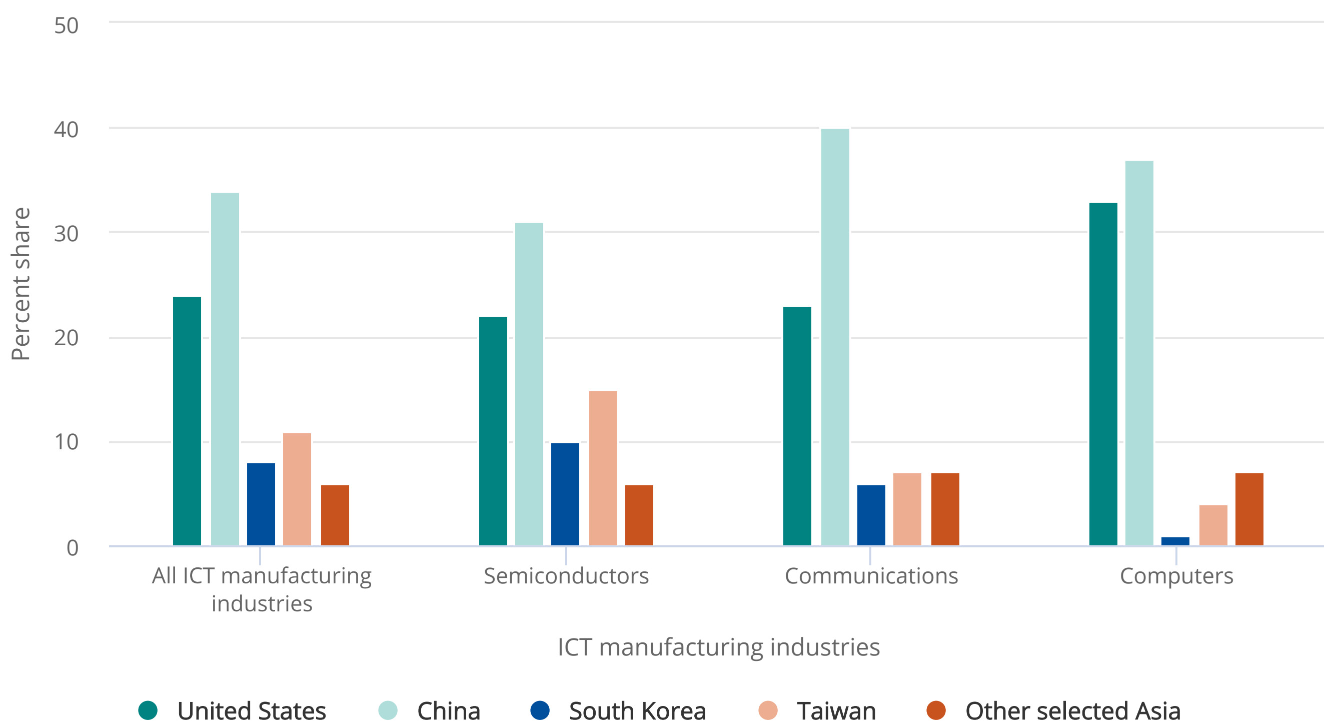
IHS Global Insight, World Industry Service database (2017). See Appendix Table 6-20 and Appendix Table 6-26 through Appendix Table 6-32.

Science and Engineering Indicators 2018

Over the last decade, China's global share in high-technology manufacturing more than doubled (10%–24%), and it surpassed Japan in 2008 and the EU in 2012 to become the world's second largest producer (Figure 6-11; Appendix Table 6-8). China had the most rapid growth in its ICT manufacturing industries resulting in its global share more than doubling from 14% to 34% (Figure 6-15; Appendix Table 6-14, Appendix Table 6-15, and Appendix Table 6-16). China overtook the United States in 2013 to become the world's largest global producer in ICT manufacturing industries.

FIGURE 6-15

Global share of selected regions, countries, or economies in ICT manufacturing industries: 2016



ICT = information and communications technology.

Note(s)

ICT manufacturing industries consist of computers, communications, and semiconductors. Output is measured on a value added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. China includes Hong Kong. Other selected Asia includes Malaysia, Philippines, Singapore, Thailand, Taiwan, and Vietnam.

Source(s)

IHS Global Insight, World Industry Service database (2017). See Appendix Table 6-20 and Appendix Table 6-26 through Appendix Table 6-32.

Science and Engineering Indicators 2018

China functions as the final assembly location for ICT goods assembled in “Factory Asia”—the electronics goods production network centered in East Asia (WTO and IDE-JETRO 2011:14–15). China has global manufacturing scale, a network of suppliers, a large labor force of skilled and production workers, and the ability to quickly ramp up production that is required for many ICT products that have short development cycles (Donofrio and Whitefoot 2015:26). South Korea and Taiwan are major global producers in semiconductors and communications that supply advanced components and inputs to China. Asian countries that supply components and inputs to China, perform final assembly of ICT goods, or both include Indonesia, Malaysia, Philippines, Thailand, and Vietnam.

China has also become a major global producer of pharmaceuticals with its global share tripling over the last decade to reach 22% in 2016 to become the world's third largest producer (Figure 6-13; Appendix Table 6-17). China's rapid growth has originated from production of generic drugs by China-based firms and the establishment of production facilities controlled by U.S. and EU multinationals, often in partnership with Chinese companies. The rapidly expanding middle class, reform of China's health care system, and increasing demand for health care has fueled the rapid expansion of China's pharmaceuticals industry.[10] China's pharmaceuticals industry largely produces mature and existing technologies, such as generics, that do not require close integration of production with R&D. However, China's industry is expected to move into emerging and complex technologies as companies invest in R&D facilities and research collaborations increase with academia (Donofrio and Whitefoot 2015:26). Output of China's testing, measuring, and control instruments industry has grown rapidly, although from a low base (Appendix Table 6-18).

China has been moving up the value chain in manufacture of high-technology goods, albeit progress has been uneven.[11] For example, China has made impressive progress in its supercomputing ability over the last few years, an area that it had little presence in a decade ago (see sidebar China's Progress in Supercomputers).[12] The first large Chinese-made jetliner, the C919, successfully completed its maiden test flight in 2017, a key step in China's plan to move up the value chain and become a global competitor in advanced technologies. Although more than 200 Chinese companies and 36 universities have been involved in the research and development of the C919, the plane relies on foreign-made technology for critical systems, including its engines.[13] Although Chinese semiconductor companies have gained global market share, China remains very reliant on semiconductors supplied by foreign firms for most of its production of smartphones and other electronic products (PwC 2014). Chinese-owned high-technology companies have not met many of the ambitious targets and goals of the Chinese government's indigenous innovation program. China's rapidly growing domestic market is prompting some foreign high-technology firms to establish R&D laboratories to develop products for China's rapidly growing consumer market. However, many multinational companies (MNCs) continue to conduct some of their higher value-added activities in developed countries because of the greater availability of skilled workers, stronger intellectual property protection, or both. In addition, researchers surveyed by the Industrial Research Association perceived the quality of China's R&D to be far lower than the United States.[14]

Anecdotal reports suggest that final assembly has migrated from China to other developed Asian economies or has returned to developed countries in response to increases in transportation costs and China's manufacturing wages.[15] However, China remains an attractive location for foreign MNCs because of its well-developed and global manufacturing scale that has an extensive network of domestic suppliers. In addition, the cost of wages in capital-intensive manufacturing industries, such as ICT, is not a major factor in choosing the location of production facilities because wages are a very small share of production costs. Factors including the cost of land and energy and manufacturing scale typically are more important factors in determining the location of production facilities.[16]

SIDEBAR

China's Progress in Supercomputers

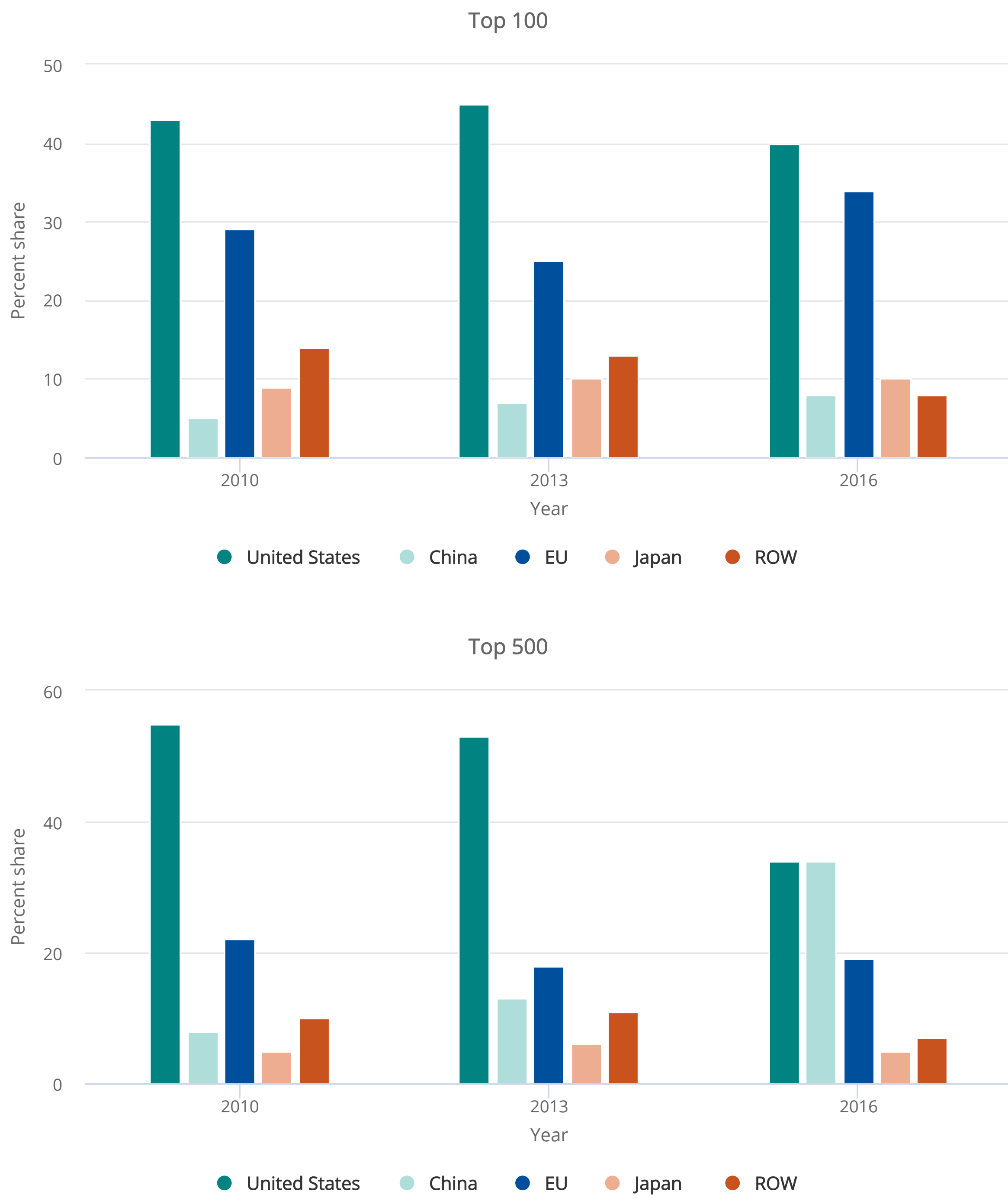
The TOP500, an organization composed of computer scientists and industry specialists, has been tracking the world's most powerful and fastest-performing supercomputers since 1993. The TOP500 provides a semiannual update of the world's top 500 supercomputers, including information on the country of origin, performance, type of application, and technology.

According to the TOP500's November 2016 report, two supercomputers in China were ranked first and second in the world, giving China two slots in the top 10 list. The world's first-ranked computer is the 93-petaflop Sunway TaihuLight supercomputer at the National Supercomputing Center in Wuxi.* The second-ranked computer is the 34-petaflop Tianhe-2 (MilkyWay-2) in the National Supercomputer Center in Guangzhou. The United States continued to have the largest share of supercomputers in the TOP10, with five in the 2016 list. In addition, China reached parity with the United States in the total number of supercomputers (171) ranked in the top 500 list (Figure 6-C). China has made rapid progress over the last several years, with its share rising from 8% in 2010 to 34% in 2016. The U.S. share has fallen sharply from 55% in 2010 to 34% in 2016.

Although its achievements are impressive, China's supercomputing ability remains limited. Much of China's supercomputing capability is concentrated in its two supercomputers that are ranked first and second in the world (Feldman 2017). Together, they represent more than half of the aggregate performance of the country's supercomputers in the TOP500 list. The majority of China's supercomputers reside in the bottom half of the TOP500 list. Although China and the United States have the same number of supercomputers in the TOP500 list, China's median rank is 316, compared to 227 for the United States. China has made far more limited progress in the TOP100-ranked supercomputers. Between 2010 and 2016, China's share rose from 5% to 8% (Figure 6-C). The United States and the EU remain dominant in the TOP100, with shares of 40% and 34%, respectively, in 2016.

FIGURE 6-C

Top-ranked supercomputers, by location of region, country, or economy: 2010–16



EU = European Union; ROW = rest of world.

Source(s)

TOP500 November 2016, 2013, and 2010 reports, https://www.top500.org/lists/, accessed 15 February 2017.

Science and Engineering Indicators 2018

In addition, the majority of the Chinese supercomputers in the TOP500 list are probably not being used for applications that require the processing ability of supercomputers, including quantum mechanics, weather forecasting, climate research, oil and gas exploration, and molecular modeling and physical simulations. Of the 171 Chinese supercomputers in the TOP500 list, 114 are installed at Internet data center companies, cloud service providers, telecommunications firms, and electric companies (Feldman 2017). These supercomputers have less advanced technology and capability than leading-edge supercomputers and are likely being used for routine activities such as running Web-based or back-office applications. In contrast, most U.S.-based supercomputers are installed at federal national laboratories, universities, and research institutes (Feldman 2017).

* One petaflop is equivalent to one thousand million million (10^{15}) floating-point operations per second.

High-Technology Manufacturing Industries in the EU

Growth of high-technology manufacturing industries in the EU has trailed that in the United States in the post-global recession period (Figure 6-11; Appendix Table 6-8), similar to trends seen in the commercial knowledge-intensive services sector. The EU's output remained relatively flat between 2011 and 2016, coinciding with its lackluster economic growth (Figure 6-9). The EU's global share slipped from 18% to 16% during this period. Although aircraft and spacecraft and pharmaceuticals each grew 14%, output in the ICT manufacturing industries contracted 27% (Appendix Table 6-14 through Appendix Table 6-17, and Appendix Table 6-19). The EU is the largest global producer in pharmaceuticals (26% global share in 2016) (Figure 6-13). The EU is the second largest global producer in aircraft and spacecraft (22% global share) and testing, measuring, and control equipment (19% global share) (Appendix Table 6-18).

High-Technology Manufacturing Industries in Japan and Taiwan

Output of Japan's high-technology manufacturing industries was stagnant between 2011 and 2016, coinciding with its weak and halting recovery from the global recession (Figure 6-9 and Figure 6-11; Appendix Table 6-8). Over the last decade, value-added output contracted by 27%, resulting in Japan's global share dropping from 13% to 6%. Output of ICT industries alone fell by 54%. Japan's deep decline coincides with the decade-long stagnation of its economy, the loss of competitiveness of Japanese electronics firms, and the transfer of production to China and other countries (Appendix Table 6-14, Appendix Table 6-15, and Appendix Table 6-16).

Taiwan's output rose by 19% between 2011 and 2016, almost entirely due to gains in its ICT industries, which dominate its high-technology manufacturing industries. Taiwan is the third largest global producer of ICT manufacturing industries (11%) after China and the United States (Figure 6-15; Appendix Table 6-14, Appendix Table 6-15, and Appendix Table 6-16).

High-Technology Manufacturing Industries in Other Countries

Other major Asian producers—Malaysia, Singapore, and South Korea—showed little change in their global shares between 2011 and 2016 (Appendix Table 6-8). Over the last decade, companies based in these economies have moved up the value chain to become producers of semiconductors and other sophisticated components that are supplied to China and other countries. Output in Vietnam more than doubled between 2011 and 2016 (Appendix Table 6-8), largely due to growth in ICT manufacturing industries. Vietnam has become a low-cost location for assembly of cell phones and other ICT products, with some firms shifting production out of China, where labor costs are higher.[17]

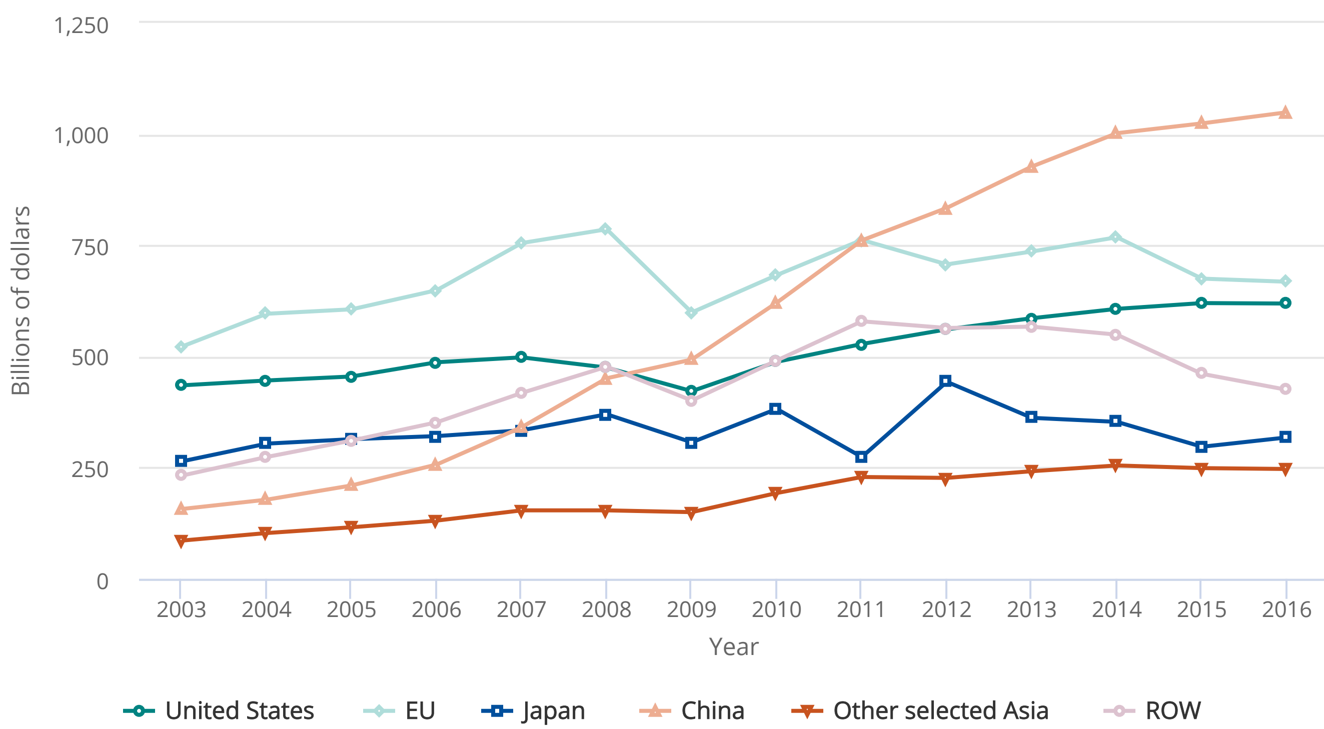
India's high-technology manufacturing output fell 14% during this period. India is a major producer in the pharmaceuticals industry (2% global share), with Indian firms manufacturing generic drugs and performing clinical trials for multinational pharmaceutical companies based in the United States and the EU (Appendix Table 6-8 and Appendix Table 6-17).[18]

Global Trends in Medium-High-Technology Industries

Global value added of medium-high-technology manufacturing was $3.3 trillion in 2016, about twice as large as high tech manufacturing, making up 29% of the manufacturing sector (Figure 6-1 and Figure 6-16; Appendix Table 6-7 and Appendix Table 6-13). The three largest industries are chemicals excluding pharmaceuticals, machinery and equipment, and motor vehicles and parts ($0.8–$0.9 trillion in output) (Appendix Table 6-20, Appendix Table 6-21, and Appendix Table 6-22). The fourth largest industry is electrical machinery and appliances ($0.5 trillion) (Appendix Table 6-23). Railroad and other transportation equipment is a far smaller industry ($0.1 trillion) (Appendix Table 6-24).

FIGURE 6-16

Output of MHT manufacturing industries for selected regions, countries, or economies: 2003–16



EU = European Union; MHT = medium-high technology; ROW = rest of world.

Note(s)

Output is measured on a value added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. MHT manufacturing industries are based on a former classification by the Organisation for Economic Co-operation and Development and include motor vehicles and parts, electrical machinery, machinery and equipment, chemicals excluding pharmaceuticals, and railroad and other transportation equipment. Data are not available for EU members Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Other selected Asia includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea,Taiwan, and Vietnam.

Source(s)

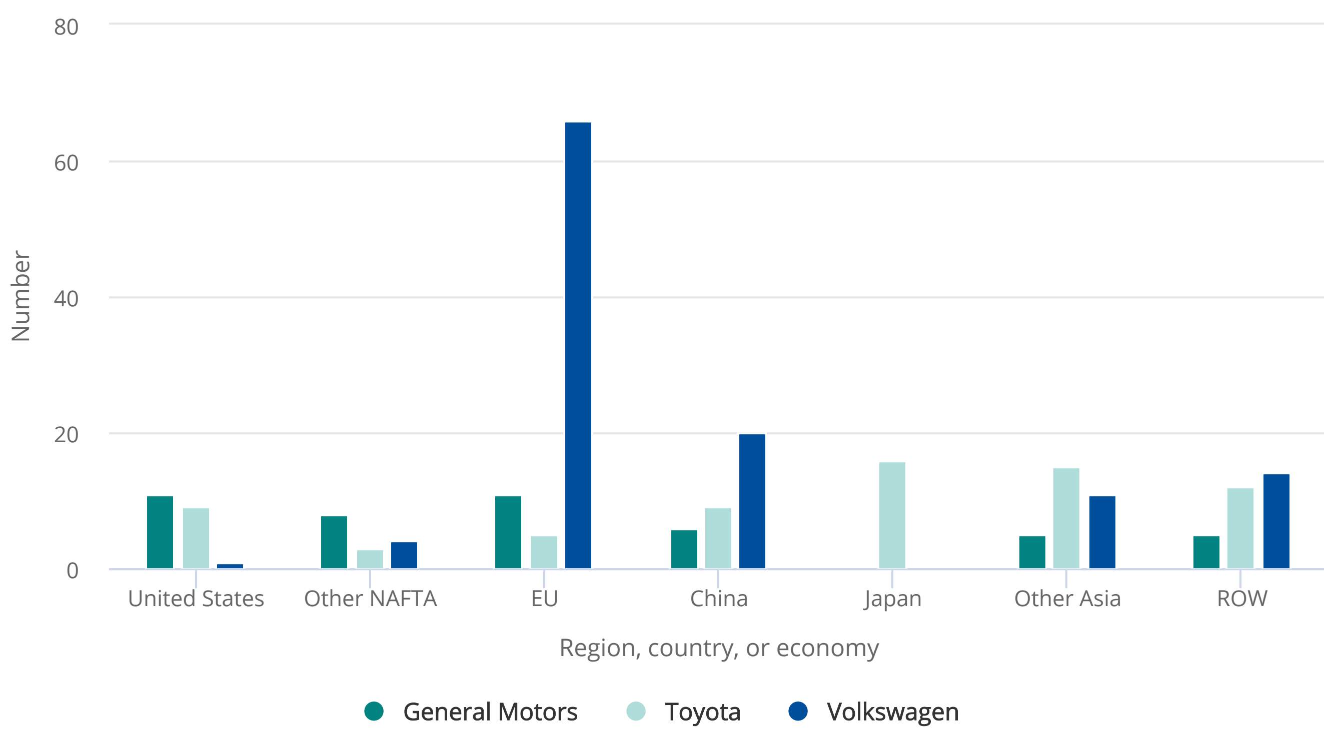
IHS Global Insight, World Industry Service database (2017). See Appendix Table 6-8.

Science and Engineering Indicators 2018

Although these industries have global and often complex value chains, production activities are generally located closer to the final market compared to consumer electronics and other ICT industries with lightweight products (Donofrio and Whitefoot 2015:25). Because many inputs and components are manufactured near or at the final market, the value added may be credited to the company's subsidiary or contractor. For example, in the motor vehicles and parts industry, the manufacturing facilities of three major global automakers—General Motors, Toyota, and Volkswagen—are widely dispersed and clustered in the regions or countries of their final markets (Figure 6-17). Transportation costs are high in many of these industries because the final products and major components in many of these industries are large and heavy, particularly automobiles, large appliances, and heavy equipment. Furthermore, co-location of R&D and design near the customers is advantageous for understanding customer needs and local market demand (Donofrio and Whitefoot 2015:25).

FIGURE 6-17

Manufacturing facilities of General Motors, Toyota, and Volkswagen, by selected region, country, or economy: 2016



EU = European Union; NAFTA = North American Free Trade Agreement; ROW = rest of world.

Note(s)

Other Asia includes India, Malaysia, Philippines, South Korea, Taiwan, Thailand, and Vietnam.

Source(s)

Toyota, http://www.toyota-global.com/company/profile/facilities/, accessed 14 February 2017; General Motors, https://media.gm.com/media/us/en/gm/plants-facilities.html, accessed 14 February 2017; Volkswagen, https://www.volkswagenag.com/en/group/portrait-and-production-plants.html, accessed 14 February 2017.

Science and Engineering Indicators 2018

China is the largest global producer (32% global share) (Figure 6-16; Appendix Table 6-7) in medium-high-technology manufacturing industries. The EU is second (20%) closely followed by the United States (19%). Japan is the fourth largest producer (10%).

Medium-High-Technology Industries in China

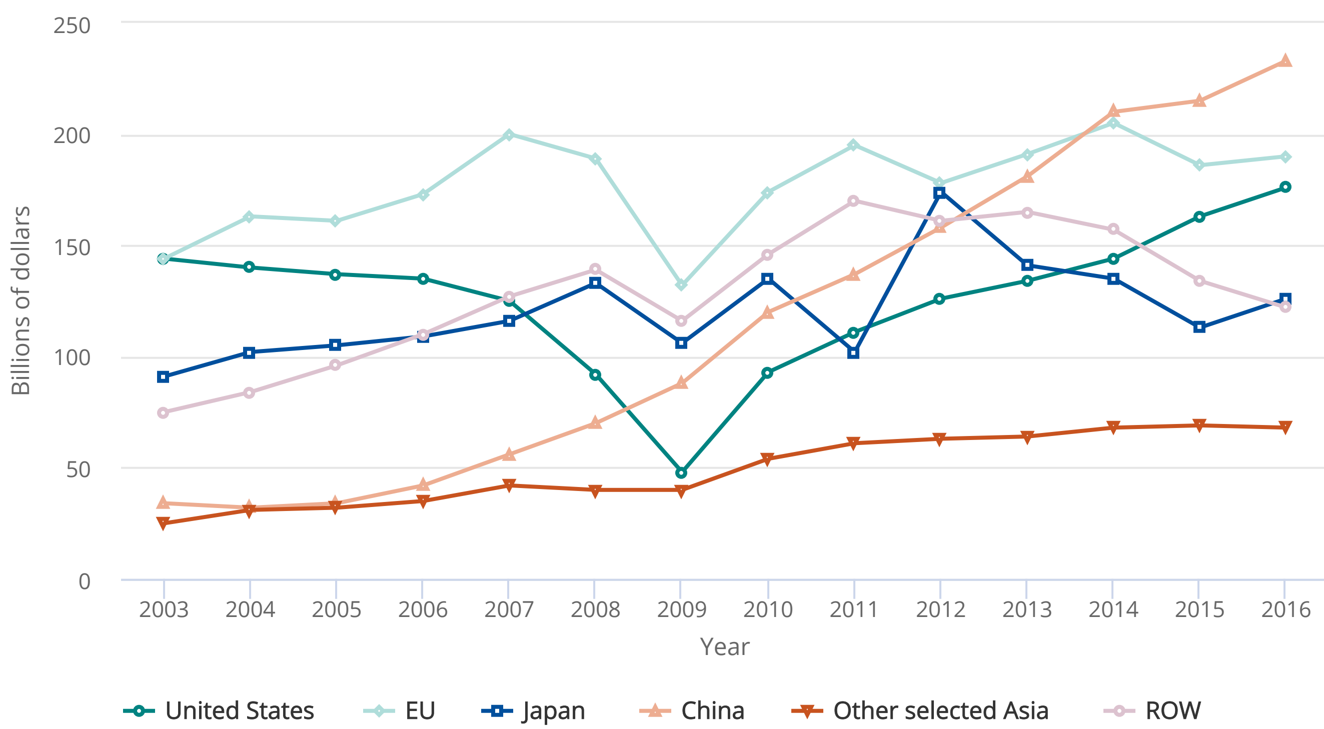
China's medium-high-technology manufacturing industries grew 38% between 2011 and 2016 (Figure 6-16; Appendix Table 6-7). Growth in output of these industries slowed significantly in 2015–16, similar to the moderation in growth of China's high-technology manufacturing industries.

China surpassed the United States in 2009 to become the world's second largest producer in medium-high-technology industries and surpassed the EU in 2012 to become the world's largest producer. The motor vehicle and parts industry led growth in China, with output rising almost sixfold over the last decade (Figure 6-18; Appendix Table 6-20). China's automobile industry is composed of joint ventures with multinational companies and indigenous manufacturers. Although most cars and trucks manufactured in China are sold for the rapidly growing domestic market, China's industry is exporting an increasing number of cars, trucks, and parts (see "China's Trade in Medium-High-Technology Goods" in section Global Trade in Commercial Knowledge- and Technology-Intensive Goods and Services).[19]

China surpassed the United States to become the world's largest producer of chemicals (excluding pharmaceuticals) in 2013 (28% global share in 2016) (Appendix Table 6-21). China accounts for nearly half of global production in electrical machinery and appliances (44%) and is the largest global producer in machinery and equipment (32%) (Appendix Table 6-22 and Appendix Table 6-23).

FIGURE 6-18

Output of motor vehicles and parts industry for selected regions, countries, or economies: 2003–16



EU = European Union; ROW = rest of world.

Note(s)

Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. Medium-high technology manufacturing industries are based on a former classification by the Organisation for Economic Co-operation and Development and include automotive; chemicals (excluding pharmaceuticals); electrical machinery; motor vehicles; railroad, shipbuilding, and other transportation equipment; and machinery, equipment, and appliances. Data are not available for EU members Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Other selected Asia includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea,Taiwan, and Vietnam.

Source(s)

IHS Global Insight, World Industry Service database (2017). See Appendix Table 6-8.

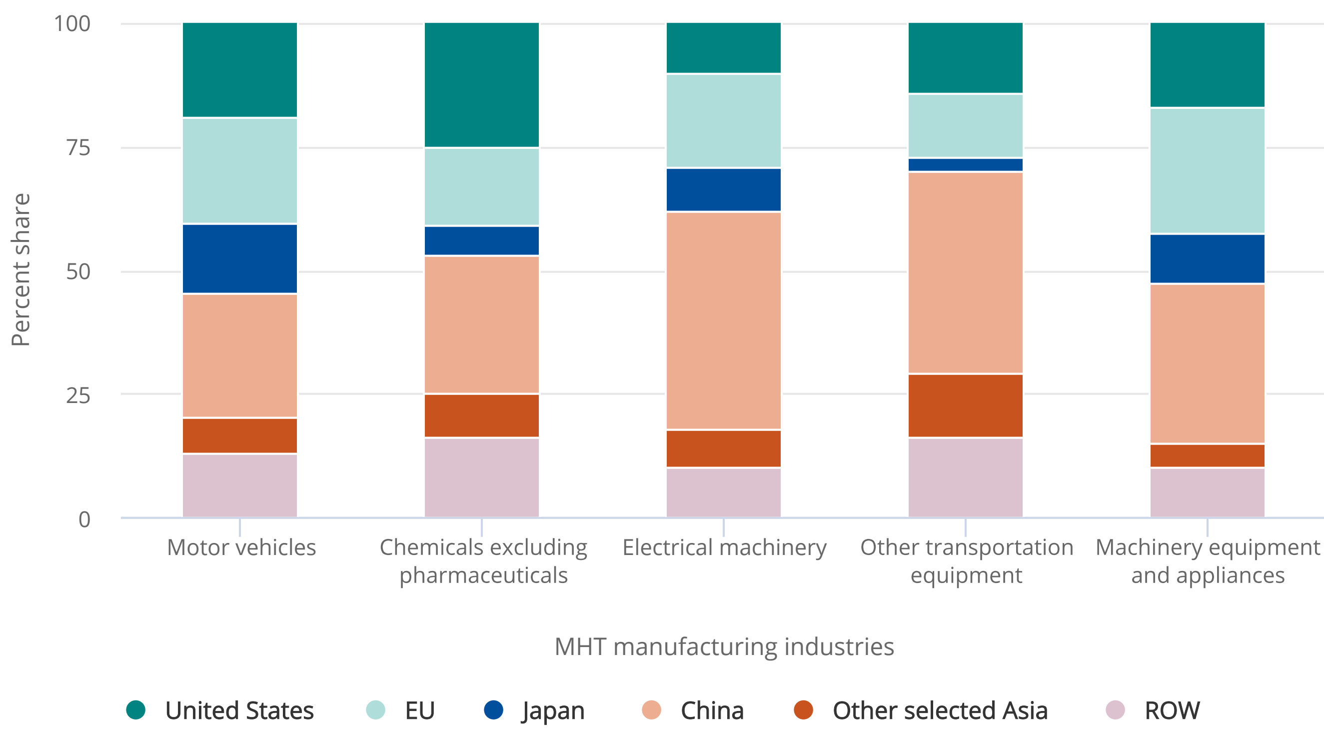
Science and Engineering Indicators 2018

Medium-High-Technology Industries in the United States

U.S. medium-high-technology manufacturing industries grew at the same pace as Japan in the 2011–16 post-global recession period (16%–17%). Output of the EU's industries contracted by 12% during this period. However, China grew far faster (38%) than the United States (Figure 6-16; Appendix Table 6-7). Just like in China, the motor vehicle and parts industry drove overall growth of these industries in the United States, with output rising nearly 60% during this period (Figure 6-18; Appendix Table 6-20). The global share of the U.S. motor vehicle industry climbed from 14% to 19% between 2011 and 2016, returning to its pre-global recession level. The United States has the world's third largest motor vehicle industry, behind the EU (21%) and the largest global producer, China (25%) (Figure 6-19).

FIGURE 6-19

Global share of selected regions, countries, or economies of MHT manufacturing industries: 2016



EU = European Union; MHT = medium-high technology; ROW = rest of world.

Note(s)

MHT manufacturing industries include motor vehicles and parts, electrical machinery, machinery and equipment, chemicals excluding pharmaceuticals, and railroad and other transportation equipment. Output is measured on a value added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. Data are not available for EU members Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Other selected Asia includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Vietnam.

Source(s)

IHS Global Insight, World Industry Service database (2017). See Appendix Table 6-20 and Appendix Table 6-26 through Appendix Table 6-32.

Science and Engineering Indicators 2018

The rapid recovery of the U.S. automobile industry following the global recession has been driven in part by the federal government's bailout and financial restructuring of General Motors and Chrysler in 2009, which restored those firms to profitability and helped preserve the extensive domestic network of suppliers and parts to these and other automotive firms (Klier and Rubenstein 2013:146–55). Sales of motor vehicles and parts soared following the recession due to pent-up demand from the collapse of sales during the recession and greater availability of credit. Many automobiles sold in the United States by U.S. and foreign-based companies are manufactured in plants and use suppliers and parts located in the United States or nearby in Canada or Mexico.[20] In addition, many of these companies have R&D facilities in the United States to understand customer needs and quickly modify or innovate in design, capabilities, or the manufacturing process.[21]

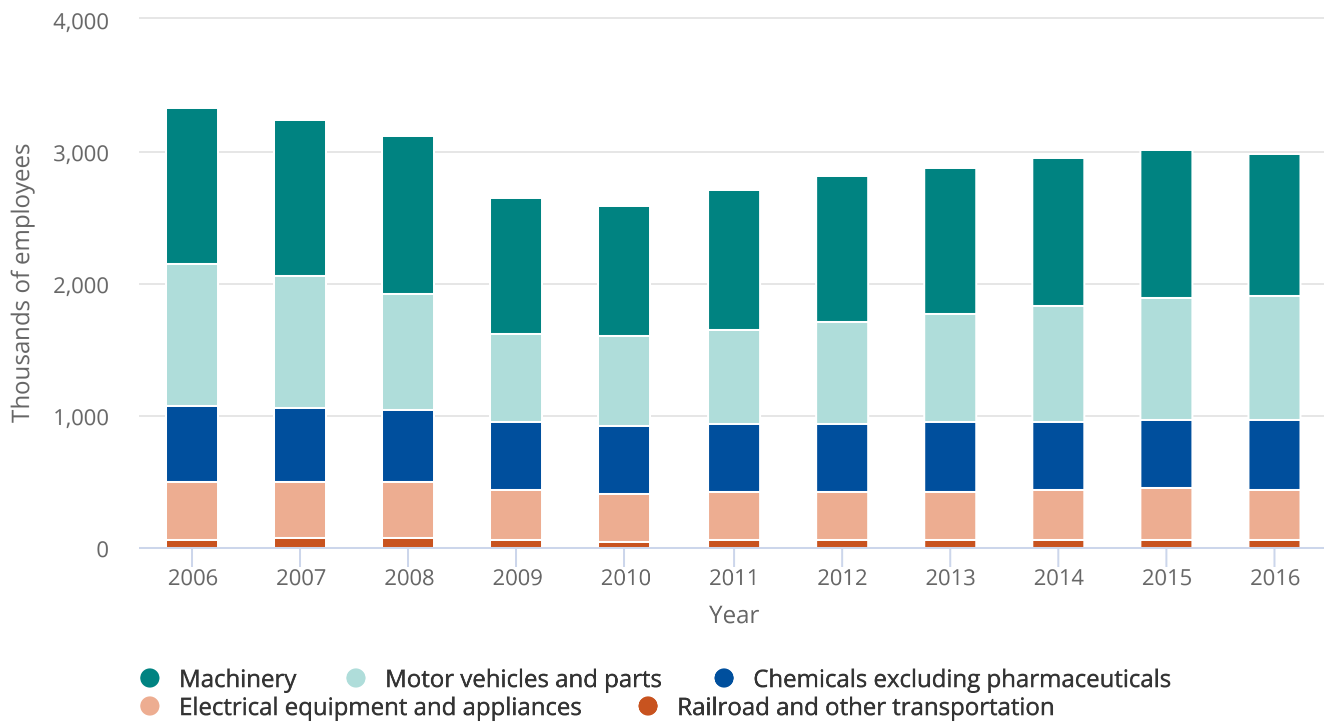
In other industries, output in electrical machinery and appliances increased by 17% between 2011 and 2016 (Appendix Table 6-23). The U.S. global share in this industry remained flat during this period (11% in 2016). Growth was sluggish in chemicals excluding pharmaceuticals (5%) and in machinery and equipment (7%) (Appendix Table 6-21 and Appendix Table 6-22). The United States is the second largest global producer of chemicals excluding pharmaceuticals (25%) closely behind China. The United States is the third largest global producer of machinery and equipment (17% global share).

Over the last decade, the U.S. global share of medium-high-technology manufacturing has slipped from 22% to 19%, largely due to much faster growth in China (Figure 6-16; Appendix Table 6-7). Despite the slight decline in the U.S. global share, U.S. medium-high-technology manufacturing output grew by 27% over the last decade. Chemicals excluding pharmaceuticals and motor vehicles and parts drove growth of these industries, with output rising by 39% and 31%, respectively (Appendix Table 6-20, Appendix Table 6-21).

U.S. employment in medium-high-technology manufacturing has grown substantially in the post-global recession period, adding 280,000 jobs to reach 3.0 million in 2016 (Figure 6-20). The motor vehicle industry drove the gain in employment with the addition of 220,000 jobs. Despite this robust growth, employment in medium-high-technology manufacturing industries remains slightly below its level prior to the global recession.

FIGURE 6-20

U.S. employment in MHT manufacturing industries: 2006–16



MHT = medium-high technology.

Note(s)

MHT manufacturing industries are based on a former classification by the Organisation for Economic Co-operation and Development and include automotive; chemicals (excluding pharmaceuticals); electrical machinery; motor vehicles; railroad and other transportation equipment; and machinery, equipment, and appliances.

Source(s)

Bureau of Labor Statistics, Current Employment Statistics (2016), https://www.bls.gov/ces/, accessed 15 August 2017.

Science and Engineering Indicators 2018

Medium-High-Technology Industries in the EU

The EU's medium-high technology manufacturing industries grew slower than those of the United States. The EU's output declined by 12% between 2011 and 2016, coinciding with its lackluster economic recovery from the global recession (Figure 6-9). The EU's global share declined from 24% to 20% during this period.

The extent of decline in EU output varied across individual industries. Output in chemicals excluding pharmaceuticals and electrical machinery and appliances fell by 19% between 2011 and 2016 (Appendix Table 6-21 and Appendix Table 6-23). Output of motor vehicles and parts remained flat (Figure 6-18; Appendix Table 6-20). The German auto industry is the dominant producer in the EU, and companies including BMW, Mercedes, and Volkswagen have been successful in the EU and the global market. In addition, Germany had comparatively stronger growth than other EU countries in the post-global recession period.

Over the last decade, the EU's global share in medium-high-technology manufacturing has fallen substantially (from 30% to 20%) with declines in each of the four industries.

Medium-High-Technology Industries in Japan

Japan's medium-high-technology manufacturing industries grew by 16% between 2011 and 2016, far faster than its high-technology manufacturing industries (Figure 6-11 and Figure 6-16; Appendix Table 6-7 and Appendix Table 6-8). Despite the rise in output, Japan's global share in medium-high technology manufacturing remained flat (10%) during this period.

The motor vehicles and parts industry grew the fastest (23%) followed by a 17% increase each in electrical equipment and appliances and machinery and equipment (Figure 6-18; Appendix Table 6-20, Appendix Table 6-22, and Appendix Table 6-23). Japanese automakers, including Toyota and Honda, are leading global automakers and are very successful in many developed and developing countries. Over the last decade, Japan's global share in medium-high-technology manufacturing has fallen from 15% to 10%, coinciding with the long-term stagnation of Japan's economy and the migration of manufacturing and routine activities to China and other countries. For example, Toyota has more than three-quarters of its manufacturing plants located outside of Japan (Figure 6-17).

Medium-High-Technology Industries in Other Countries

In other developing countries, Brazil, India, Indonesia, and Mexico have global shares of 1%–2% (Appendix Table 6-7). Output in Brazil has fallen steeply in the last several years across all industries due to Brazil's economic recession. Brazil's global share slid from 4% to 2% between 2011 and 2016. India's output was stagnant during this period. Indonesia's output grew 27%, led by strong gains in chemicals excluding pharmaceuticals, electrical equipment and appliances, and machinery and equipment. Mexico's output rose by 7% between 2011 and 2016, led by motor vehicles and parts (29%). Mexico assembles many cars for sale in the United States and has benefitted from the rapid recovery of the U.S. auto industry.

Industries That Are Not Knowledge or Technology Intensive

S&T are used in many industries besides KTI industries. Service industries not classified as knowledge-intensive services—which include wholesale and retail trade, restaurant and hotel, transportation and storage, and real estate—may incorporate advanced technology in their services or in the delivery of their services. Manufacturing industries not classified as high technology or medium-high technology may use advanced manufacturing techniques, incorporate technologically advanced inputs in manufacturing, or perform or rely on R&D. Industries not classified as either manufacturing or services—agriculture, construction, mining, and utility—also may incorporate recent S&T in their products and processes. For example, agriculture relies on breakthroughs in biotechnology, construction uses knowledge from materials science, mining depends on earth sciences, and utilities rely on advances in energy science.

In the non-knowledge-intensive service industries—wholesale and retail trade, restaurant and hotel, transportation and storage, and real estate—the United States, the EU, China, and Japan were the four largest producers in 2016 (Table 6-2). Over the last decade, in all four industry categories, the global shares of the EU and Japan declined; China's global share grew rapidly and by 2016 it surpassed Japan's share. The U.S. global share remained steady in real estate and transport and storage and declined slightly in retail and wholesale trade and restaurants and hotels.

The non-knowledge-intensive manufacturing industries (non-high-technology and non-medium-high-technology manufacturing industries) are divided into two categories, as formerly classified by the OECD: medium-low technology and low technology. In both of these categories, patterns and trends diverged somewhat from those in high-technology manufacturing and were broadly consistent with medium-high-technology manufacturing (Table 6-2). China's global share of value added grew rapidly between 2006 and 2016 (Table 6-2), and it became the world's largest producer by 2016 in both categories. The global shares of the EU and Japan declined in both categories. The U.S. global share fell slightly in medium-low technology industries and had a deeper decline in low-technology manufacturing industries.

TABLE 6-2

Global value added for selected industries, by selected region, country, or economy: 2006 and 2016

(Percent share)

Region, country, or economy	Real estate		Transport and storage		Retail and wholesale trade		Restaurants and hotels		Medium-low-technology manufacturing industries		Low-technology manufacturing industries	
	2006	2016	2006	2016	2006	2016	2006	2016	2006	2016	2006	2016
Global value added (current $billions)	4,534	6,724	2,140	3,049	5,543	7,966	1,216	1,884	2,114	2,698	2,152	3,180
China	3	11	8	16	5	15	5	13	12	30	13	32
EU	32	24	30	22	27	20	31	24	26	17	28	17
Japan	10	8	10	7	9	6	11	9	11	9	9	6
United States	34	33	22	21	32	29	31	29	22	20	21	16

EU = European Union.

Note(s)

Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. China includes Hong Kong. Medium-low-technology manufacturing industries consist of building and repairing of ships and boats; rubber and plastics products; coke, refined petroleum products, and nuclear fuel; other nonmetallic mineral products; and basic metal and fabricated metal products and are formerly classified by the Organisation for Economic Co-operation and Development (OECD). Low-technology manufacturing industries include recycling; wood, pulp, paper, paper products, printing, and publishing; food products, beverages, and tobacco; and textiles, textile products, leather, and footwear and are formerly classified by the OECD. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

Source(s)

IHS Global Insight, World Industry Service database (2016).

Science and Engineering Indicators 2018

In the nonmanufacturing and non-services industries—agriculture, forestry, and fishing; construction; mining; and utilities—China's global share grew substantially between 2006 and 2016 (Table 6-3). China became the world's largest producer in agriculture, and reached parity with the United States and the EU as the largest global producer in construction. China became the second largest global producer in utilities. The global share of the United States fell in these industries. The EU and Japan had generally steeper declines in these industries.

TABLE 6-3

Global value added for selected industries, by selected region, country, or economy: 2006 and 2016

(Percent)

Region, country, or economy	Agriculture, forestry, and fishing		Construction		Mining		Utilities	
	2006	2016	2006	2016	2006	2016	2006	2016
Global value added (current $billions)	2,157	4,050	2,698	3,900	1,760	1,937	1,506	2,048
China	20	35	6	20	9	13	11	22
EU	15	8	31	19	7	3	28	21
Japan	4	2	9	7	0	0	6	3
United States	9	6	26	20	16	14	29	26

EU = European Union.

Note(s)

Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. China includes Hong Kong. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

Source(s)

IHS Global Insight, World Industry Service database (2016).

Science and Engineering Indicators 2018

Identifying industries that are KTI by their industry classification has many limitations. These limitations include (1) firms are classified in one industry although many have activities in multiple industries and (2) the difficulty of capturing the value added contributed by countries and industries for KTI products and services produced in global value chains. “Platform-based” companies, which include Amazon, Facebook, and Uber, are an example of firms that produce KTI goods and services and use innovative technologies that are likely not categorized in KTI industries. The United States is a global leader in these types of companies. (For a discussion of these companies, see sidebar Platform-Based Companies.)

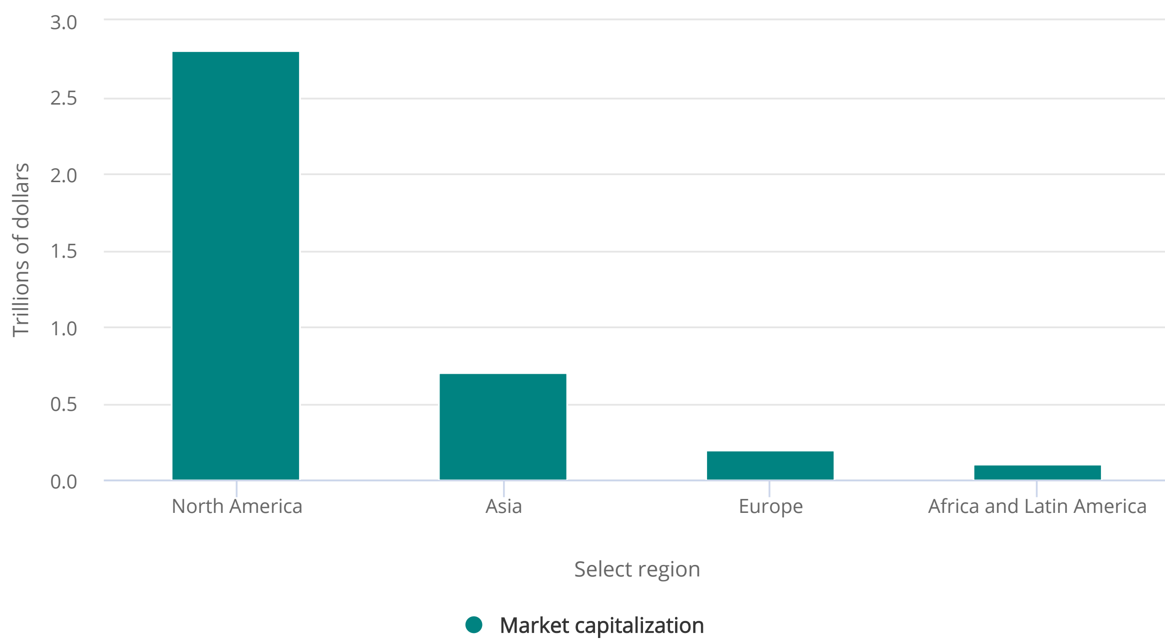
SIDEBAR

Platform-Based Companies

“Platform-based” companies combine a set of marketing and organizational innovations with novel linkages to external resources, including user-created content and data, to create new and innovative business models. These companies combine existing products and services and ICT infrastructure in new ways. They leverage ICT infrastructure and technology to create networks or social media platforms that help create demand for their products and services and provide a vehicle for targeted advertising and collecting extensive data on user’s preferences that can be sold to third parties. Platform-based companies operate in and compete directly and indirectly with traditional companies. For example, Uber is a direct competitor to traditional taxi companies and indirectly competes with automobile manufacturers, as some consumers decide not to own automobiles. Other examples of platform-based companies are Apple, Airbnb, Facebook, Instagram, Google, Amazon, WhatsApp, and Netflix. The United States dominates the new platform-based companies by a wide margin compared to the rest of the world (Figure 6-D) (Sturgeon 2016; Van Alstyne 2016).

FIGURE 6-D

Headquarters of platform companies, by selected region: 2015



Source(s)

Van Alstyne M, Platform Shift: How New Biz Models Are Changing the Shape of Industry (2016), https://ilp.mit.edu/images/conferences/2014/ict/presentations/vanalstyne.ict.2014.pdf.

Science and Engineering Indicators 2018

---

[1] Data on the health care sector include social services.

[2]See Bresnahan and Trajtenberg (1995) and DeLong and Summers (2001) for discussions of ICT and general-purpose technologies.

[3] For a discussion of potential economic benefits of the Internet of Things, see Mandel (2013:2–4).

[4] In the education sector, countries compete to attract foreign students to study and train. In the health sector, some countries promote "medical tourism" to attract foreigners to obtain medical care that is often cheaper than that provided in their home country.

[5] See Jensen (2012) for a discussion of U.S. business services firms helping to build infrastructure in developing countries.

[6] This chapter defines the global recession occurring in 2008–2010 and the post-global recession starting in 2011 for consistency of comparing trends across countries. However, the scale and timing of the recession and recovery varies by country.

[7] See China Daily (2016) and KPMG (2009) for a discussion of China's outsourcing of business services to firms in other countries.

[8] The testing, measuring, and navigation instruments industry includes medical and optical equipment.

[9] Source: The World Bank, World Development Indicators database http://data.worldbank.org/data-catalog/world-development-indicators.

[10] China's government has increased subsidies and support for the public health system, expanded insurance coverage of rural residents, encouraged use of private health insurance through tax breaks to policy holders, and changed regulation and financial support to lower costs of drugs to patients and the public health system. See Cao (2014) and Hsu (2015).

[11]See Williamson and Raman (2011) for a discussion of China's acquisition of foreign companies.

[12] China had 18 of its supercomputers listed in the world's top 500 supercomputers in November 2016 (Top 500, https://www.top500.org/statistics/sublist/).

[13]See Watt and Wong (2017).

[14]See Industrial Research Institute (2016).

[15] See *Economist* (2013) for a discussion of multinational firms choosing to have more of their manufacturing take place in developed countries.

[16] For example, the solar photovoltaic manufacturing industry is capital-intensive. See Goodrich et al. (2013:2813–17) for a comparison of the costs of solar PV manufacturing in China and the United States.

[17] See Green (2014) and Tomiyama (2015) for a discussion on the move of electronics manufacturing from China to Vietnam.

[18] See PwC (2014) and Indian Brand Equity Foundation (2017) for information on India's pharmaceutical industry.

[19] China is one of the world's largest exporters of automobile parts. It is now the fourth-largest exporter behind Germany, the United States, and Japan according to AmChamChina (2015).

[20] See Donofrio and Whitefoot (2015:23–27), for a discussion of factors that influence the location of plants and suppliers in the automotive and other industries.

[21] Toyota, among others, has located much of the design and production of its minivans and large pickup trucks in the United States because it is home to many of the customers of these vehicles. See Donofrio and Whitefoot (2015:25).

Global Trends in Trade of Knowledge- and Technology-Intensive Products and Services

The second section of this chapter examines patterns of trade associated with KTI industries in the United States and other economies. (For an explanation of KTI industries, please see section Chapter Overview.) In the modern world economy, production has become more globalized (i.e., value is added to a product or service in more than one nation) and less often vertically integrated (i.e., conducted under the auspices of a single company and its subsidiaries) than in the past. The fragmentation of production into specific activities and across national boundaries has led to the rise of global value chains and has increased trade in intermediate products (OECD, WTO, and World Bank Group 2014). Trade in intermediate goods and services and capital goods accounts for 70% of global trade, an indicator of the globalization and extent of global value chains (OECD 2014:7). Between 1995 and 2009, the cross-border flows of intermediate goods and services, as well as final products associated with manufacturing value chains, significantly increased (Donofrio and Whitefoot 2015:21). Global value chains have allowed developing countries to industrialize faster and gain income and jobs from providing components, supplies, or specific services, rather than creating an entire industry (OECD and WTO 2013:89).

The globalization of production and rise of global value chains have affected all industries, but their impact has been pronounced in many commercial KTI industries, particularly the ICT industries, and medium-high-technology industries, including motor vehicles and parts and electrical machinery and appliances. The broader context is the rapid expansion of these industrial and service capabilities in many developing countries, both for export and internal consumption, accompanied by an increasing supply of skilled, internationally mobile workers. (See Chapter 2 and Chapter 3 for discussions on internationally mobile students and workers.)

This section focuses on cross-border trade of international knowledge-intensive services and high-technology and medium-high-technology products. Trade data are a useful though imperfect indicator of globalization (for a discussion, see sidebar Measurement and Limitations of Trade Data and sidebar Measurement of Trade in Value-Added Terms).

This discussion of trade trends in knowledge-intensive services and high-technology manufactured products focuses on (1) the trading zones of the North American Free Trade Agreement (NAFTA), with a particular focus on the United States, and the EU, (2) China, and (3) Japan and other Asian economies.

The EU, East Asia, and NAFTA have substantial flows of intraregional trade. China's economy has extensive trade between mainland China and Hong Kong. This section treats trade within these three regions and the economy of China in different ways. Intra-EU and NAFTA exports are not counted because they are integrated trading zones with common external trade tariffs and few restrictions on intraregional trade. Trade between mainland China and Hong Kong is excluded because it is essentially intra-economy trade. (Data on trade in commercial knowledge-intensive services between China and Hong Kong are not available.) Intra-Asian trade is counted for other Asian countries because they have a far smaller degree of political and trade integration.

SIDEBAR

Measurement and Limitations of Trade Data

Trade data are classified by the qualities and characteristics of the products or services themselves, in contrast to industry output data that classify a firm in one industry on the basis of the primary activity of the firm.* Thus, the industry and trade classifications are not compatible with each other and cannot be mapped onto each other. For example, an export classified as a computer service may have originated from a firm that is classified in the computer manufacturing industry because its primary activity is manufacturing computers.

Data on exports and imports represent the market value of products and services in international trade. Exports of products are assigned by the importing country's port of entry to a single country of origin. For goods manufactured in multiple countries, the country of origin is determined by where the product was "substantially transformed" into its final form, which is usually the country of final assembly.

The value of product trade entering or exiting a country's ports may include the value of components, inputs, or services classified in different product categories or originating from countries other than the country of origin. For example, China is credited with the full value (i.e., factory price plus shipping cost) of a smartphone when it is assembled in China, though made with components imported from other countries. In these data, a country whose firms provide high-value services such as design, marketing, and software development for products or services that are produced in a different country are typically not credited for these contributions.

* Traded goods are assigned one product code according to the Harmonized Commodity Description and Coding System, or Harmonized System (HS). HS is used to classify goods traded internationally and was developed under the auspices of the Customs Co-operation Council. Beginning on 1 January 1989, HS numbers replaced schedules previously adhered to in more than 50 countries, including the United States. For more information, see https://www.census.gov/foreign-trade/guide/sec2.html#htsusa.

Global Trade in Commercial Knowledge- and Technology-Intensive Goods and Services

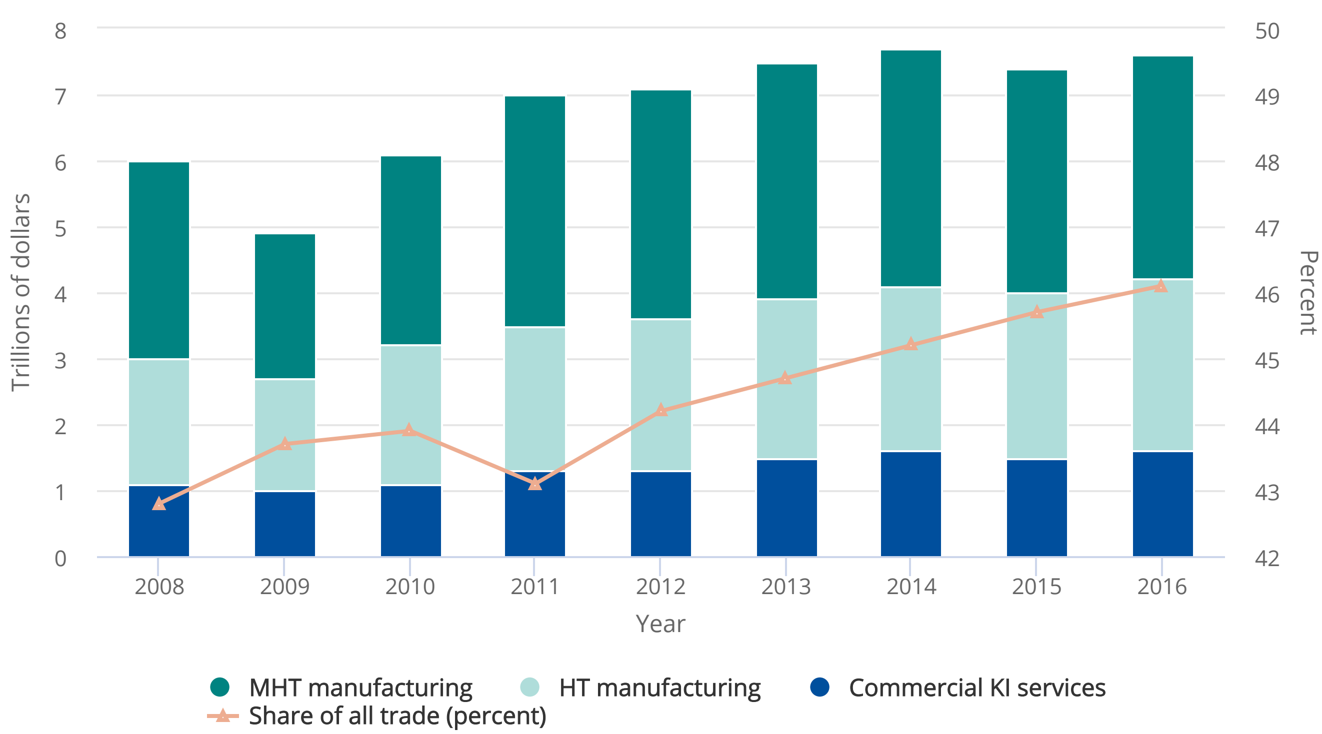
Exported goods and services to other countries are an indicator of a country's economic success in the global market because exports capture the country's products that compete in the world market. In addition, exports bring in income from external sources and do not consume the income of a nation's own residents. However, the use of exports as an indicator of a country's success in global markets has limitations. Exports of goods and services produced in global value chains, including those that have advanced technologies or are knowledge intensive, contain inputs and components supplied by other countries. For example, the value of China's exports of high-technology goods is significantly lower when the foreign content of its exports is excluded (see sidebar Measurement of Trade in Value-Added Terms).

Global trade in commercial KTI goods and services consists of 14 categories. Three categories are knowledge-intensive services—telecommunications, computer, and information; finance; and other business.[1] Eleven are technology-intensive products that consist of six high-technology goods—aerospace; communications; computers; pharmaceuticals; semiconductors; and testing, measuring, and control instruments—and five medium-high-technology goods.

Global exports of commercial KTI goods and services account for 46% of all goods and services exports (Figure 6-21). Global commercial KTI exports were an estimated $7.5 trillion in 2016, consisting of $1.6 trillion of commercial knowledge-intensive services, $2.6 trillion of high-technology products, and $3.4 trillion of medium-high-technology products (Appendix Table 6-25, Appendix Table 6-26, and Appendix Table 6-27).

FIGURE 6-21

Global exports of commercial KTI products and services: 2008–16



HT = high technology; KI = knowledge intensive; KTI = knowledge and technology intensive; MHT = medium-high technology.

Note(s)

Exports of commercial KTI products and services consist of exports of commerical KI services and high technology and medium-high technology manufacturing products. World exports of high technology and medium-high technology exports do not include intra-EU-European Union (EU), intra-North American Free Trade Agreement (NAFTA), and exports betweeen China and Hong Kong. Exports of the EU do not include intra-EU exports. Exports of NAFTA do not include intra-NAFTA exports. Exports of China do not include exports between mainland China and Hong Kong. World exports of commercial KI services consist of other business services; telecommunications and computer and information services; and financial services. Financial services include finance and insurance. World exports and total EU exports of commercial KI services do not include intra-EU trade.

Source(s)

IHS Global Insight, special tabulations of the World Trade Service database (2017) and World Trade Organization, Trade and tariff data. https://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 15 September 2017. See Appendix Table 6-25, Appendix Table 6-30, and Appendix Table 6-31.

Science and Engineering Indicators 2018

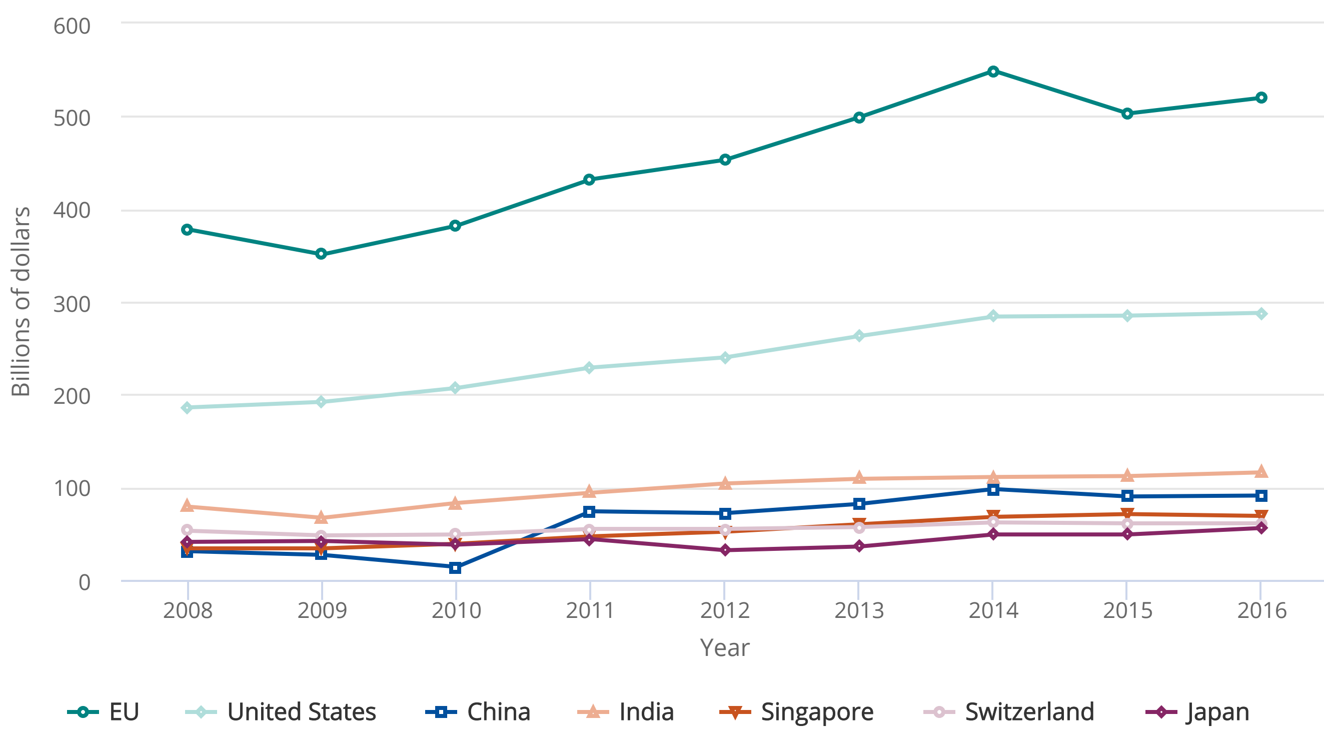
Trade in Commercial Knowledge-Intensive Services

Global exports of commercial knowledge-intensive services make up 43% of all exports of commercial services.[2] Among the commercial knowledge-intensive services, the largest is other business services, which include R&D services, and architectural, engineering, and other technical services ($822 billion) (Appendix Table 6-28).[3] The other two services are finance (which includes insurance and pension) ($399 billion) and telecommunications, computer, and information services ($347 billion) (Appendix Table 6-29 and Appendix Table 6-30).

The EU was the largest exporter of commercial knowledge-intensive services, with a global share of 33% in 2016 (Figure 6-22; Appendix Table 6-25). The United States was the second largest at 18%. Both had substantial surpluses in trade of commercial knowledge-intensive services (Figure 6-23).[4] India is the third largest with a 7% global export share, closely followed by China. Both China and India had surpluses in trade of commercial KI services.

FIGURE 6-22

Commercial KI service exports, by selected region, country, or economy: 2008–16



EU = European Union; KI = knowledge intensive.

Note(s)

Commercial KI service exports consist of communications, business services, financial services, telecommunications, and computer and information services. Financial services include finance, pension, and insurance services. EU exports do not include intra-EU exports.

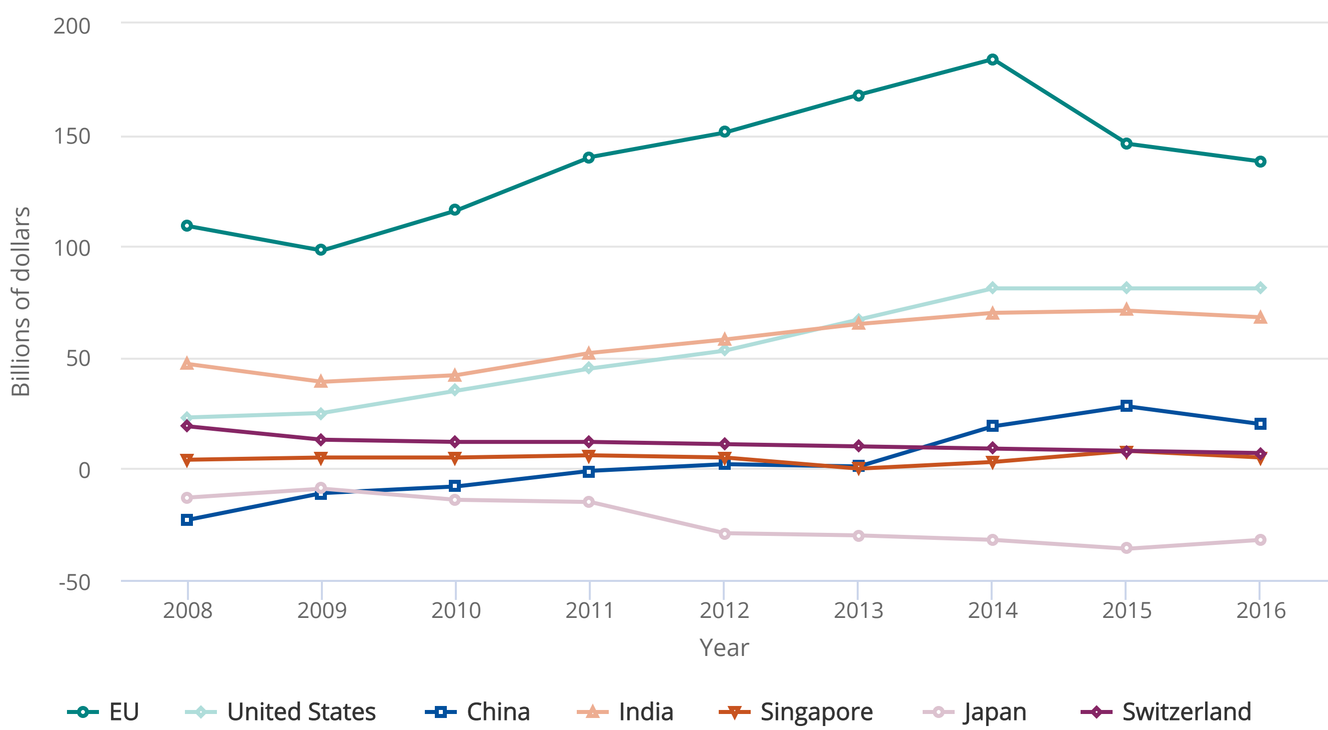
Source(s)

World Trade Organization, International trade and tariff data, https://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 15 September 2017.

Science and Engineering Indicators 2018

FIGURE 6-23

Trade balance of commercial KI services, by selected region, country, or economy: 2008–16



EU = European Union; KI = knowledge intensive.

Note(s)

Commercial KI service exports consist of communications, business services, financial services, telecommunications, and computer and information services. Financial services include finance, pension, and insurance services. EU exports do not include intra-EU exports.

Source(s)

World Trade Organization, International trade and tariff data, https://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 15 September 2017.

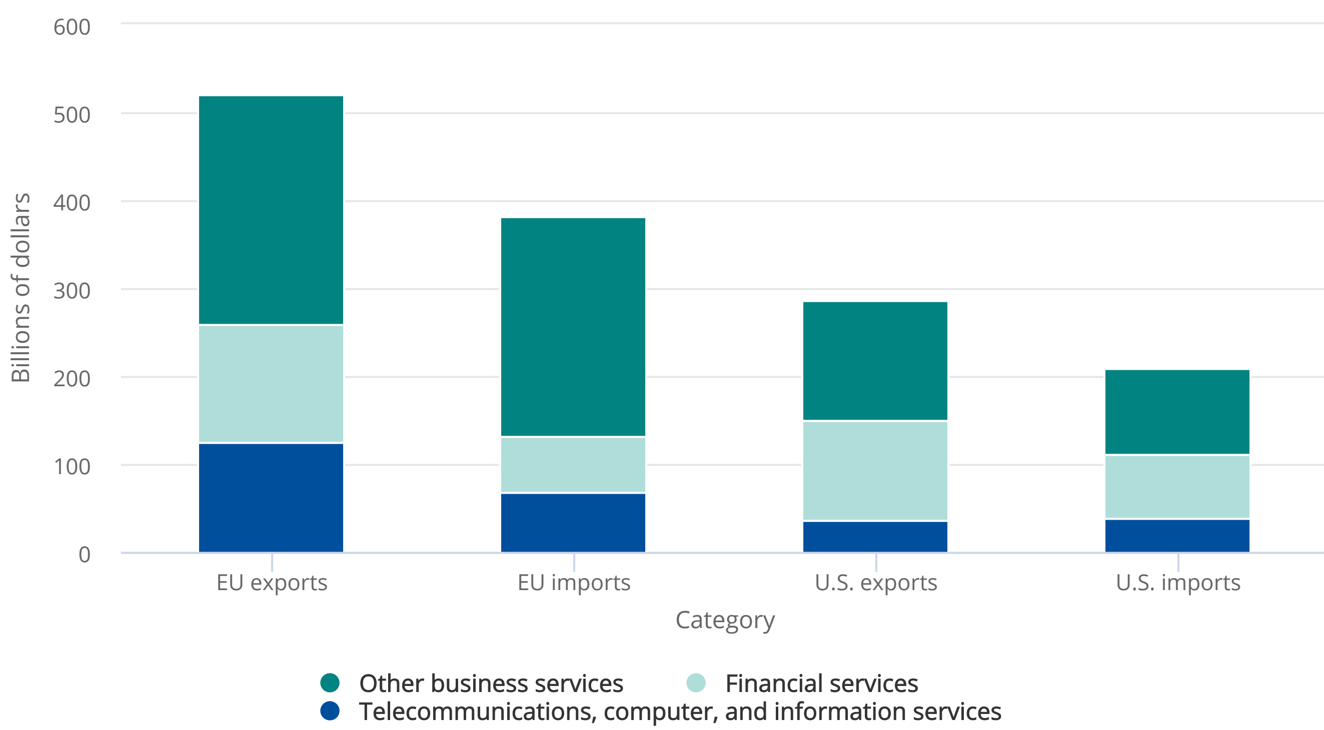
Science and Engineering Indicators 2018

EU Trade in Commercial Knowledge-Intensive Services.

The EU's exports of commercial knowledge-intensive services grew 20% between 2011 and 2016 to reach $520 billion (Figure 6-22; Appendix Table 6-25). Output in the EU's commercial KI industries declined during this period, in sharp contrast to the rise in exports. The euro's substantial depreciation against the dollar, which made EU exports more competitive in global markets, may have contributed to the growth of commercial knowledge-intensive exports (see sidebar Currency Exchange Rates of Major Economies) (Figure 6-6; Appendix Table 6-4). Exports of other business services and telecommunications, computer, and information services drove overall growth, increasing 26% and 29%, respectively, during this period (Appendix Table 6-28 and Appendix Table 6-29). The EU's trade surplus in commercial knowledge-intensive services was $138 billion in 2016, unchanged from its level in 2011 (Figure 6-23 and Figure 6-24; Appendix Table 6-25).

FIGURE 6-24

U.S. and EU commercial KI services trade, by category: 2016



EU = European Union; KI = knowledge intensive.

Note(s)

Commercial KI services trade consists of communications, other business services, financial services, and computer and information services. Financial services include finance and insurance. EU trade does not include intra-EU trade.

Source(s)

World Trade Organization, International trade and tariff data, https://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 15 January 2017.

Science and Engineering Indicators 2018

U.S. Trade in Commercial Knowledge-Intensive Services.

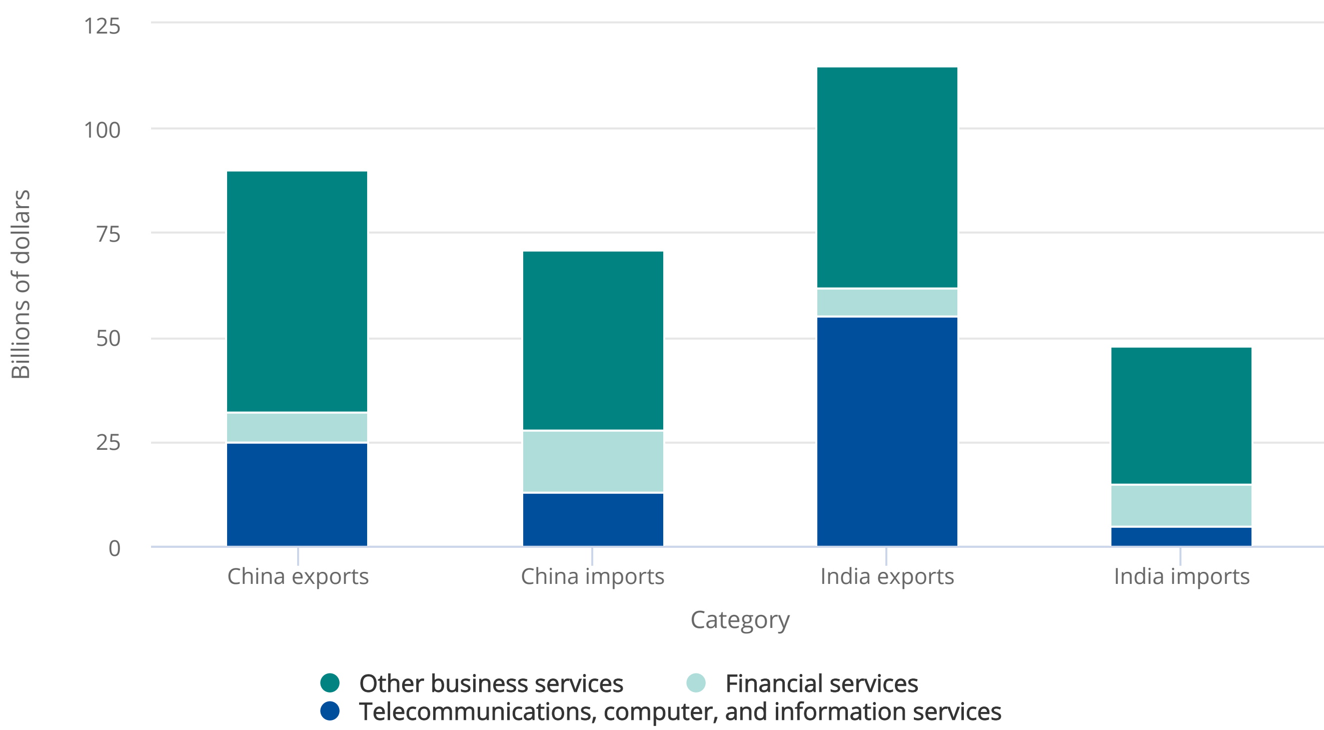
U.S. exports of commercial knowledge-intensive services grew 26% from 2011 to 2016 to reach $288 billion (Figure 6-22; Appendix Table 6-25). The growth of U.S. exports was spurred by growth in other business services (28%) and telecommunications, computer, and information services (28%) (Appendix Table 6-28 and Appendix Table 6-29). The U.S. trade surplus widened from $45 billion to $81 billion, reflecting growing surpluses in other business and financial services (Figure 6-23 and Figure 6-24).

China's and India's Trade in Commercial Knowledge-Intensive Services

China's and India's exports each grew 22% between 2011 and 2016, slightly faster than the EU (Figure 6-22; Appendix Table 6-25). India's growth was led by other business services (38%), coinciding with the Indian firms that provide accounting and other services to firms in developed countries (Appendix Table 6-28). Indian firms also have been very successful in providing IT services to firms in developing countries; India is the world's second largest exporter of telecommunications, computer, and information services (16% global share) (Appendix Table 6-29). India's trade surplus grew from $52 billion to $68 billion from 2011 to 2016 due to the widening of its surplus in other business services and telecommunications, computer, and information services (Figure 6-23 and Figure 6-25).

FIGURE 6-25

China's and India's trade in commercial KI services, by category: 2016



KI = knowledge intensive.

Note(s)

Commercial KI services trade consists of communications, other business services, financial services, and computer and information services. Financial services include finance and insurance.

Source(s)

World Trade Organization, International trade and tariff data, https://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 15 January 2017.

Science and Engineering Indicators 2018

China's growth in commercial KI exports was led by a near doubling of its exports of telecommunications, computer, and information services between 2011 and 2016 (Figure 6-22; Appendix Table 6-25 and Appendix Table 6-29). China's global share in telecommunications, computer, and information services edged up from 5% to 7% during this period, coinciding with rapid growth of Chinese firms providing IT services to developed countries, making it the world's fourth largest exporter after India.[5]

Trade in High-Technology Products

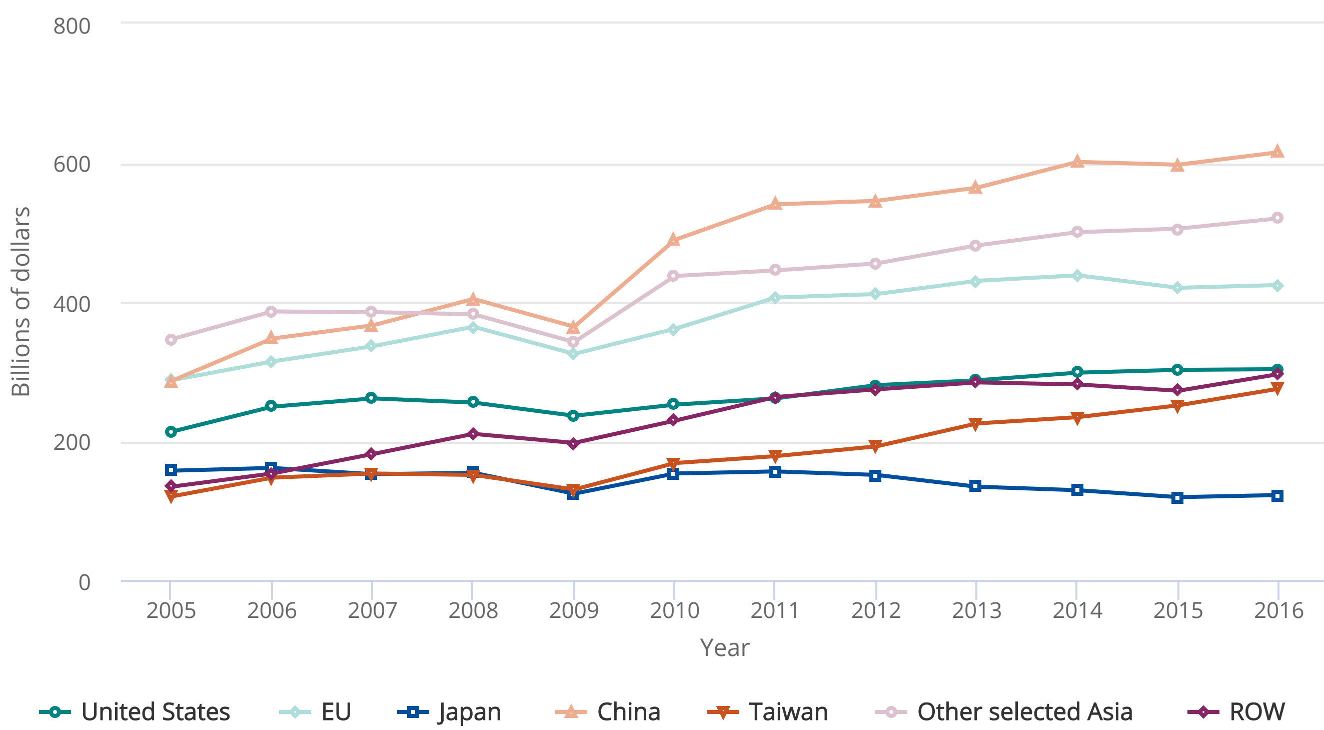
High-technology product exports accounted for 19% of the $13.0 trillion in total manufactured goods exports.[6] The value of global high-technology product exports ($2.6 trillion in 2016) was dominated by ICT products—communications, computers, and semiconductors—with a collective value of $1.4 trillion, more than half of the total in this category (Appendix Table 6-26, and Appendix Table 6-31 through Appendix Table 6-34). Aircraft and spacecraft; pharmaceuticals; and testing, measuring, and control instruments combined added about $1.1 trillion in 2016 (Appendix Table 6-35, Appendix Table 6-36, and Appendix Table 6-37).

China is the world's largest exporter of high-technology goods (24% global share) and has a substantial surplus (Figure 6-26 and Figure 6-27; Appendix Table 6-26). However, because many of China's exports consist of inputs and components imported from other countries, China's exports and trade surplus are likely much less in value-added terms (see sidebar Measurement of Trade in Value-Added Terms).

The EU is the second largest global exporter (17% global share), and its trade position is roughly in balance (Figure 6-26 and Figure 6-27; Appendix Table 6-26). The United States is the third largest exporter (12%) closely followed by Taiwan (11%). The United States has a deficit and Taiwan has a substantial surplus. (For a list of regions and countries and economies in world trade data, see Appendix Table 6-38.)

FIGURE 6-26

Exports of HT products, by selected region, country, or economy: 2005–16



EU = European Union; HT = high technology; ROW = rest of world.

Note(s)

HT products aircraft and spacecraft; communications and semiconductors; computers; pharmaceuticals; and testing, measuring, and control instruments. Data are not available for EU members Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Other selected Asia consists of Indonesia, Malaysia, Philippines, Singapore, South Korea, Thailand, Taiwan, and Vietnam. Exports of the United States exclude exports to Canada and Mexico. Exports of the EU exclude intra-EU exports. Exports of China exclude exports between China and Hong Kong.

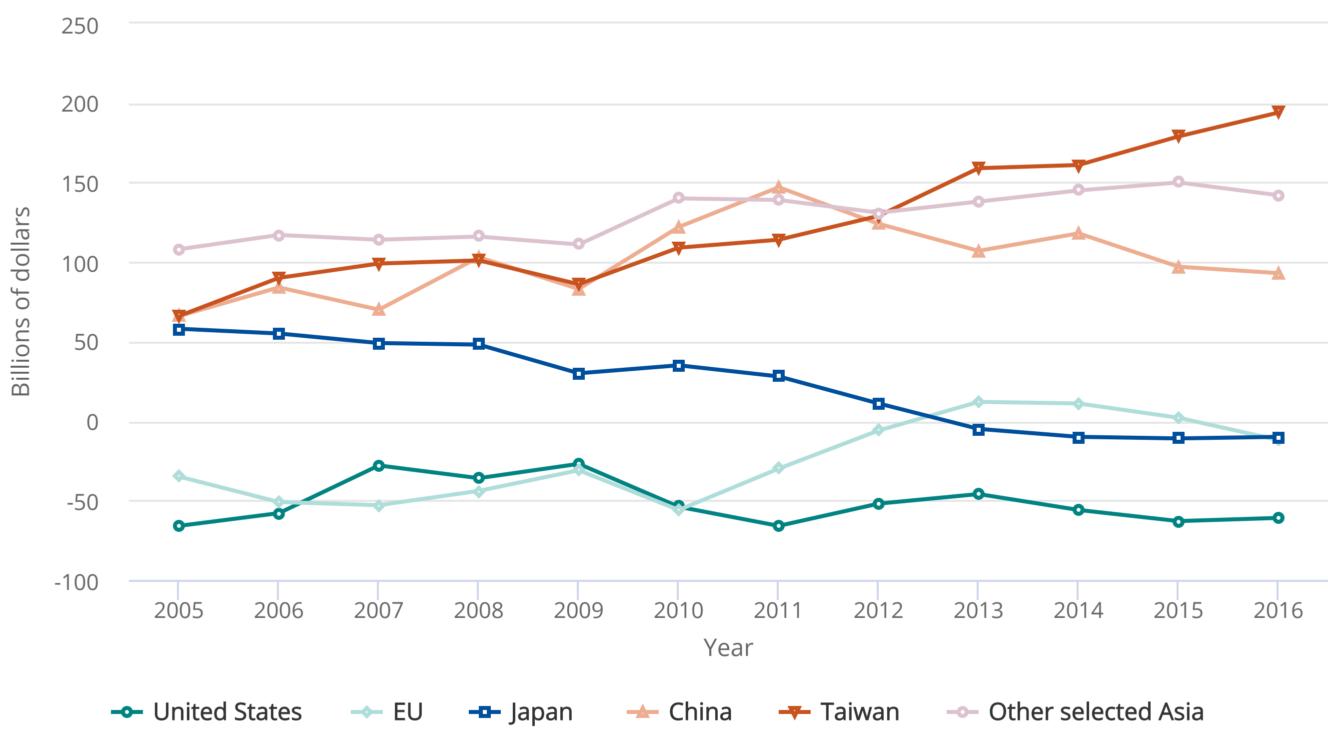
Source(s)

IHS Global Insight, World Trade Service database (2018). See Appendix Table 6-20.

Science and Engineering Indicators 2018

FIGURE 6-27

Trade balance of HT products, by selected region, country, or economy: 2005–16



EU = European Union; HT = high technology.

Note(s)

HT products include aircraft and spacecraft; communications and semiconductors; computers; pharmaceuticals; and testing, measuring, and control instruments. Data are not available for EU members Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Other selected Asia consists of Malaysia, Philippines, Singapore, South Korea, Thailand, Taiwan, and Vietnam. Exports and imports of the United States exclude exports to Canada and Mexico. Exports and imports of the EU exclude intra-EU exports. Exports and imports of China exclude exports between China and Hong Kong.

Source(s)

IHS Global Insight, World Trade Service database (2017). See Appendix Table 6-20.

Science and Engineering Indicators 2018

China's Trade in High-Technology Goods

Between 2011 and 2016, China's high-technology exports grew 14% to reach $615 billion, and the trade surplus fell from $147 billion to $93 billion (Figure 6-26 and Figure 6-27; Appendix Table 6-26). Growth of China's high-technology products exports has slowed sharply in the post-global recession period. Exports grew at an annualized average of 3% between 2011 and 2016, compared to 24% between 2001 and 2008. China's slowdown in high-technology exports reflects the cooling-off of China's economic growth and sluggish export demand by the EU, Japan, and large developing countries that have had slow or negative economic growth. China's global share stayed stable at 24% in the post-global recession period after increasing rapidly in the prior decade.

China's ICT exports also grew at a much slower rate in the post-global recession period than prior to the recession (Appendix Table 6-31 through Appendix Table 6-34). China's ICT exports dominate its high-technology exports, and China is the world's largest exporter of ICT products (Appendix Table 6-31). China's ICT trade surplus slightly narrowed to reach $153 billion during this period.

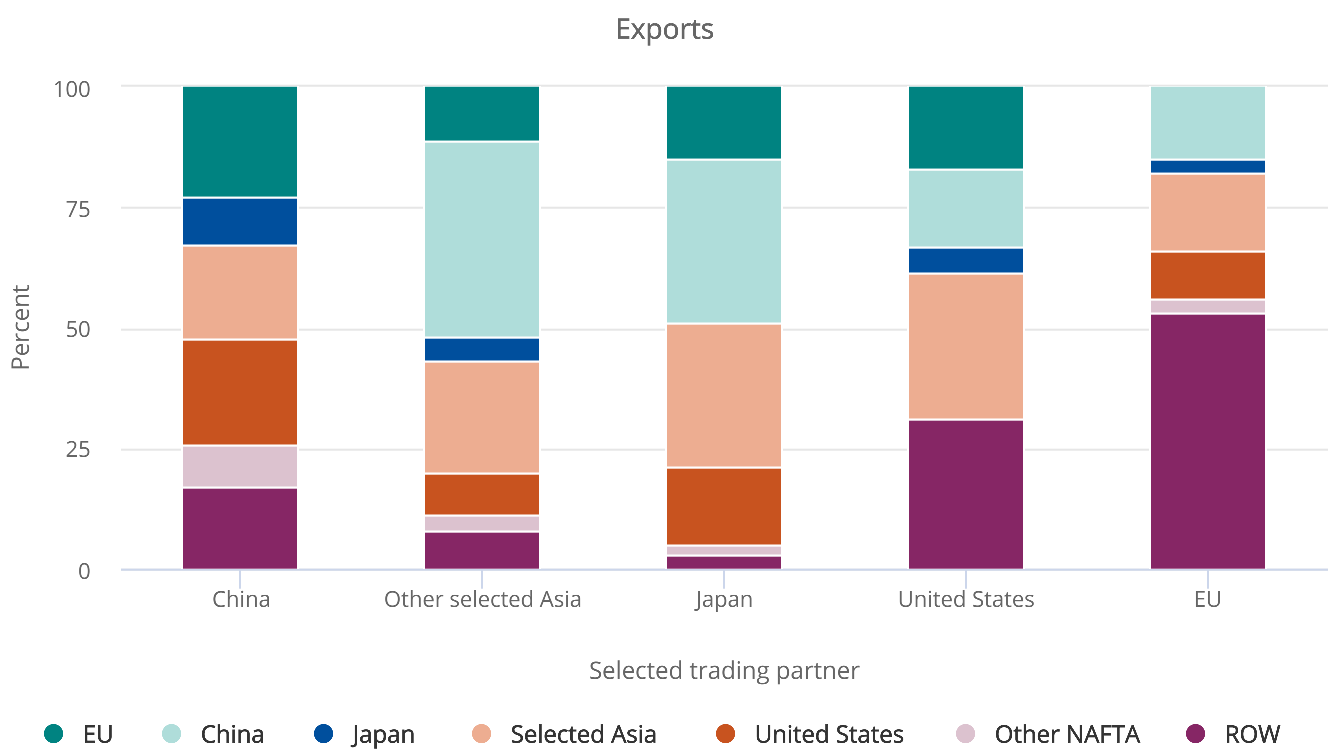
China is the hub of "Factory Asia," which produces much of the world's ICT products. The patterns of China's trade with its major partners shows its integration with other Asian producers that supply components and parts (Figure 6-28). Imports from eight Asian economies—Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam—account for three-quarters of China's ICT imports. However, conventional trade statistics do not measure the contribution by countries that produce ICT and other products in global value chains. Data on value-added trade, which estimates the contribution of countries for goods produced in global value chains, suggest that the United States, the EU, South Korea, and Taiwan are a significant source of China's imports of ICT goods in the form of inputs and components (see sidebar Measurement of Trade in Value-Added Terms).

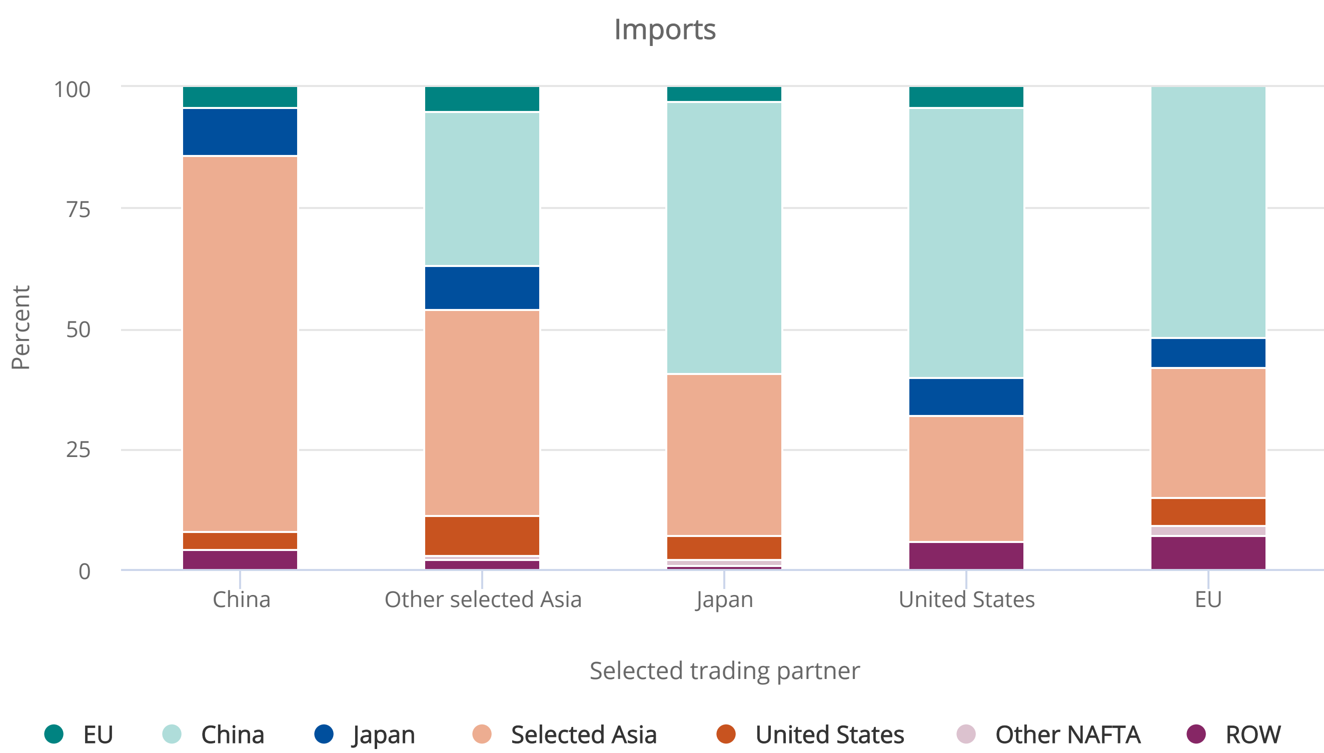
More than half of China's ICT exports are destined for the three major developed economies—the EU (23%), the United States (22%), and Japan (10%). China's export share with the eight Asian economies is 20%, far less than its import share (Figure 6-28).

China's exports of testing, measuring, and control instruments grew more than twice as fast (30%) as its ICT exports between 2011 and 2016 to reach $72 billion (Appendix Table 6-31 and Appendix Table 6-35).

FIGURE 6-28

Trade in ICT products of selected regions, countries, or economies, by selected trading partner: 2016





EU = European Union; ICT = information and communications technology; NAFTA = North American Free Trade Agreement; ROW = rest of world.

Note(s)

ICT products include communications, semiconductors, and computers and office machinery. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Other selected Asia includes Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam.

Source(s)

IHS Global Insight, World Trade Service database (2016). See Appendix Table 6-20.

Science and Engineering Indicators 2018

EU Trade in High-Technology Goods

The EU's high-technology exports edged up 5% between 2011 and 2016, with the EU's global share remaining stable at 17%–18% (Figure 6-26; Appendix Table 6-26). Output of the EU's high-technology manufacturing industries increased slightly during this period, in contrast to growth in exports (Figure 6-11). The euro's substantial depreciation against the dollar, which made EU exports more competitive in global markets, among other things, may have contributed to the growth of exports (see sidebar Currency Exchange Rates of Major Economies) (Figure 6-11; Appendix Table 6-8). Aircraft and pharmaceuticals grew the fastest, driving the growth of the EU's high-technology exports (Appendix Table 6-36 and Appendix Table 6-37). The EU is the world's largest exporter of pharmaceuticals, and its global share remained roughly stable at 44%–46% in the post-global recession period (Appendix Table 6-36). The EU's trade surplus in pharmaceuticals slightly increased during this period. The EU is the world's second largest exporter in aircraft; the EU's global share slid from 39% to 32% (Appendix Table 6-37). The

EU's trade surplus slightly narrowed during this period. Exports of ICT products declined sharply (25%), and the EU's global share dropped from 7% to 5% (Appendix Table 6-31 through Appendix Table 6-34).

U.S. Trade in High-Technology Goods

U.S. high-technology product exports grew 16% in the post-global recession period, with the U.S. global share remaining stable at 12% (Figure 6-26; Appendix Table 6-26). The U.S. trade deficit remained in a range of $46–$66 billion (Figure 6-27).[7] Aircraft drove overall export growth, increasing by 52% (Appendix Table 6-37). Exports of aircraft climbed to $130 billion, and the related trade surplus widened from $57 billion to $89 billion. The United States maintained its dominance as the world's largest exporter of aircraft (43% global share). Pharmaceutical exports reached $50 billion, and the deficit widened from $26 billion to $45 billion (Appendix Table 6-36).

ICT product exports declined by 13% to reach $64 billion between 2011 and 2016, with the U.S. global share declining from 6% to 4% (Appendix Table 6-31 through Appendix Table 6-34). Much of the U.S. trade deficit in ICT products ($106 billion) is with China; more than half of U.S. imports are from China, while China has a far smaller share of U.S. ICT exports (Figure 6-28). However, conventional trade statistics attribute the substantial foreign content as part of the value of China's ICT exports. The United States and other countries export sophisticated ICT inputs and components to China and other Asian economies, and they are then assembled in China. For example, the United States exports slightly half of its total ICT exports to Asian economies involved in ICT production and trade, including China (16%), Japan (5%), and eight other Asian economies —Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam (30%) (Figure 6-28). Some of the U.S. ICT exports to other Asian economies likely end up in China. The United States likely has higher exports and a lower trade deficit on value-added terms, which attributes the U.S. content embodied in exports by China and other countries to the value of U.S. exports (see sidebar Measurement of Trade in Value-Added Terms).

High-Technology Goods Trade of Other Countries

Taiwan's high-technology exports grew by more than 50% during the post-global recession period, reaching $275 billion (Figure 6-26; Appendix Table 6-26). Taiwan's global share rose from 8% to 11% to nearly reach the level of the United States. Taiwan's rapid gains in high-technology exports were due to growth of ICT product exports (56%), which reached $238 billion (Appendix Table 6-31 through Appendix Table 6-34). Taiwan is the world's second largest exporter of ICT products (17% global share) behind China (Appendix Table 6-31).

Vietnam's exports grew the fastest of any country, with its high-technology exports increasing nearly five-fold to reach $63 billion (Appendix Table 6-26). ICT exports, which comprise nearly all of Vietnam's high-technology exports, reached $61 billion (Appendix Table 6-31 through Appendix Table 6-34). Vietnam has become a low-cost location for assembly of cell phones and other ICT products, with some firms shifting production out of China, where labor costs are higher.[8]

India's exports grew 38% between 2011 and 2016 to reach $31 billion. Exports of pharmaceuticals grew by 61% to reach $19 billion (Appendix Table 6-36). India and China are the largest exporters of pharmaceutical goods among developing countries, with a 5% and 4% global share, respectively.

SIDEBAR

Measurement of Trade in Value-Added Terms

Manufactured goods increasingly embody elements produced by global supply chains, and the conventional trade measures reported throughout this chapter count the gross value of both intermediate and final goods upon crossing international borders. The Trade in Value Added joint initiative of the Organisation for Economic Co-operation and Development (OECD) and the World Trade Organization (WTO) aims to correct this shortcoming by recording only net value added at each crossing. This approach has two advantages: First, it provides more accurate measures of the value of global trade; and second, it enables better estimates of national contributions to the value of goods and services—their value-added—in international trade.

Although it does not cover all six high-technology goods, the OECD/WTO database has value-added and conventional data on the computer, electrical, and optical equipment category. This category is roughly equivalent to four of the six products classified as high technology—communications, computers, semiconductors, and scientific measuring instruments. These industries are most often produced in complex and dispersed global supply chains across multiple countries. Foreign content accounted for 42% of global exports of optical and electrical equipment in 2011, the highest share among the OECD/WTO classified manufacturing industries.*

The OECD/WTO data suggest that China has a weaker position in trade of computer, electrical, and optical equipment on a value-added basis compared to a conventional basis. China is the world's largest exporter (33% global share) on a conventional basis, with a wide lead over the EU, the United States, Japan, South Korea, and Taiwan (Figure 6-E). Although it continues to be the largest global exporter on a value-added basis, China's global share is comparatively lower (19%), and its lead over the United States and other major exporters is far narrower. The large decline of China's global share moving from a conventional to a value-added basis is due to the high share of foreign content in China's exports. The value-added measurement of China's exports attributes the foreign content of China's exports to the countries that supplied the components. These countries include the EU, the United States, Japan, and other Asian countries.

FIGURE 6-E

Exports of computer, electrical, and optical equipment, by selected region, country, or economy on conventional and value-added basis: 2011

EU = European Union.

Note(s)

Exports measured on a conventional basis are based on customs data and include intermediate inputs and components imported from other countries. Exports measured on a value-added basis estimate the value added of inputs and components originating from the region, country, or economy and exclude intermediate inputs and components imported from other countries. The EU includes the current 28 member countries. EU exports exclude exports among EU member countries. China includes Hong Kong. China's exports exclude exports between China and Hong Kong. U.S. exports exclude exports to Canada and Mexico.

Source(s)

Organisation for Economic Co-operation and Development, Trade in Value Added Database, https://stats.oecd.org/Index.aspx?DataSetCode=TIVA2015_C1, accessed 3 November 2017.

Science and Engineering Indicators 2018

In addition to a smaller global export share, China's trade surplus shrank from $120 billion on a conventional basis in 2011 to $1 billion on a value-added basis (Figure 6-F). The decline in China's overall trade surplus is largely due to a sharp fall in its bilateral surplus with the United States, which declined from nearly $120 billion to under $20 billion. The decline in China's trade surplus with the United States was mainly due to increases in imports from the United States, which rose from 6% of total imports on a conventional basis to 13% on a value-added basis. This suggests that China's imports contain inputs and components supplied by the United States that are credited to the United States when utilizing the value-added basis. China's trade deficits with South Korea and Taiwan fell, coinciding with a decline in their share of China's total imports.

FIGURE 6-F

China's trade balance in the electrical and optical equipment industry, by selected region, country, or economy on conventional and value-added basis: 2011

EU = European Union; ROW = rest of world.

Note(s)

Exports and imports measured on a conventional basis are based on customs data and include intermediate inputs and components imported from other countries. Exports and imports measured on a value added basis estimate the value added of inputs and components originating from the region, country, or economy and exclude intermediate inputs and components imported from other countries. The EU includes the current 28 member countries. EU exports exclude exports and imports among EU member countries. China includes Hong Kong. China's exports and imports exclude exports and imports between China and Hong Kong. U.S. exports and imports exclude exports and imports to Canada and Mexico. Other selected Asia includes India, Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam.

Source(s)

Organisation for Economic Co-operation and Development, Trade in Value Added Database, https://stats.oecd.org/Index.aspx?DataSetCode=TIVA2015_C1, accessed 3 November 2017.

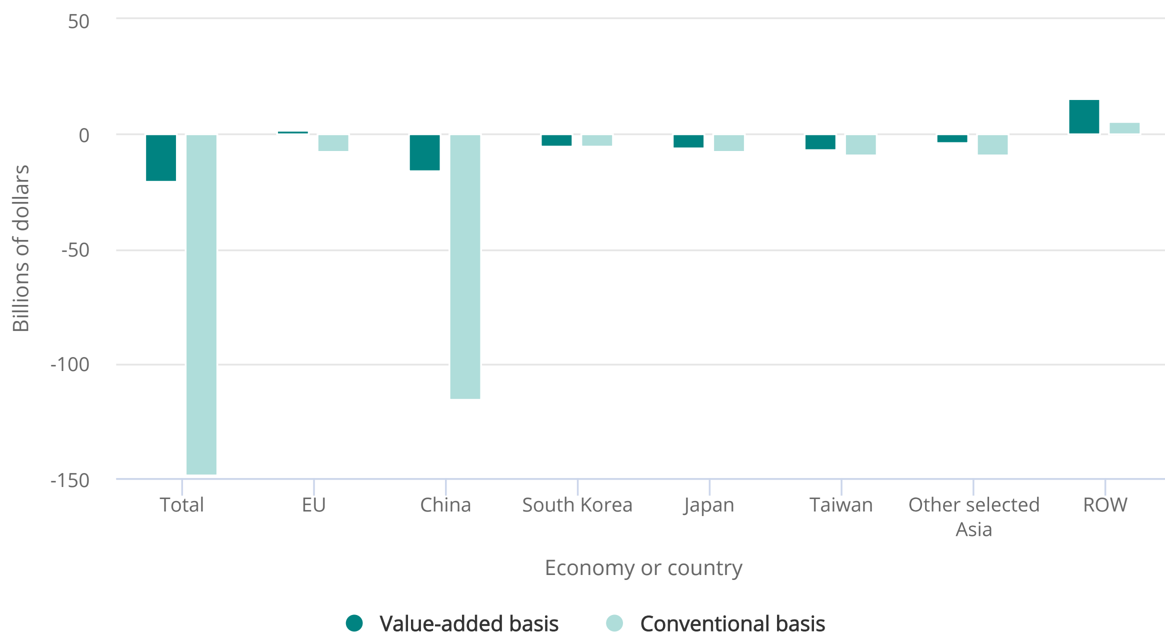
Science and Engineering Indicators 2018

The United States had a comparatively stronger trading position on a value-added basis compared to a conventional basis. On a conventional basis, the United States was tied with Japan, South Korea, and Taiwan as the world's third-largest exporter (7% global share), and is far below China (Figure 6-E). On a value-added basis, the U.S. export share jumped to 16%, making it the world's second-largest exporter, with a far narrower gap with first-ranked China. Measuring U.S. exports on a value-added basis credited the United States for the exports of inputs and components to China and other countries, which were credited to the location of final assembly on a conventional basis.

The higher U.S. global export share on a value-added basis coincides with a much narrower U.S. trade deficit, which dropped from nearly $150 billion on a conventional basis to $21 billion on a value-added basis (Figure 6-G). The narrower trade deficit is largely due to a much smaller bilateral trade deficit with China. The improvement in the bilateral deficit is primarily due to lower Chinese imports, which declined from about half of total U.S. imports on a conventional basis to 30% on a value-added basis. The import shares of Japan, South Korea, and Taiwan, which are major suppliers of inputs to China, rose from a collective share of 17% to 33% of total U.S. imports, suggesting that these three economies were exporting intermediate inputs to the United States that were then further processed and exported to China.

FIGURE 6-G

U.S. trade balance in the electrical and optical equipment industry, by selected country or economy on conventional and value-added basis: 2011



EU = European Union; ROW = rest of world.

Note(s)

Exports and imports measured on a conventional basis are based on customs data and include intermediate inputs and components from other countries. Exports and imports measured on a value added basis estimate the value added of inputs and components originating from the region, country, or economy and exclude imports of inputs and components from other countries. The EU includes the current 28 member countries. EU exports exclude exports and imports among EU member countries. China includes Hong Kong. China's exports and imports exclude exports and imports between China and Hong Kong. U.S. exports and imports exclude exports and imports to Canada and Mexico. Other selected Asia includes India, Indonesia, Malaysia, Philippines, Thailand, and Vietnam.

Source(s)

Organisation for Economic Co-operation and Development, Trade in Value Added Database, https://stats.oecd.org/Index.aspx?DataSetCode=TIVA2015_C1, accessed 3 November 2017.

Science and Engineering Indicators 2018

Data on the OECD/WTO trade in value-added indicators and additional information are available at https://www.oecd.org/industry/ind/measuringtradeinvalue-addedanoecd-wtojointinitiative.htm.

* OECD, Trade in Value Added Database, October 2015 http://stats.oecd.org/Index.aspx?DataSetCode=TIVA2015_C1.

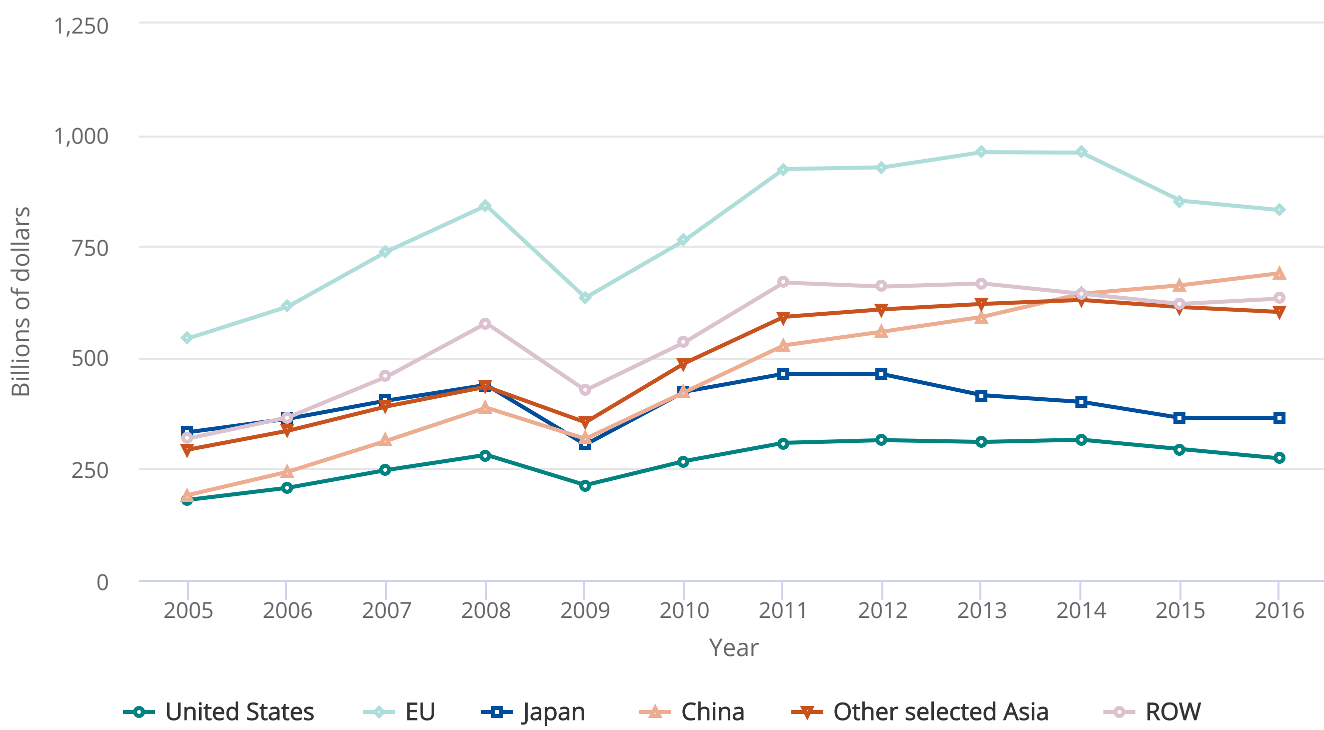
Medium-High-Technology Products

Medium-high-technology product exports accounted for 25% of the $13.0 trillion in total manufactured goods exports.[9] Global medium-high-technology product export value ($3.4 trillion in 2016 measured conventionally at port of entry) was dominated by three products—chemicals excluding pharmaceuticals ($1.2 trillion), machinery and equipment ($1.0 trillion), and motor vehicles and parts ($0.7 trillion) (Figure 6-29; Appendix Table 6-27, Appendix Table 6-39, Appendix Table 6-40, and Appendix Table 6-41). Electrical equipment and appliances added $0.5 trillion, and railroad and other transportation accounted for $24 billion (Appendix Table 6-42 and Appendix Table 6-43).

The EU is the world's largest exporter of medium-high-technology goods (25% global share). China, the second largest global exporter with a 20% global share, also has a substantial trade surplus, as does Japan (11% global share) (Figure 6-29 and Figure 6-30; Appendix Table 6-27). In contrast, the United States, the fourth largest exporter (8% global share), has a substantial deficit ($225 billion). For a list of regions and countries/economies in world trade data, see Appendix Table 6-38.

FIGURE 6-29

Exports of MHT products, by selected region, country, or economy: 2005–16



EU = European Union; MHT = medium-high technology; ROW = rest of world.

Note(s)

MHT products include motor vehicles and parts, electrical machinery, machinery and equipment, chemicals excluding pharmaceuticals, and railroad and other transportation equipment. Data are not available for EU members Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Other selected Asia consists of Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. Exports of the United States exclude exports to Canada and Mexico. Exports of the EU exclude intra-EU exports. Exports of China exclude exports between China and Hong Kong.

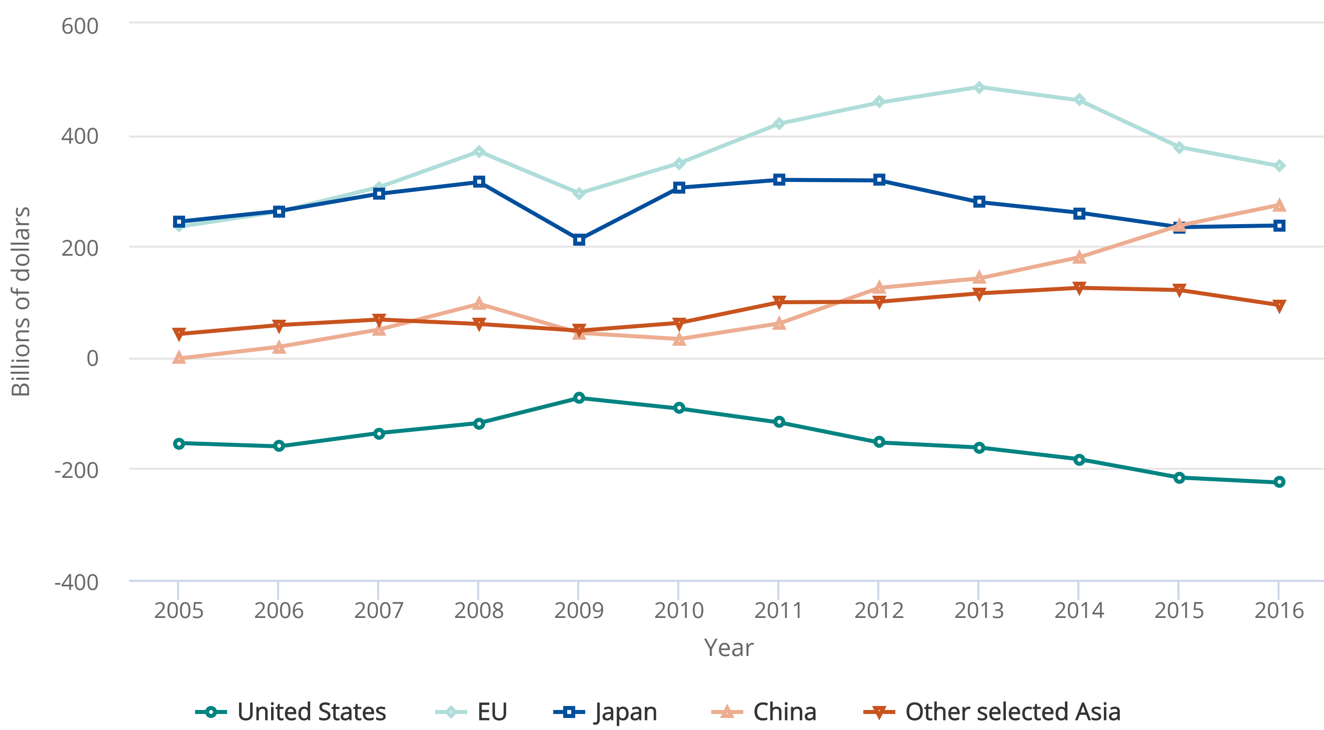
Source(s)

IHS Global Insight, World Trade Service database (2017). See Appendix Table 6-20.

Science and Engineering Indicators 2018

FIGURE 6-30

Trade balance of MHT products, by selected region, country, or economy: 2005–16



EU = European Union; MHT = medium-high technology.

Note(s)

MHT products include motor vehicles and parts, electrical machinery, machinery and equipment, chemicals excluding pharmaceuticals, and railroad and other transportation equipment. Data are not available for EU members Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Other selected Asia consists of Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam. Exports and imports of the United States exclude exports to Canada and Mexico. Exports and imports of the EU exclude intra-EU exports. Exports and imports of China exclude exports between China and Hong Kong.

Source(s)

IHS Global Insight, World Trade Service database (2017). See Appendix Table 6-20.

Science and Engineering Indicators 2018

EU Trade in Medium-High-Technology Goods

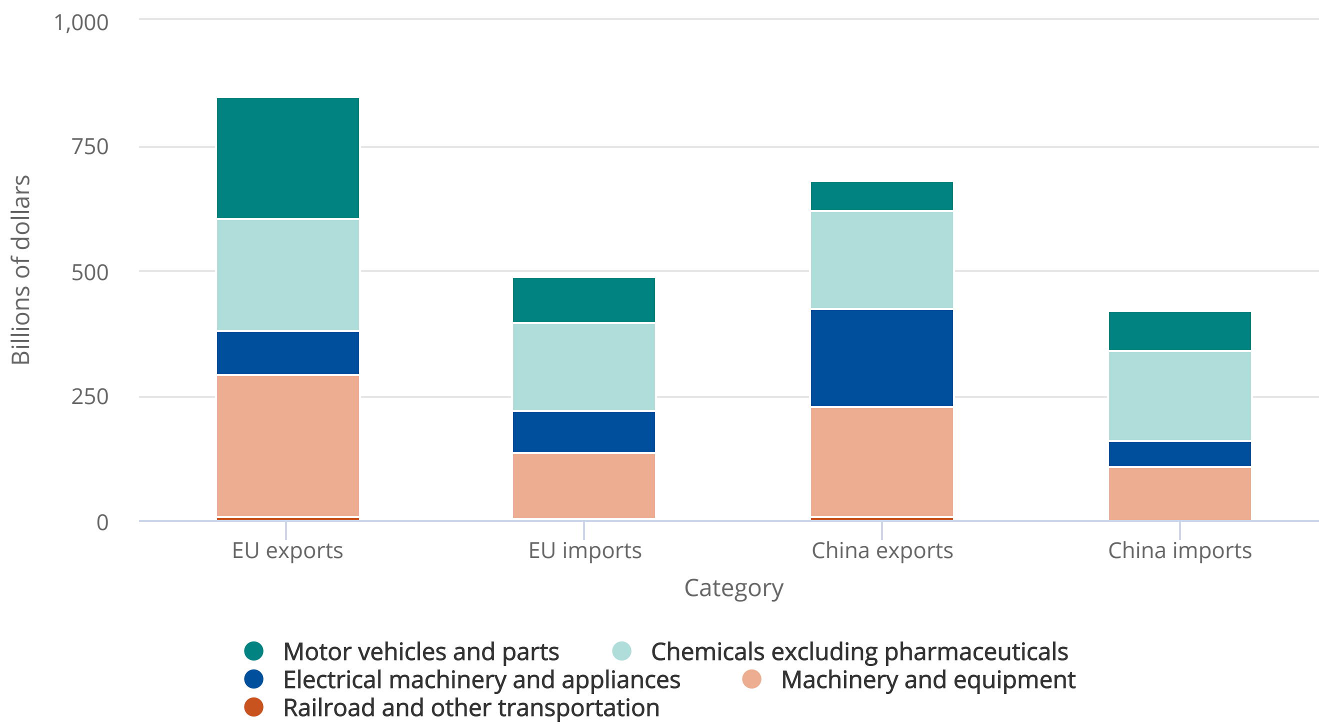
The EU's medium-high-technology exports fell 10% between 2011 and 2016, with its trade surplus falling from $420 billion to $344 billion (Figure 6-29, Figure 6-30, and Figure 6-31; Appendix Table 6-27).

Exports of chemicals excluding pharmaceuticals, machinery and equipment, and electrical equipment and appliances each fell by 9%–13% during this period (Appendix Table 6-40, Appendix Table 6-41, and Appendix Table 6-42). The EU is the world's largest exporter of chemicals excluding pharmaceuticals and machinery and equipment. The EU's global share stayed stable in chemicals excluding pharmaceuticals (19%–20%) and fell slightly in machinery and equipment to reach 29%. The trade surplus in machinery and equipment fell from $190 billion to $152 billion.

Exports of motor vehicles and parts were stagnant during this period (Appendix Table 6-39). The EU is the world's largest exporter of motor vehicles and parts, excluding the considerable amount of intra-EU exports (34% global share). The considerable value of intra-EU trade in this industry suggests that much of the inputs, components, and final assembly is located in the EU and that many EU-produced cars and trucks are sold within the EU.[10] The United States and China are major export markets for the EU.

FIGURE 6-31

China and EU MHT trade, by product: 2016



EU = European Union; MHT = medium-high technology.

Note(s)

MHT products include motor vehicles and parts, electrical machinery, machinery and equipment, chemicals excluding pharmaceuticals, and railroad and other transportation equipment. China includes Hong Kong. Data are not available for EU members Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Exports and imports of China exclude exports between China and Hong Kong. Exports and imports of the EU exclude intra-EU exports.

Source(s)

IHS Global Insight, World Trade Service database (2017). See Appendix Table 6-20.

Science and Engineering Indicators 2018

China's Trade in Medium-High-Technology Goods

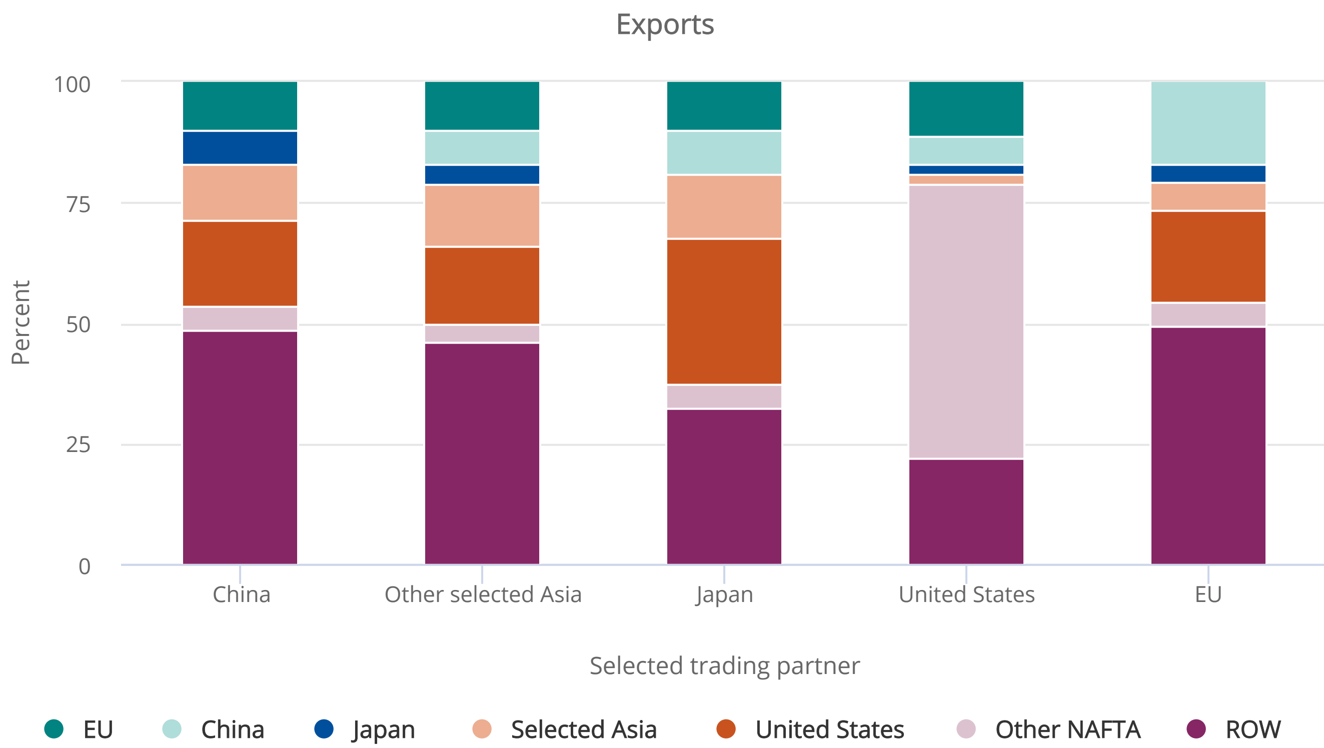
China was the only major economy whose exports of medium-high-technology expanded between 2011 and 2016, reaching $689 billion, a 31% increase (Figure 6-29; Appendix Table 6-27). China's trade surplus widened from $61 billion to $274 billion (Figure 6-30 and Figure 6-31). Over the last decade, China's exports have nearly tripled, and China's global share has climbed from 11% to 20%. China surpassed Japan in 2011 to become the world's second largest exporter, and its gap with the EU, the world's largest exporter, has narrowed considerably.

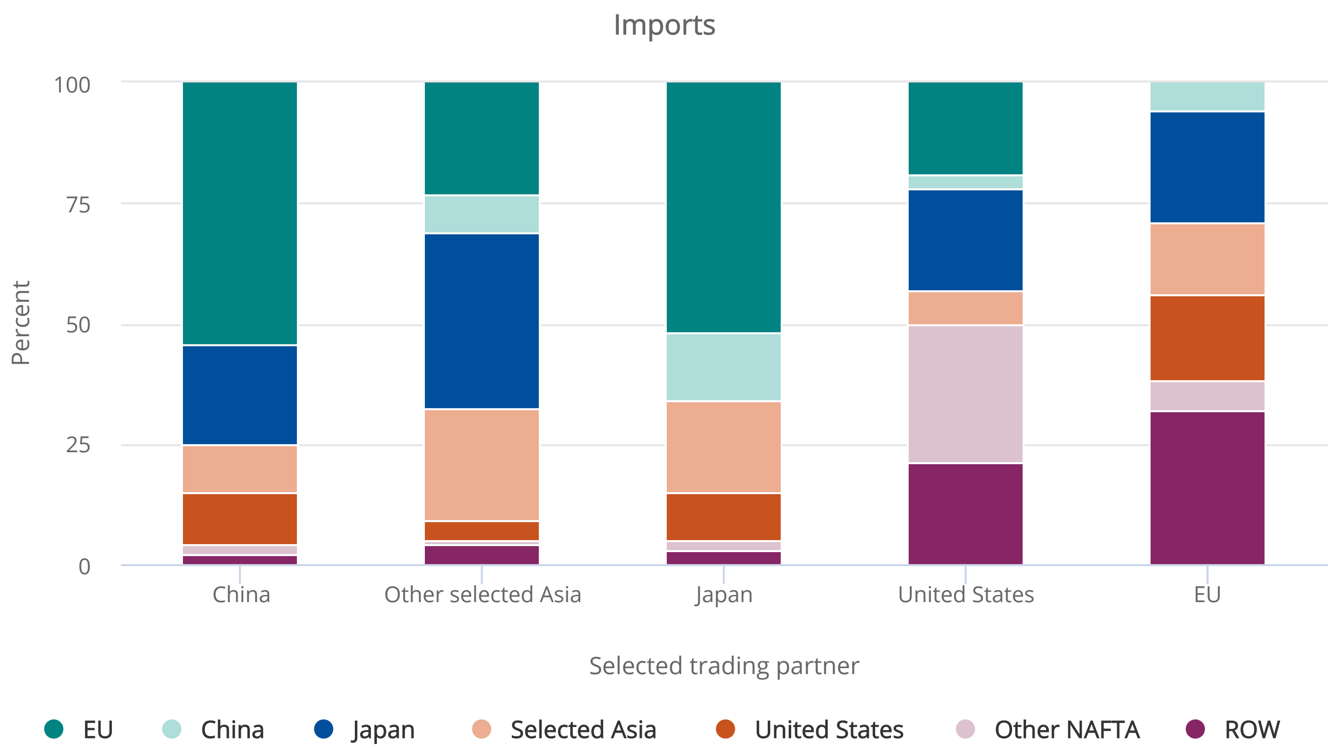
Growth of China's medium-high-technology exports following the global recession has slowed markedly since prior to the recession, from 27% annualized average between 2001 and 2008 to 6% between 2011 and 2016 (Figure 6-29; Appendix Table 6-27). The slowdown of China's medium–high technology exports coincides with the cooling off of growth its high technology exports.

Exports of machinery and equipment drove overall export growth, increasing 40% to reach $218 billion in 2016 (22% global share) (Figure 6-31; Appendix Table 6-41). The trade surplus grew from $21 billion to $111 billion. Exports of motor vehicles and parts had the highest growth rate among the medium-high-technology products (52%), albeit rising from a low base to reach $59 billion (Appendix Table 6-39). Although most cars and trucks manufactured in China are sold for the rapidly growing domestic market, China's industry is also exporting an increasing number of cars and trucks.[11] Major markets for China's exports of motor vehicles and parts are the United States (18% of total exports), other selected Asian economies (12%), and the EU (10%) (Figure 6-32). Exports of electrical equipment and appliances grew by 28% to reach $196 billion (Appendix Table 6-42). China is the dominant global exporter in these products (41% global share). The trade surplus widened from $103 billion to $145 billion.

FIGURE 6-32

Trade in motor vehicles and parts of selected regions, countries, or economies, by selected trading partner: 2016





EU = European Union; NAFTA = North American Free Trade Agreement; ROW = rest of world.

Note(s)

Data are not available for EU members Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. EU exports and imports exclude intra-EU trade. China exports and imports exclude trade between China and Hong Kong. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Other selected Asia includes Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam.

Source(s)

IHS Global Insight, World Trade Service database (2016). See Appendix Table 6-20.

Science and Engineering Indicators 2018

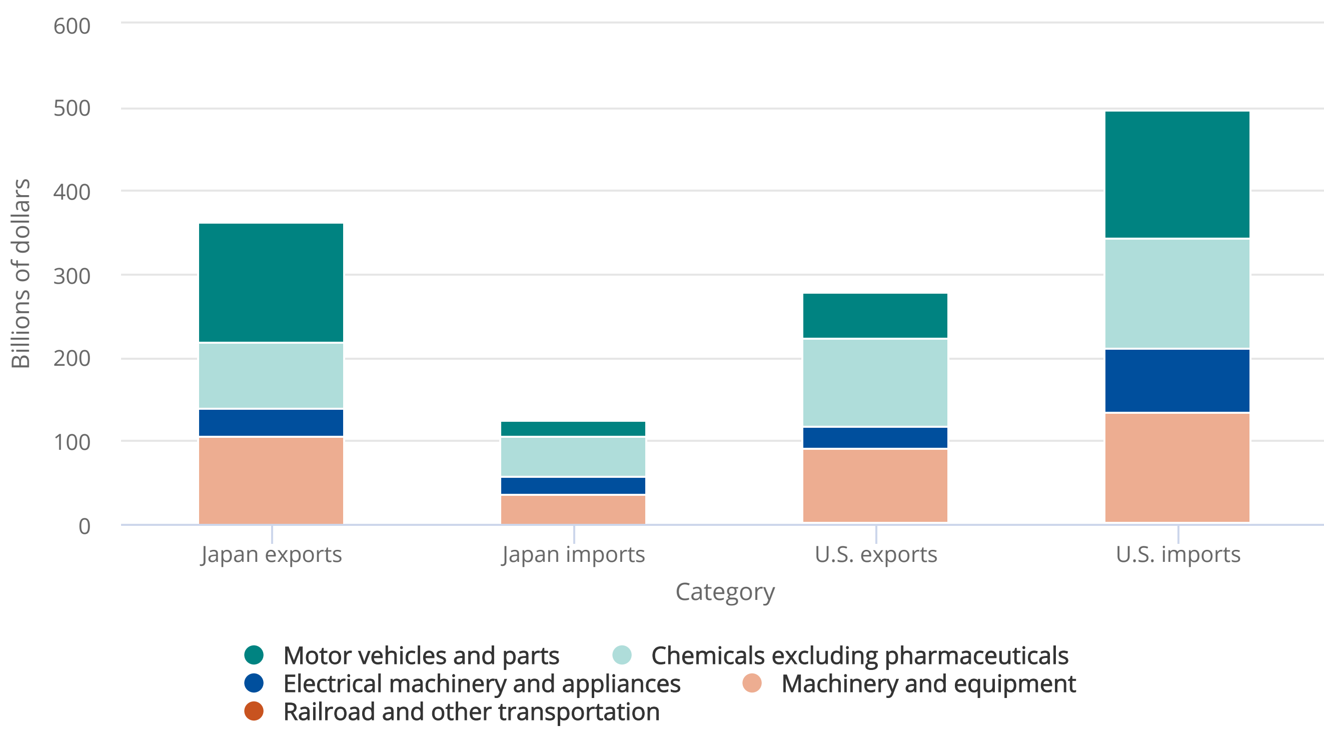
Japan's Trade of Medium-High-Technology Goods

Japan's medium-high-technology exports fell 21% between 2011 and 2016 to reach $364 billion, and its trade surplus declined $80 billion to reach $237 billion (Figure 6-29, Figure 6-30, and Figure 6-33; Appendix Table 6-27).

Exports of chemicals excluding pharmaceuticals, machinery and equipment, and electrical equipment and appliances fell by 25%–27% (Appendix Table 6-40, Appendix Table 6-41, and Appendix Table 6-42). Exports of motor vehicles and parts fell by 11% to reach $144 billion, and the trade surplus declined from $144 billion to $125 billion (Figure 6-33; Appendix Table 6-39). Japan is the second largest exporter of motor vehicles and parts (20% global share). The United States is a major market for Japan's exports of automobiles, trucks, and parts (30% of total exports) (Figure 6-32). The EU (10%) and several Asian countries—Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam (13%)—receive a comparatively smaller share of Japan's exports.

FIGURE 6-33

Japan and United States trade in MHT products, by product: 2016



MHT = medium-high technology.

Note(s)

MHT products include motor vehicles and parts, electrical machinery, machinery and equipment, chemicals excluding pharmaceuticals, and railroad and other transportation equipment. Exports and imports of the United States exclude exports to Canada and Mexico.

Source(s)

IHS Global Insight, World Trade Service database (2017). See Appendix Table 6-20.

Science and Engineering Indicators 2018

U.S. Trade of Medium-High-Technology Goods

U.S. medium-high-technology product exports declined 12% in the post-global recession period of 2011–16 to reach $273 billion (Figure 6-29; Appendix Table 6-27). The U.S. trade deficit nearly doubled from $117 billion to $225 billion during this period (Figure 6-30)[12] Output of U.S. medium-high-technology industries rose by 17% during this period, in contrast to the decline in exports (Figure 6-16 and Figure 6-29; Appendix Table 6-7 and Appendix Table 6-27). The dollar's substantial appreciation against the euro, yen, and other currencies, which made U.S. exports less competitive, may have been a factor in the decline in exports (see sidebar Currency Exchange Rates of Major Economies).

Exports of chemicals excluding pharmaceuticals declined by 15% between 2011 and 2016 to reach $106 billion (Appendix Table 6-40). Exports of machinery and equipment declined by 9% to reach $90 billion (Appendix Table 6-41). Exports of motor vehicles and parts fell slightly from $56 billion to $54 billion (Appendix Table 6-39). The largest major export market is the other NAFTA countries—Canada and Mexico (57%) suggesting that much of the production of inputs, components, and final assembly is located within NAFTA (Figure 6-32).[13] This is because transportation costs are high and companies find it advantageous to co-locate R&D and testing near production so that they can effectively understand and respond to local market conditions.

---

[1] Other business services include trade-related services, operational leasing (rentals), and miscellaneous business, professional, and technical services. These include legal, accounting, management consulting, public relations services, advertising, market research and public opinion polling, R&D services, architectural, engineering, and other technical services, agricultural, mining, and on-site processing (WTO 2016:83).

[2] See World Trade Organization, Statistics, Trade in Services (2016).

[3] Other business services include trade-related services, operational leasing (rentals), and miscellaneous business; professional and technical services such as legal, accounting, management consulting, public relations services, advertising, market research, and public opinion polling; R&D services; architectural, engineering, and other technical services; and agricultural, mining, and on-site processing.

[4] A trade surplus occurs when exports exceed imports. A trade deficit occurs when imports exceed exports.

[5] See China Daily (2016) and KPMG (2009) for a discussion of China's outsourcing of business services to other countries.

[6] See IHS Global Insight, World Trade Service database (2016).

[7] The U.S. trade balance is affected by many factors, including currency fluctuations, differing fiscal and monetary policies, and export subsidies and trade restrictions between the United States and its trading partners.

[8] See Green (2014) and Tomiyama (2015) for a discussion on the move of electronics manufacturing from China to Vietnam.

[9] See IHS Global Insight, World Trade Service database (2016).

[10]Intra-EU exports of motor vehicles and parts were $421 billion in 2016. EU exports to the rest of the world were $244 billion. Source: IHS Global Insight, World Trade database.

[11] See https://en.wikipedia.org/wiki/Automotive_industry_in_China.

[12] The U.S. trade balance is affected by many factors, including currency fluctuations, differing fiscal and monetary policies, and export subsidies and trade restrictions between the United States and its trading partners.

[13] U.S. exports of motor vehicles and parts to NAFTA (Canada and Mexico) were $68 billion in 2016. U.S. exports to the rest of the world were $54 billion. Source: IHS Global Insight, World Trade database.

Global Trends in Sustainable Energy Research and Technologies

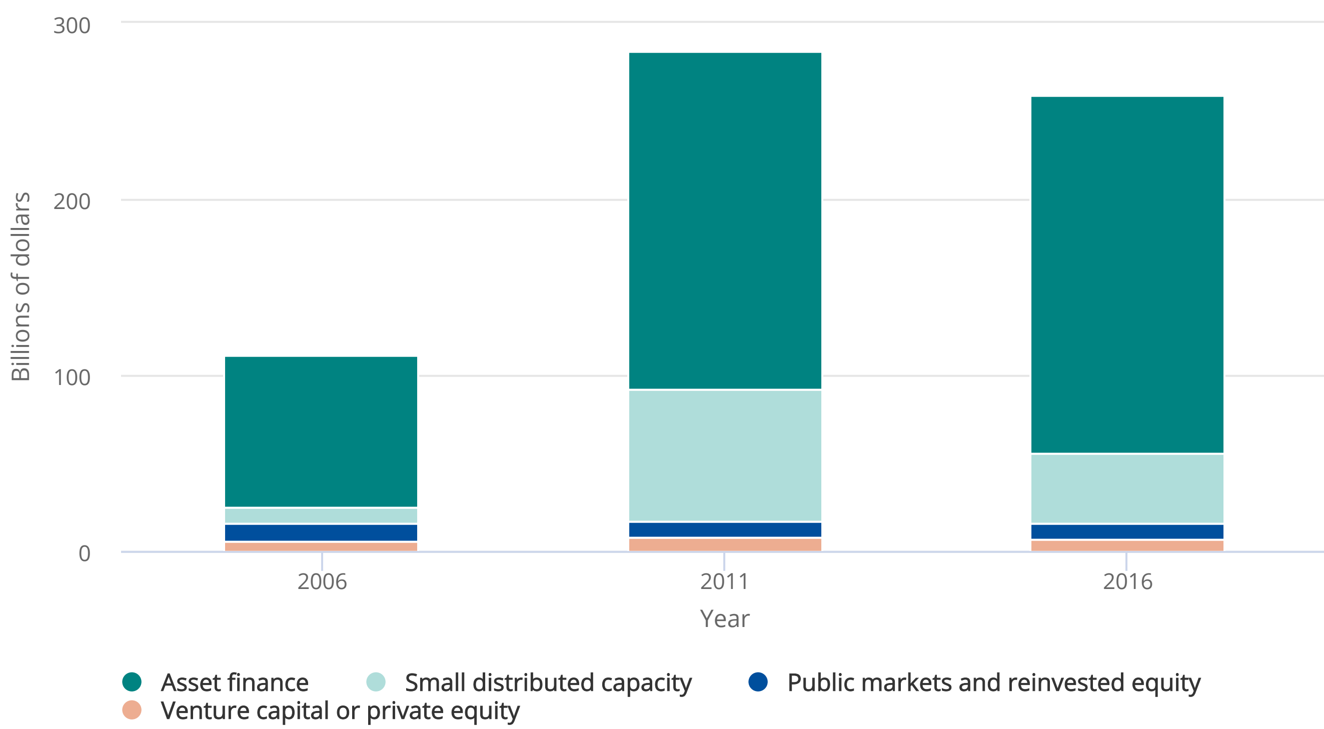
Like KTI industries, sustainable energy has a strong link to scientific R&D and innovation and constitutes a key element of a nation's infrastructure. This section is devoted to examining sustainable energy research and technologies, which include biofuels, solar, wind, energy efficiency, pollution prevention, smart grid, and CO_2 sequestration.

This section examines private investment, public research, development and demonstration (RD&D), and patenting in sustainable energy technologies. We define sustainable energy technologies to include non-fossil fuel energy sources, and technologies that increase energy efficiency or mitigate pollution from fossil fuel sources. Energy from finite sources such as natural gas is not included in the discussion of this section. The coverage of sustainable energy technologies varies among the RD&D, private investment, and patenting used in this section. For example, the public RD&D includes coverage of nuclear energy, which is not covered by the private investment data. In addition, the public RD&D data discussed here are not comparable with the energy R&D data described in Chapter 4.[1]

Private investment consists of early-stage financing—venture capital and private equity—and later stage financing. The data show that, globally, private investment in sustainable energy technologies are significantly larger than public investment (Figure 6-34 and Figure 6-35). Both types of investment have declined in magnitude in recent years due to several factors. Some governments have cut back funding in research on sustainable energy technologies, have curtailed subsidies and incentives to deploy sustainable energy in response to fiscal austerity and sustainable energy technologies becoming economically competitive with fossil fuels in some countries, or both. In addition, the rapidly declining costs of solar photovoltaics have greatly increased the amount of solar energy generated per dollar of investment.

FIGURE 6-34

Private investment in sustainable energy technologies, by type of financing: 2006, 2010, and 2016



Note(s)

Sustainable energy technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency technologies. Private investment includes asset finance, small distributed capacity, venture capital, private equity, reinvested equity, and public markets. Mergers and acquisitions are excluded.

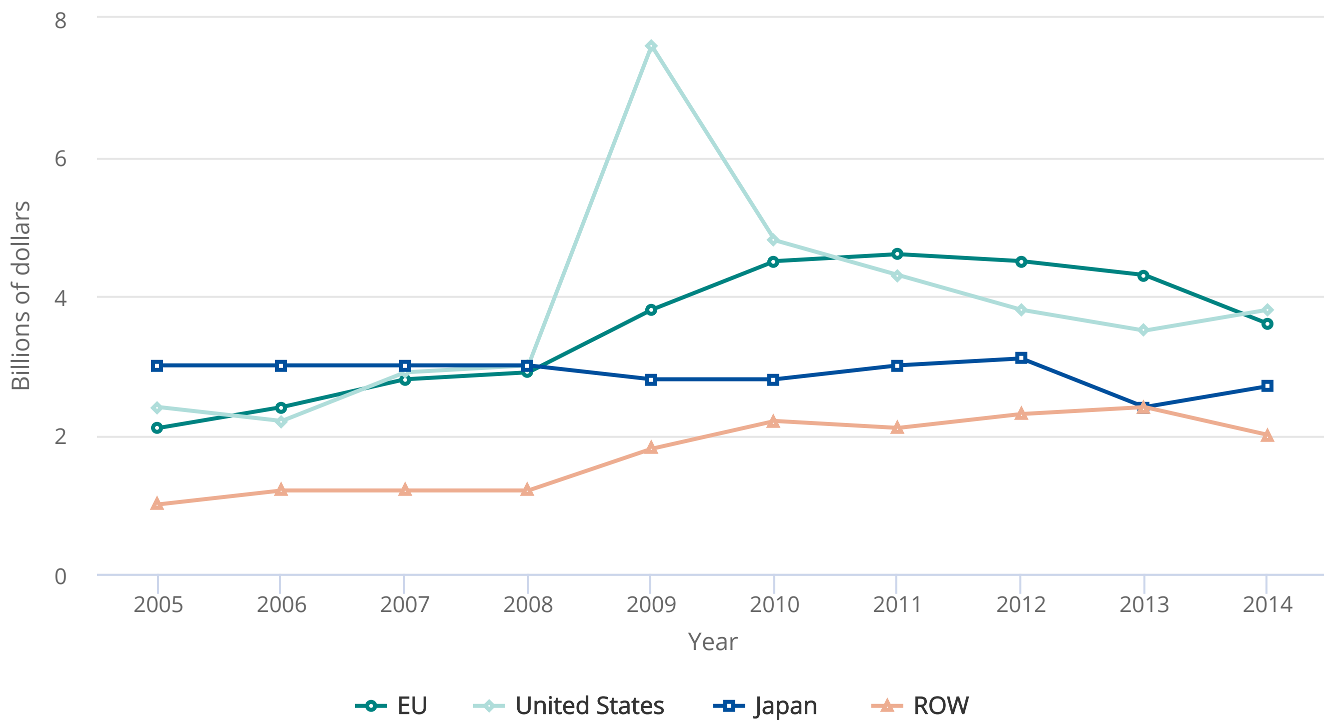
Source(s)

Bloomberg New Energy Finance, https://about.bnef.com/, accessed 15 May 2017.

Science and Engineering Indicators 2018

FIGURE 6-35

Government RD&D expenditures on sustainable energy technologies, by selected region, country, or economy: 2005–14



EU = European Union; RD&D = research, development, and demonstration; ROW = rest of world.

Note(s)

Sustainable energy technologies include renewables (solar, wind, biofuels, ocean energy, and hydropower), nuclear, hydrogen and fuel cells, CO_2 capture and storage, other power and storage, and energy efficiency. The EU includes Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Spain, Sweden, and the United Kingdom. ROW includes New Zealand, South Korea, and Switzerland.

Source(s)

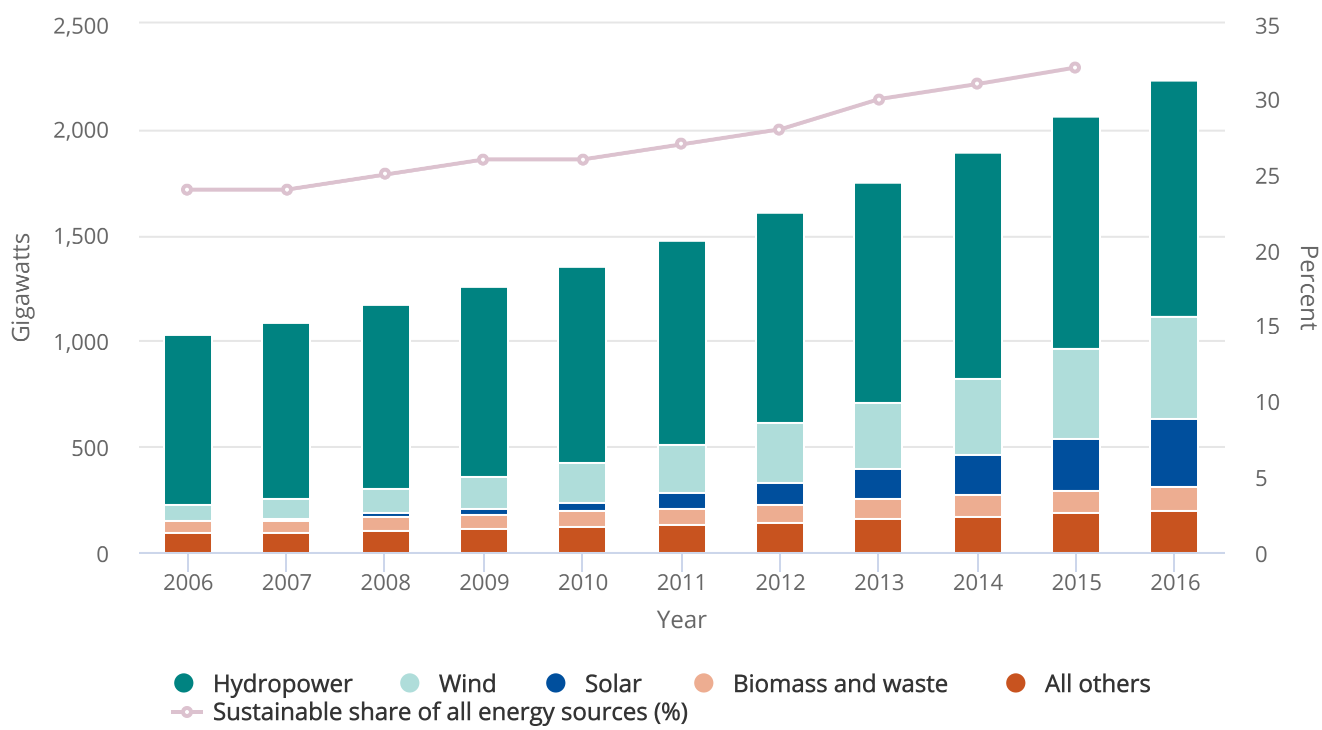
International Energy Agency, Statistics and Balances, https://www.iea.org/statistics/statisticssearch/, accessed 15 February 2017. See Appendix Table 6-54.

Science and Engineering Indicators 2018

Despite the recent decline of private investment, the sustainable energy share of all energy sources rose from 28% to 32% between 2012 and 2015 (Figure 6-36). The deployment of existing solar and wind projects already under construction and the much cheaper costs of building solar generation capacity drove the increase in the sustainable share during this period.

FIGURE 6-36

Global generation capacity of sustainable energy, by source: 2006–16



Note(s)

Data are not available for all years. Renewable energy includes biomass and waste, geothermal, hydropower, marine, solar, and wind. Renewable share of total is not available for 2016.

Source(s)

Bloomberg New Energy Finance, https://about.bnef.com/, accessed 15 May 2017.

Science and Engineering Indicators 2018

Private Investment in Sustainable Energy Technologies

Global private investment in sustainable energy technologies, including solar, wind, biofuels, geothermal, and energy smart—was $260 billion in 2016 (Figure 6-34).[2] Private investment consists of early-stage financing—venture capital and private equity ($7.5 billion)—and later stage financing ($252.1 billion)—asset finance (capital based on future expected income streams), public markets, reinvested equity, and small distributed capacity (Appendix Table 6-44).[3] Global private investment is far larger than government RD&D invested in these technologies (government RD&D was estimated at $12 billion in 2014).

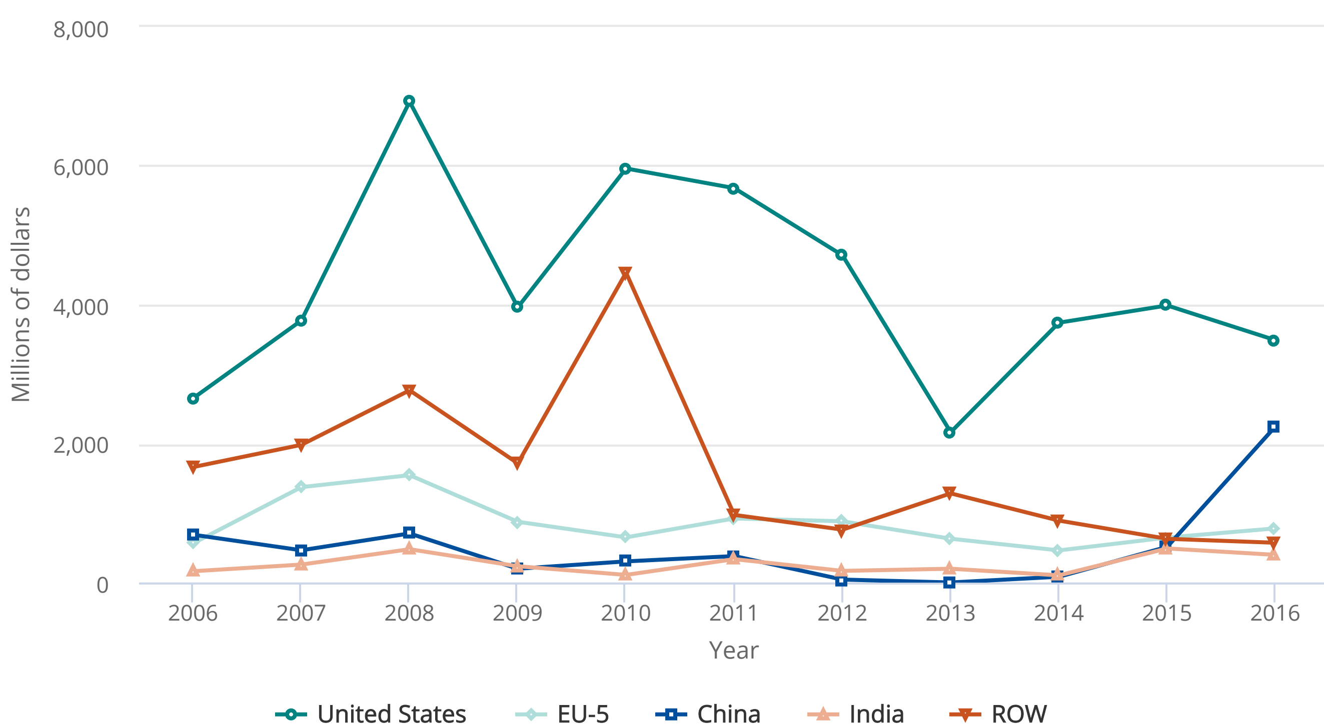
Early-Stage Private Financing of Sustainable Energy Technologies

Venture capital and private equity primarily finance nascent technologies and are important for understanding emerging technology trends. Global venture capital and private equity investment in sustainable energy technologies was $7.5 billion in

2016 (Figure 6-37). The United States attracted the most venture capital and private equity of any country ($3.5 billion in 2016). China attracted $2.2 billion, a record high and huge jump from the $0.5 billion investment in 2015. The five largest economies in the EU—France, Germany, Italy, Spain, and the United Kingdom—attracted a combined $0.8 billion. India attracted $0.4 billion. Energy smart ($4.2 billion) and solar ($2.3 billion) are the leading technologies for venture and capital and private equity investment with biofuels and wind receiving far smaller amounts (Figure 6-37 and Figure 6-38).

FIGURE 6-37

Global venture capital and private equity investment in sustainable energy technologies, by selected region or country: 2006–16



EU = European Union; ROW = rest of world.

Note(s)

EU-5 consists of France, Germany, Italy, Spain, and the United Kingdom. Sustainable energy technologies include wind, solar, biofuels, biomass, geothermal, and energy smart and efficiency technologies.

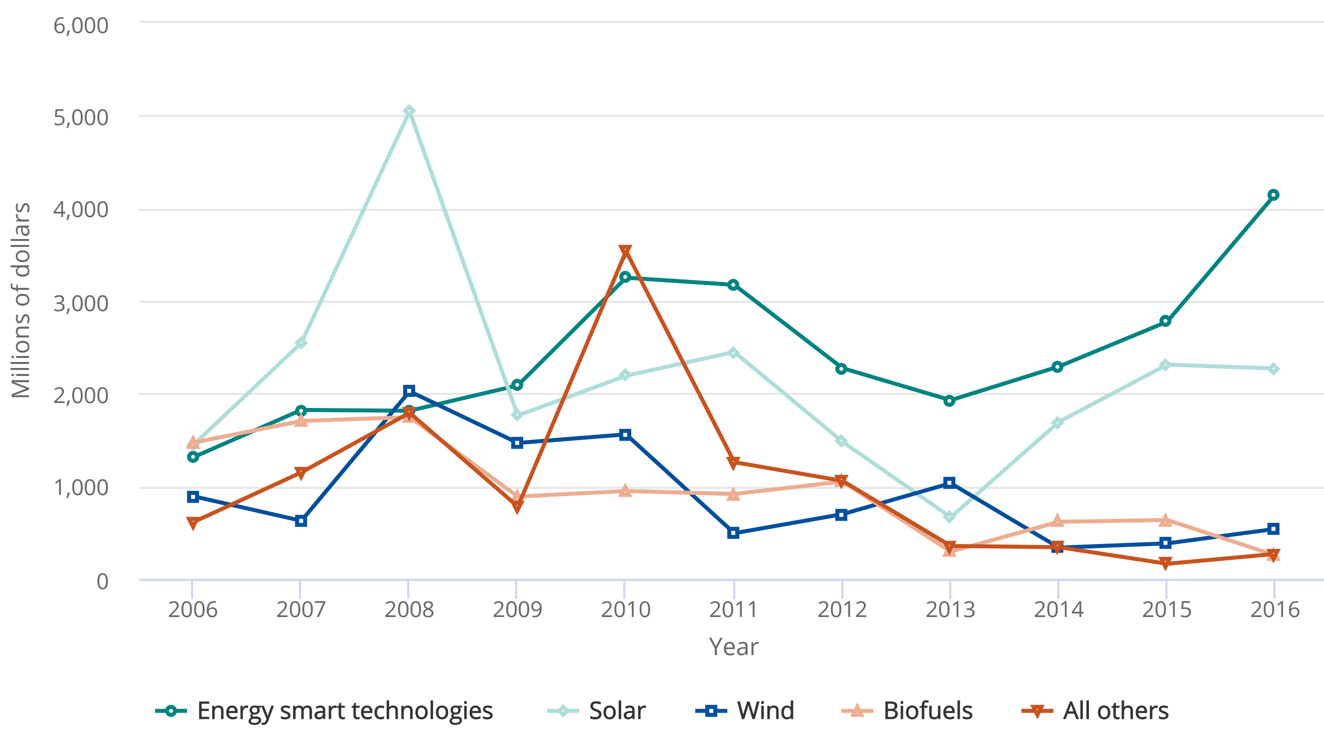
Source(s)

Bloomberg New Energy Finance, https://about.bnef.com/, accessed 15 February 2017.

Science and Engineering Indicators 2018

FIGURE 6-38

Global venture capital and private equity investment in sustainable energy technologies, by selected technology: 2006–16



Note(s)

Sustainable energy technologies include wind, solar, biofuels, biomass, geothermal, and energy smart and efficiency technologies.

Source(s)

Bloomberg New Energy Finance, https://about.bnef.com/, accessed 15 February 2017.

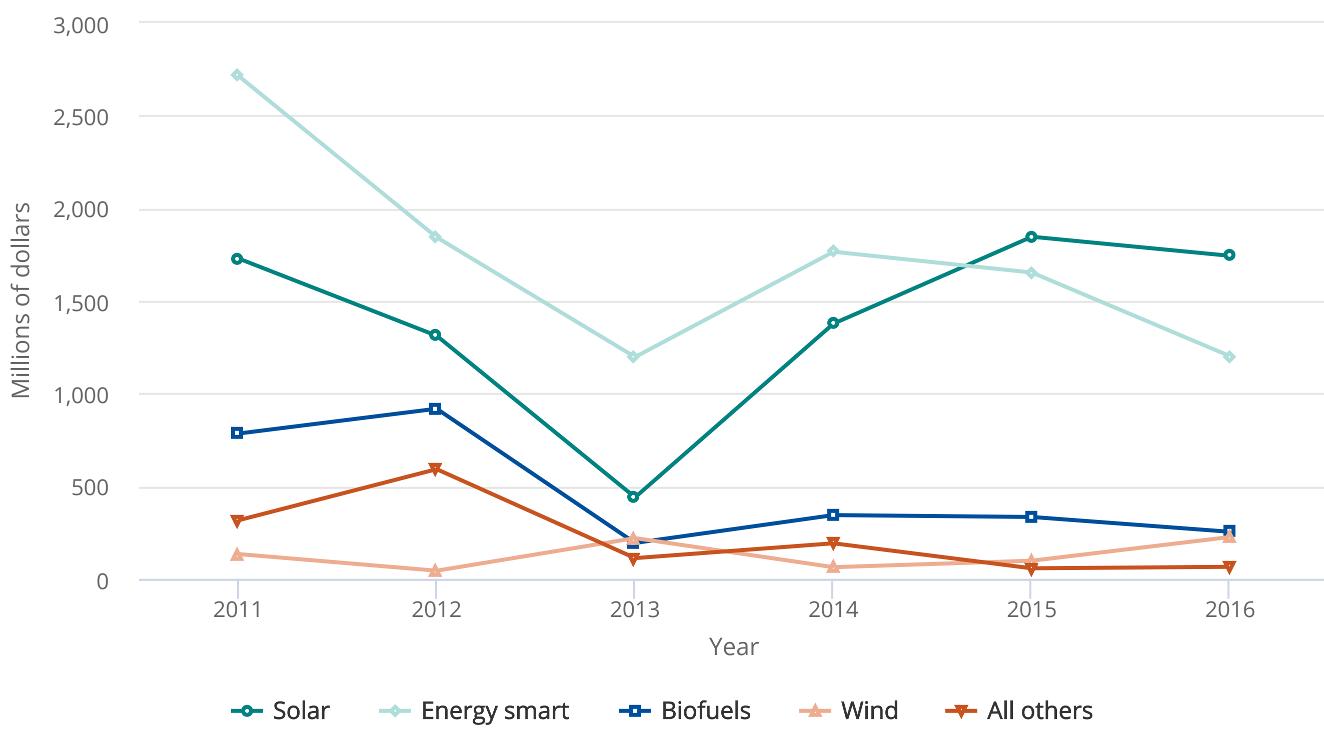
Science and Engineering Indicators 2018

Although venture capital and private equity investment grew from $4.3 billion in 2013 to $7.5 billion in 2016, it remains far below its peak in 2008 ($12.4 billion) (Figure 6-37). The sharp decline in investment starting in 2011 has been attributed to the difficulty of venture capitalists raising new funds and the lack of getting a sufficient positive return on their existing investments in sustainable energy technology companies. Commercializing energy technologies such as solar, wind, and biofuels can be very risky and sometimes requires subsequent substantial and long-term financing to build demonstration plants. Investors in venture capital have become more risk adverse and expect returns within the relatively short time horizon of 2–4 years.

U.S. venture capital and private equity investment has paralleled the trend of global venture capital and private equity investment over the post-global recession period (Figure 6-39). The largest two technology areas have been energy smart and solar between 2011 and 2015. Both areas saw declining investments following the global recession but have recovered in recent years.

FIGURE 6-39

U.S. venture capital and private equity investment in sustainable energy technologies, by selected technology: 2011–16



Note(s)

Sustainable energy technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency technologies.

Source(s)

Bloomberg New Energy Finance, https://about.bnef.com/, accessed 15 February 2017.

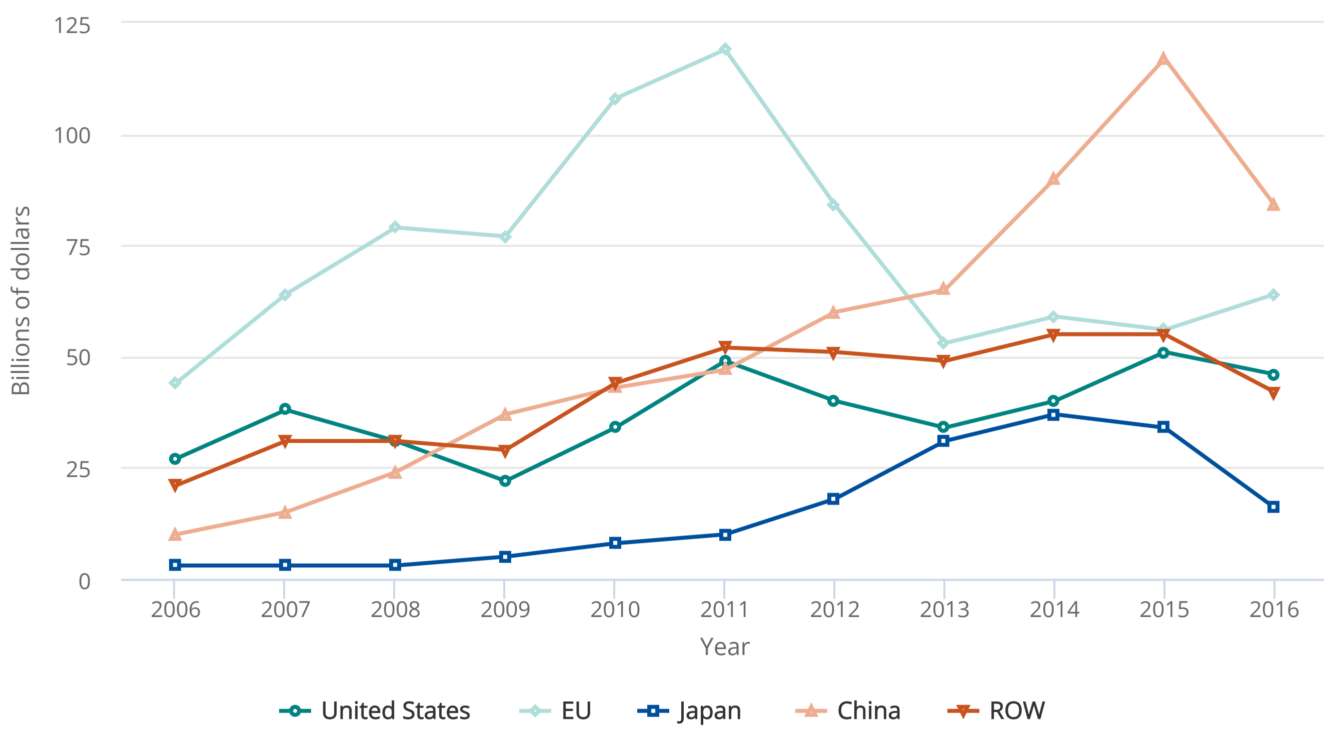
Science and Engineering Indicators 2018

Later-Stage Private Investment in Sustainable Energy Technologies

Later-stage financing is focused on the design and construction of utility-scale renewable energy power plants and installations (primarily solar) on commercial and residential buildings. Global later-stage private investment in sustainable energy technologies was $252 billion in 2016 (Figure 6-40 and Figure 6-41).[4] Two technologies—wind and solar—dominate sustainable energy technology investment, each with a share of about 40% (Appendix Table 6-44 and Appendix Table 6-45). Energy smart technologies are the third largest area (8%). China leads the world in attracting later-stage private investment in sustainable energy technologies (with a global share of 33%) followed by the EU (25%) and the United States (18%) (Figure 6-40).

FIGURE 6-40

Later-stage private investment in sustainable energy technologies, by selected region or country: 2006–16



EU = European Union; ROW = rest of world.

Note(s)

Data for 2016 are preliminary. Sustainable energy technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency technologies. Later-stage private investment includes asset financing, small scale distributed capacity, mergers and acquisitions, public equity, and reinvested equity.

Source(s)

Bloomberg New Energy Finance (2017), https://about.bnef.com/, accessed 15 February 2017.

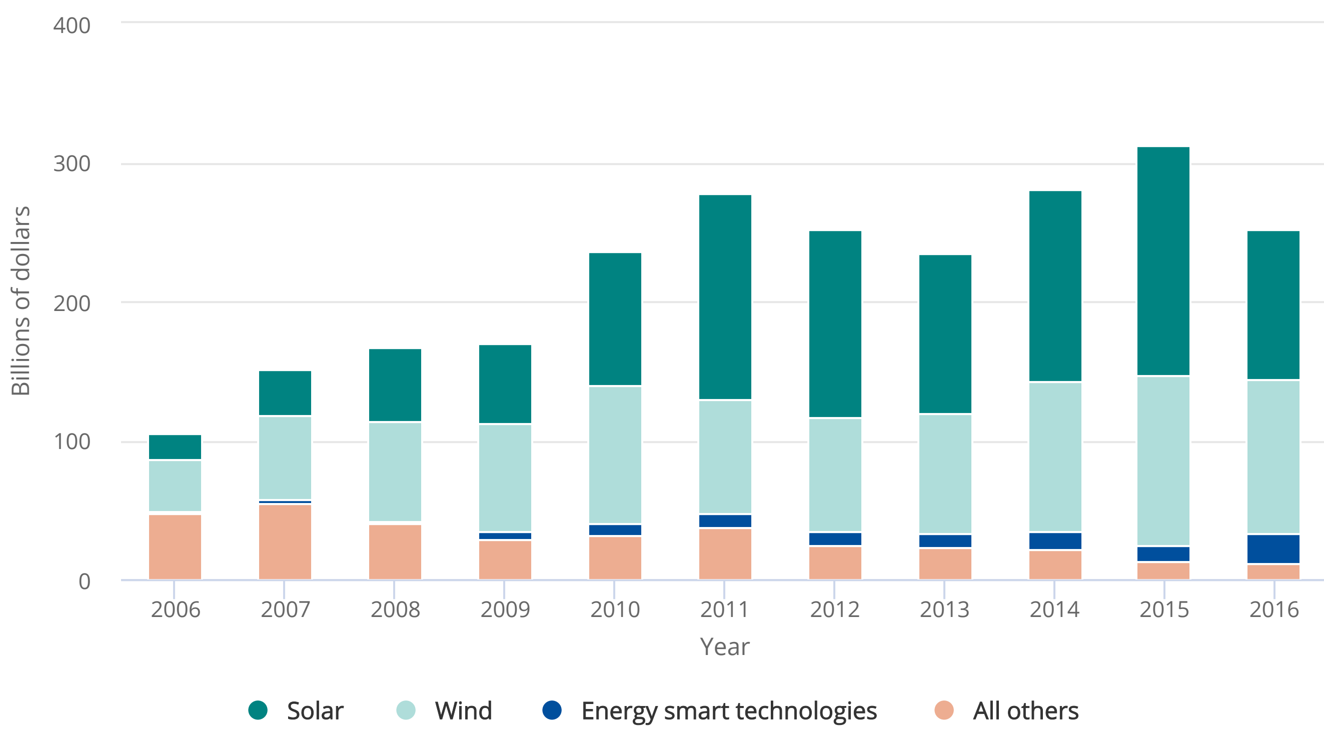
Science and Engineering Indicators 2018

Global later-stage investment in sustainable energy technologies fell 19% to $252 billion in 2016 compared to 2015, the deepest annual decline over the last decade (Figure 6-40 and Figure 6-41; Appendix Table 6-44). Solar had the deepest decline (35%) among technologies, falling from a record high in 2015 to $108 billion in 2016, and wind declined 10% to reach $111 billion (Appendix Table 6-45). Investment declined steeply in China (29%) and in Japan (51%) with a far more modest decline in the United States (8%). Investment in the EU increased by 14%. Both China and Japan have shifted some of their focus from building up energy capacity to efficiently managing and integrating existing energy capacity into electric grids (BNEF 2017).

Global sustainable energy technology investment following the global recession has fluctuated compared to the very rapid growth prior to the recession (Figure 6-40 and Figure 6-41; Appendix Table 6-45). The plateauing of global investment following the global recession has been due to several factors including the sluggish global economy, cutbacks by many governments on incentives to deploy sustainable energy, and rapid declines in costs of solar photovoltaics, which in turn have reduced the per-unit cost of investment in these technologies. As a result of these lower costs, solar generation capacity can grow despite lower current dollar expenditures.

FIGURE 6-41

Later-stage private investment in sustainable energy technologies, by selected technology: 2006–16



Note(s)

Sustainable energy technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency technologies. Later-stage private investment includes asset financing, small scale distributed capacity, mergers and acquisitions, public equity, and reinvested equity.

Source(s)

Bloomberg New Energy Finance, https://about.bnef.com/, accessed 15 February 2017.

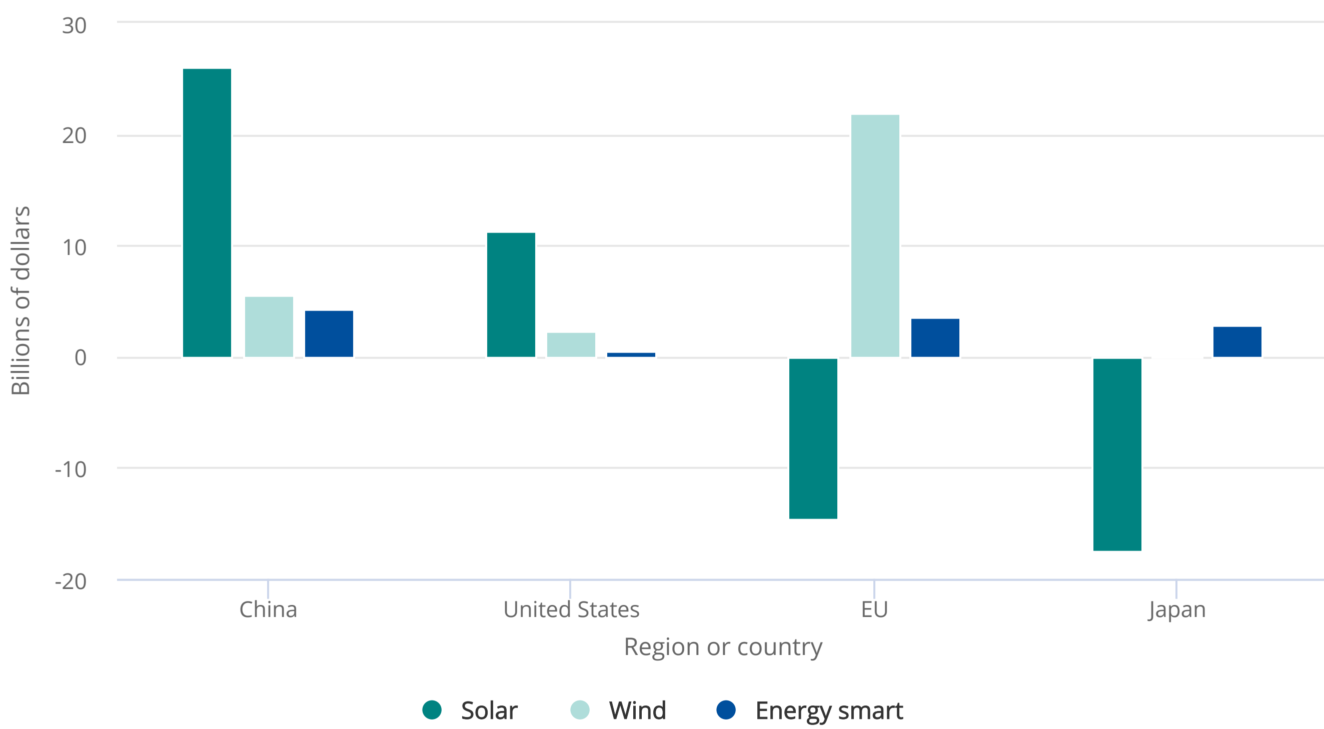
Science and Engineering Indicators 2018

Later-Stage Sustainable Energy Investment in China

Later-stage investment in China fell 29% in 2016 to $84 billion following 13 years of uninterrupted growth (Figure 6-40; Appendix Table 6-44). The sharp decline of investment in 2016 reflects the government paring back its incentives for building solar and wind energy capacity and focusing on investing in its electric grids and reforming the power market to efficiently utilize its existing wind and energy capacity.[5] In addition, the plunging cost of solar photovoltaics has sharply raised the amount of solar energy capacity produced per dollar of investment. The rapid growth of sustainable energy technology investment between 2002 and 2015 has been driven by the government's policies and generous incentives targeted at wind and solar energy to make China a major world producer and build up its energy capacity in these technologies. Between 2013 and 2016, investment in solar drove China's growth in later stage sustainable energy technology investment (Figure 6-42; Appendix Table 6-44). Solar investment climbed from $27 billion to $39 billion, making China the leading country in solar investment. China's rapid rise reflects its emergence as a major manufacturer of low-cost photovoltaic modules and rapidly growing installation of utility scale and residential solar in China. China had modest growth in investment in wind energy (from $26 billion in 2011 to $35 billion in 2016) (Appendix Table 6-45).

FIGURE 6-42

Cumulative change in later-stage sustainable energy technologies private investment, by selected region or country and technology area: 2013–16



EU = European Union.

Note(s)

Sustainable energy technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency technologies. Later-stage private investment includes asset financing, small scale distributed capacity, mergers and acquisitions, public equity, and reinvested equity

Source(s)

Bloomberg New Energy Finance, https://about.bnef.com/, accessed 15 February 2017.

Science and Engineering Indicators 2018

Later-Stage Sustainable Energy Investment in the EU

EU investment in 2016 rose 14% to reach $64 billion (Figure 6-40; Appendix Table 6-44). Between 2013 and 2016, investment in the EU rose from $53 billion to $64 billion, driven by a $22 billion increase in wind investment driven by several large wind offshore installations (BNEF 2017) (Figure 6-42; Appendix Table 6-45). The EU surpassed China during this period to become the world's largest recipient of wind investment. Solar investment declined by $15 billion during this period. The big drop in EU investment between 2011 and 2013 reflects a mix of factors including retroactive cuts in support for existing solar projects in Spain and other countries, cutbacks in incentives to deploy solar and wind energy, the economic downturn in Spain and southern European countries, the slowdown in solar investment in Germany and Italy, and the big fall in the cost of solar photovoltaics (Appendix Table 6-44).

Later-Stage Sustainable Energy Investment in the United States

U.S. sustainable energy technology investment fell 8% (from $51 billion to $46 billion) in 2016 (Figure 6-40; Appendix Table 6-44). Investment in the United States has fluctuated between $34 billion and $51 billion in the post-global recession period. The changing status of two key federal government tax incentives, the Production Tax Credit (PTC) for wind and the Investment Tax Credit (ITC) for solar, has been a key factor in the fluctuation of U.S. investment over the last several years.[6] Solar investment has been the main component of U.S. investment between 2013 and 2016 due to deep declines in the cost of photovoltaics, which have increased solar generation per unit of investment, and the adoption of leasing and other innovative financing methods that have lowered the cost of residential solar installation (Figure 6-42; Appendix Table 6-44).[7]

Later-Stage Sustainable Energy Investment in Japan

Investment in Japan fell by half in 2016 to reach $16 billion following rapid growth between 2011 and 2014 (Figure 6-40; Appendix Table 6-45). The sharp drop in solar investment drove the steep decline in Japan's sustainable energy technology investment (Figure 6-42). Japan, like China, is cutting back on building large-scale solar installations and shifting toward managing and integrating their existing solar energy capacity into its electric grid (BNEF 2017). Sustainable energy investment in Japan soared between 2011 and 2015 largely because of generous government incentives for solar investment enacted in response to the government's push to diversify energy sources in the wake of the Fukushima nuclear reactor accident in 2011.

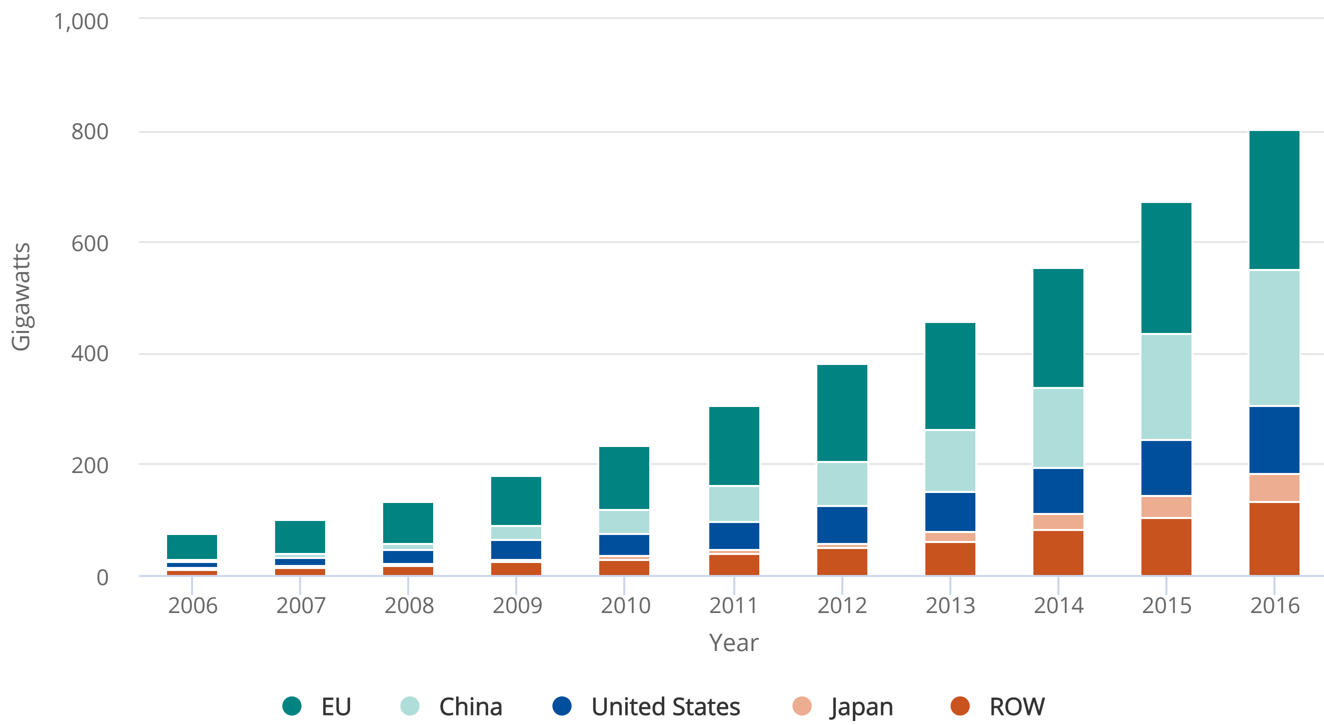
Sustainable Energy Generation Capacity

The large expansion of investment and deployment of sustainable energy technologies over the last decade has led to rapid growth in renewable energy generation capacity (Figure 6-36). Renewable energy capacity excluding hydropower jumped from 130 gigawatts in 2006 to 912 gigawatts in 2016.[8] Despite the decline in sustainable energy technology investment, the world added a record 137 gigawatts of renewable energy capacity excluding hydropower in 2016. Solar and wind have driven the surge in renewable energy capacity, accounting for more than 90% of the increase in capacity of all renewable energy sources except hydropower over the last decade. Solar and wind generation capacity added a record amount of 130 gigawatts in 2016 (Figure 6-43). Although global sustainable energy technology investment has plateaued following the global recession, sustainable energy capacity has continued to increase because the deployment of solar and wind projects already under construction and the rapidly falling costs of solar photovoltaics that have greatly increased the amount of solar energy generated per investment dollar.[9]

China has led the world in increasing solar and wind generation capacity. Between 2010 and 2016, China added a cumulative 200 gigawatts of solar and wind generation capacity with China nearly reaching the capacity of the EU (Figure 6-43). Despite the sharp fall in sustainable energy technology investment, the EU added a cumulative 137 gigawatts in capacity. The United States (82 gigawatts) added far less than China and the EU.

FIGURE 6-43

Generation capacity in solar and wind by selected region or country: 2006–16



EU = European Union; ROW = rest of world.

Source(s)

Bloomberg New Energy Finance, https://about.bnef.com/, accessed 15 February 2017.

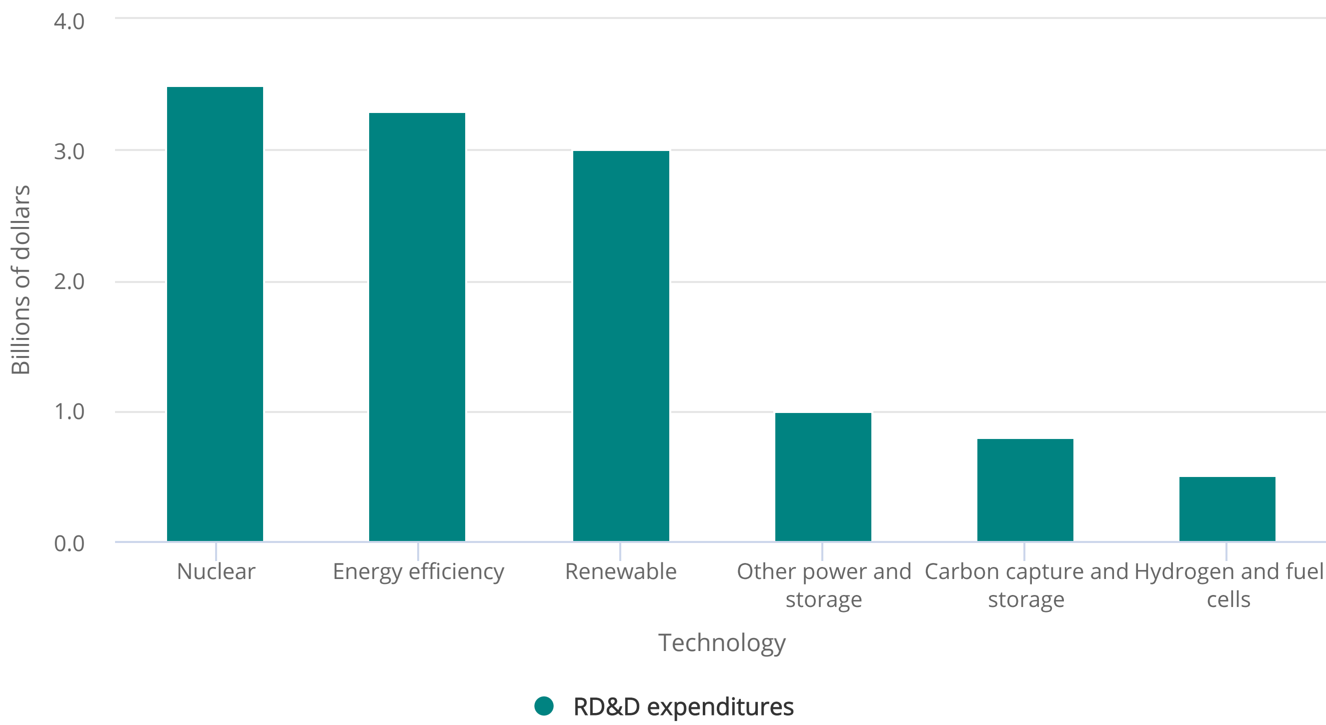
Science and Engineering Indicators 2018

Public RD&D Expenditures in Sustainable Energy Technologies

Global public investment in RD&D in sustainable energy technologies—renewables, energy efficiency, capture and storage of CO_2, nuclear, fuel cells, and other power and storage technologies—was an estimated $12.0 billion in 2014 (Figure 6-35 and Figure 6-44; Appendix Table 6-46 through Appendix Table 6-55).[10] Nuclear was the largest area ($3.5 billion), followed by energy efficiency ($3.3 billion) and renewables ($3.0 billion). These technologies typically require costly investment to construct testing and demonstration plants that businesses are unwilling to finance and thus require substantial public funding.

FIGURE 6-44

Government RD&D expenditures on sustainable energy technologies, by technology: 2014



RD&D = research, development, and demonstration.

Note(s)

Sustainable energy technologies include renewables (solar, wind, biofuels, ocean energy, and hydropower), nuclear, hydrogen and fuel cells, CO_2 capture and storage, other power and storage, and energy efficiency.

Source(s)

International Energy Agency, Statistics and Balances, https://www.iea.org/statistics/statisticssearch/, accessed 15 November 2016. See Appendix Table 6-54.

Science and Engineering Indicators 2018

Global public RD&D has steadily declined following the global recession after spiking at $16.2 billion in 2009 because of stimulus spending by the United States under the American Recovery and Reinvestment Act of 2009 (Figure 6-35; Appendix Table 6-46). Between 2011 and 2014, global public RD&D declined from $14 billion to $12 billion (Appendix Table 6-46 through Appendix Table 6-55). Nuclear declined by 19% to reach $3.5 billion. Renewables fell 23% to reach $3.0 billion with a steep decline in solar (39%). CO_2 capture and storage declined by nearly a third to reach $0.8 billion. Energy efficiency increased slightly (10%) to reach $3.3 billion.

The United States surpassed the EU in 2014 to become the world's largest investor in public RD&D despite the 12% decline in U.S. investment between 2011 and 2014 (Figure 6-35; Appendix Table 6-46). The fall in U.S. public RD&D investment between 2011 and 2014 resulted from steep declines in renewables (26%) and nuclear energy (32%) (Appendix Table 6-47 and

Appendix Table 6-50). In renewables, solar funding plunged 71% to $0.1 billion (Appendix Table 6-51). Expenditures on biofuels rose 41% to reach $0.5 billion (Appendix Table 6-53). Funding for energy efficiency technologies rose 40% to reach $1.3 billion (Appendix Table 6-48).

EU investment in RD&D fell 22% between 2011 and 2014 to reach $3.6 billion with declines across all technology areas (Figure 6-35; Appendix Table 6-46 through Appendix Table 6-54. The EU's cutbacks in RD&D funding, particularly in renewable energy coincide with fiscal austerity in many EU countries and the sharp declines in subsidies and other incentives to deploy solar and wind generation.

Japan's RD&D fell 10% between 2011 and 2014 to reach $2.7 billion (Figure 6-35; Appendix Table 6-46). Nuclear energy fell 17% to reach $1.4 billion and was far below its level in 2009 (Appendix Table 6-47). Japan's government has cut funding to nuclear RD&D in the wake of the Fukushima accident in 2011 and has diversified its energy sources, including increasing its generation of solar energy.

Patenting of Sustainable Energy Technologies

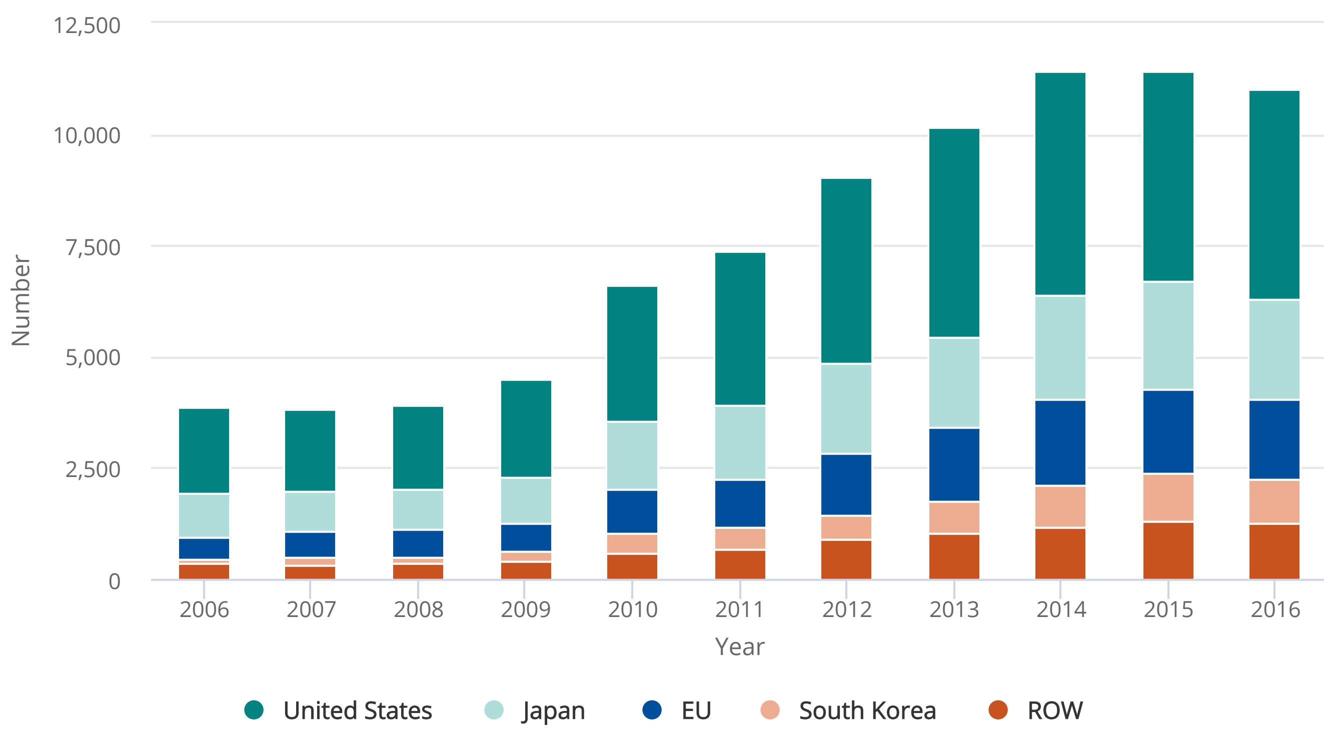
Patents are a partial indicator of invention and are used as a measure of the invention capacity of countries or to help identify nascent technologies that could be commercialized. In some technologies, including energy, venture-backed firms obtain patent protection for technologies they intend to commercialize. This section uses patent activity at the U.S. Patent and Trademark Office (USPTO). It is one of the largest patent offices in the world and has a significant share of applications from and grants to foreign inventors because of the size and openness of the U.S. market. (See Chapter 8 for a discussion of the limitations of using patents as an indicator of inventiveness and information on USPTO patents.)

Sustainable energy technology patents comprise four broad areas: alternative energy, energy storage, smart grid, and pollution mitigation (Appendix Table 6-56 through Appendix Table 6-60). These broad categories are further divided into finer technology areas (Appendix Table 6-61 through Appendix Table 6-74). (For more information on this classification of sustainable energy patent technologies, which was developed by the National Science Foundation [NSF], please see *Identifying Clean Energy Supply and Pollution Control Patents*.[11])

U.S. resident inventors were granted 43% of all sustainable energy technology patents in 2016 (Figure 6-45; Appendix Table 6-56). The next four largest recipient economies were Japan (20%), the EU (16%), and South Korea (9%). Although the global leader in attracting sustainable energy technology investment, China accounts for a relatively small share (3%) of USPTO sustainable energy technology patents (Figure 6-46).

FIGURE 6-45

USPTO patents in sustainable energy technologies, by selected region, country, or economy of inventor: 2006–16



EU = European Union; ROW = rest of world; USPTO = U.S. Patent and Trademark Office.

Note(s)

Sustainable energy technologies include alternative energy, energy storage, smart grid, and pollution mitigation. Alternative energy includes solar; wind; nuclear; fuel cell; hydropower; wave, tidal, ocean; geothermal; and electric or hybrid. Energy storage includes batteries, compressed air, flywheels, superconductivity, magnet energy systems, ultracapacitors, hydrogen production and storage, and thermal energy. Pollution mitigation includes recycling; control of air, water, and solid waste pollution; environmental remediation; cleaner coal; and capture and storage of carbon and other greenhouse gases. Technologies are classified by The Patent Board. Patent grants are fractionally allocated among regions or countries on the basis of the proportion of the residences of all named inventors.

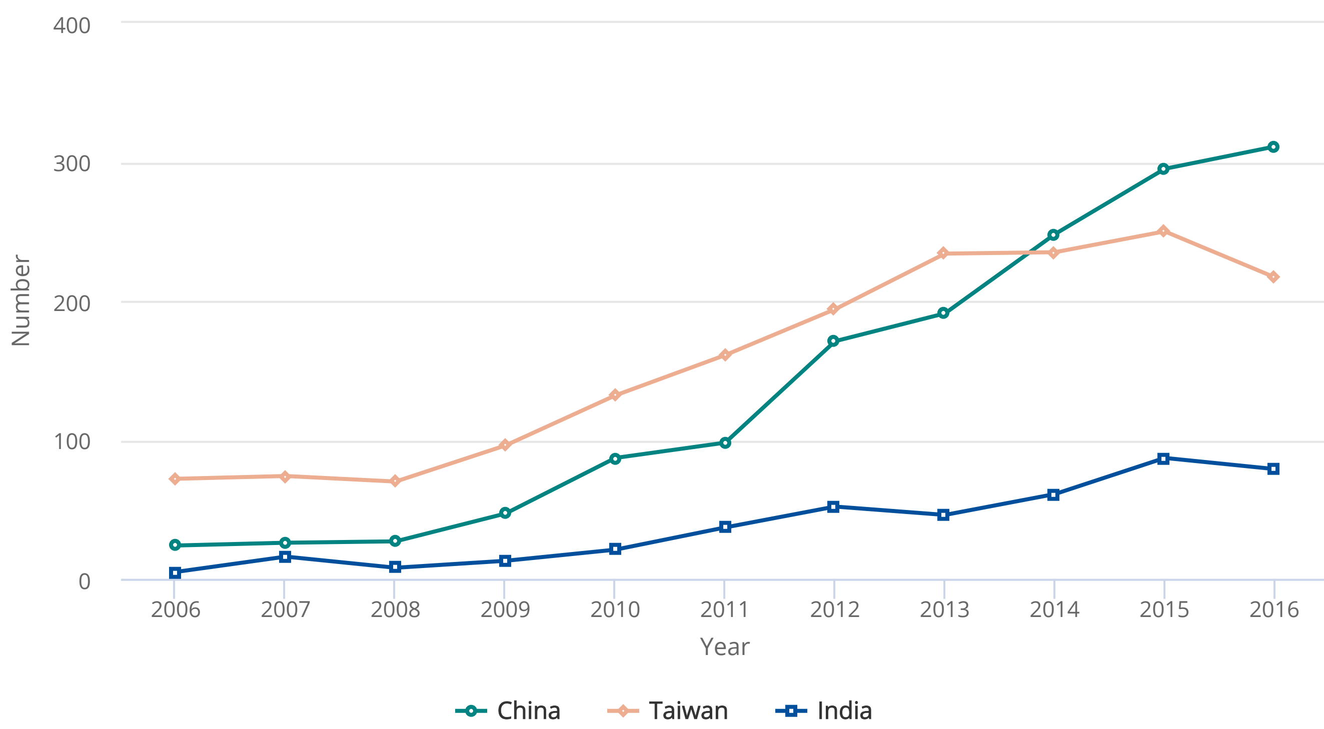
Source(s)

Science-Metrix, PatentsView, and USPTO patent data. See Appendix Table 6-57.

Science and Engineering Indicators 2018

FIGURE 6-46

USPTO patents in sustainable energy technologies, by selected region, country, or economy of inventor: 2006–16



USPTO = U.S. Patent and Trademark Office.

Note(s)

Sustainable energy technologies include alternative energy, energy storage, smart grid, and pollution mitigation. Alternative energy includes solar; wind; nuclear; fuel cell; hydropower; wave, tidal, ocean; geothermal; and electric or hybrid. Energy storage includes batteries, compressed air, flywheels, superconductivity, magnet energy systems, ultracapacitors, hydrogen production and storage, and thermal energy. Pollution mitigation includes recycling; control of air, water, and solid waste pollution; environmental remediation; cleaner coal; and capture and storage of carbon and other greenhouse gases. Technologies are classified by The Patent Board. Patent grants are fractionally allocated among regions or countries on the basis of the proportion of the residences of all named inventors.

Source(s)

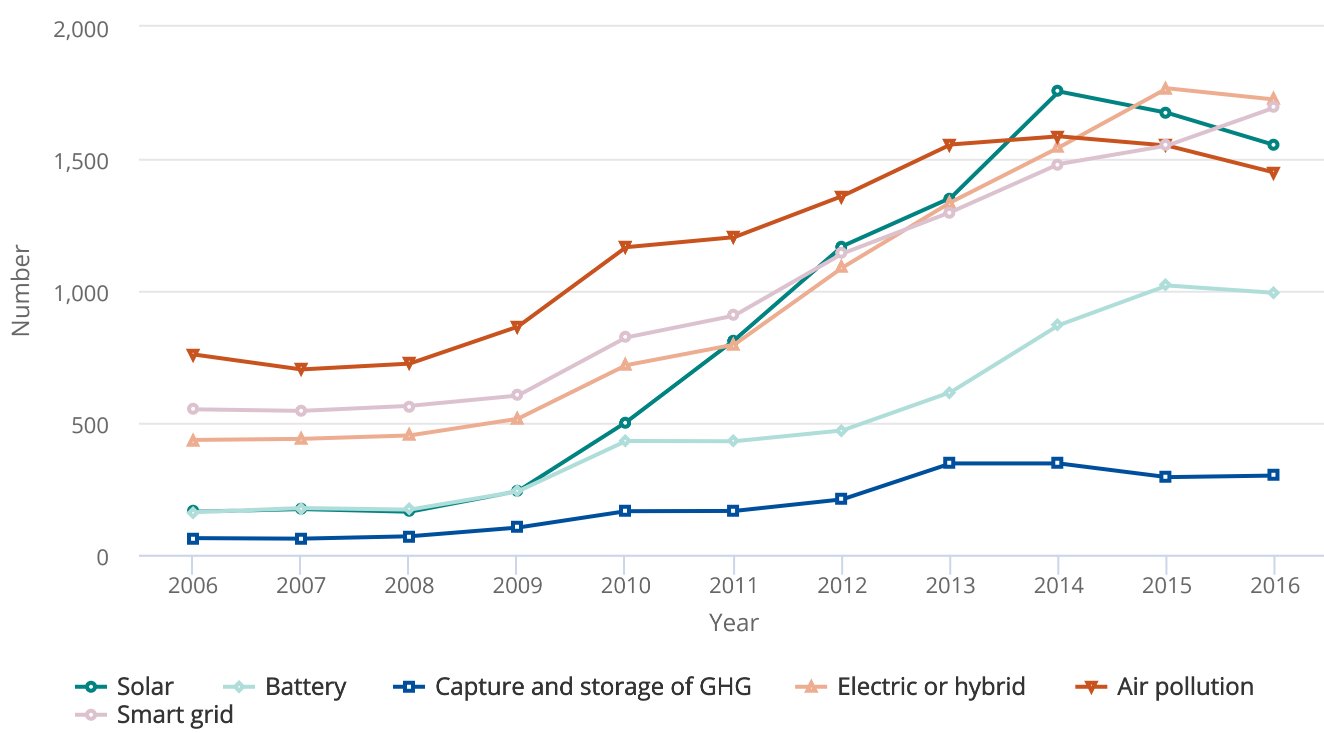
Science Metrix; PatentsView and USPTO patent data. See Appendix Table 6-57.

Science and Engineering Indicators 2018

The number of patents in these technologies has risen in line with the rapid growth of all USPTO patents since 2009 (Figure 6-45; Appendix Table 6-56).[12] Six technologies—solar, hybrid and electric vehicles, smart grid, fuel cell, battery, capture and storage of carbon and other greenhouse gases—led the growth of sustainable energy technology patents between 2009 and 2016 (Figure 6-47; Appendix Table 6-59, Appendix Table 6-61, Appendix Table 6-63, Appendix Table 6-64, Appendix Table 6-67, and Appendix Table 6-70).

FIGURE 6-47

USPTO patents in sustainable energy technologies, by selected technology: 2006–16



GHG = greenhouse gas; USPTO = U.S. Patent and Trademark Office.

Note(s)

Sustainable energy technologies include alternative energy, energy storage, smart grid, and pollution mitigation. Alternative energy includes solar; wind; nuclear; fuel cell; hydropower; wave, tidal, ocean; geothermal; and electric or hybrid. Energy storage includes batteries, compressed air, flywheels, superconductivity, magnet energy systems, ultracapacitors, hydrogen production and storage, and thermal energy. Pollution mitigation includes recycling; control of air, water, and solid waste pollution; environmental remediation; cleaner coal; and capture and storage of carbon and other GHGs. Technologies are classified by The Patent Board. Patent grants are fractionally allocated among regions or countries on the basis of the proportion of the residences of all named inventors.

Source(s)

Science-Metrix, PatentsView, and USPTO patent data. See Appendix Table 6-57.

Science and Engineering Indicators 2018

U.S. sustainable energy technology patents more than doubled between 2009 and 2016 to reach 4,700 patents led by growth in four technology areas—hybrid and electric vehicles, solar, smart grid, and energy storage (Figure 6-45; Appendix Table 6-56, Appendix Table 6-58, Appendix Table 6-59, Appendix Table 6-63, and Appendix Table 6-64).

Patents granted to inventors outside the United States, primarily in Asia, grew faster than those granted to the United States, resulting in U.S. global share declining from 49% in 2009 to 43% in 2016. Japan's patents more than doubled to reach 2,200, led by growth in solar, hybrid electric, and battery (Figure 6-45; Appendix Table 6-56, Appendix Table 6-63, Appendix Table 6-64, and Appendix Table 6-67). The number of EU patents tripled, resulting in the EU's share edging up from 14% to 16% (Figure 6-45; Appendix Table 6-56). Four technologies—solar, hybrid electric, smart grid, and wind—drove overall growth (Appendix Table 6-59, Appendix Table 6-63, Appendix Table 6-64, and Appendix Table 6-65).

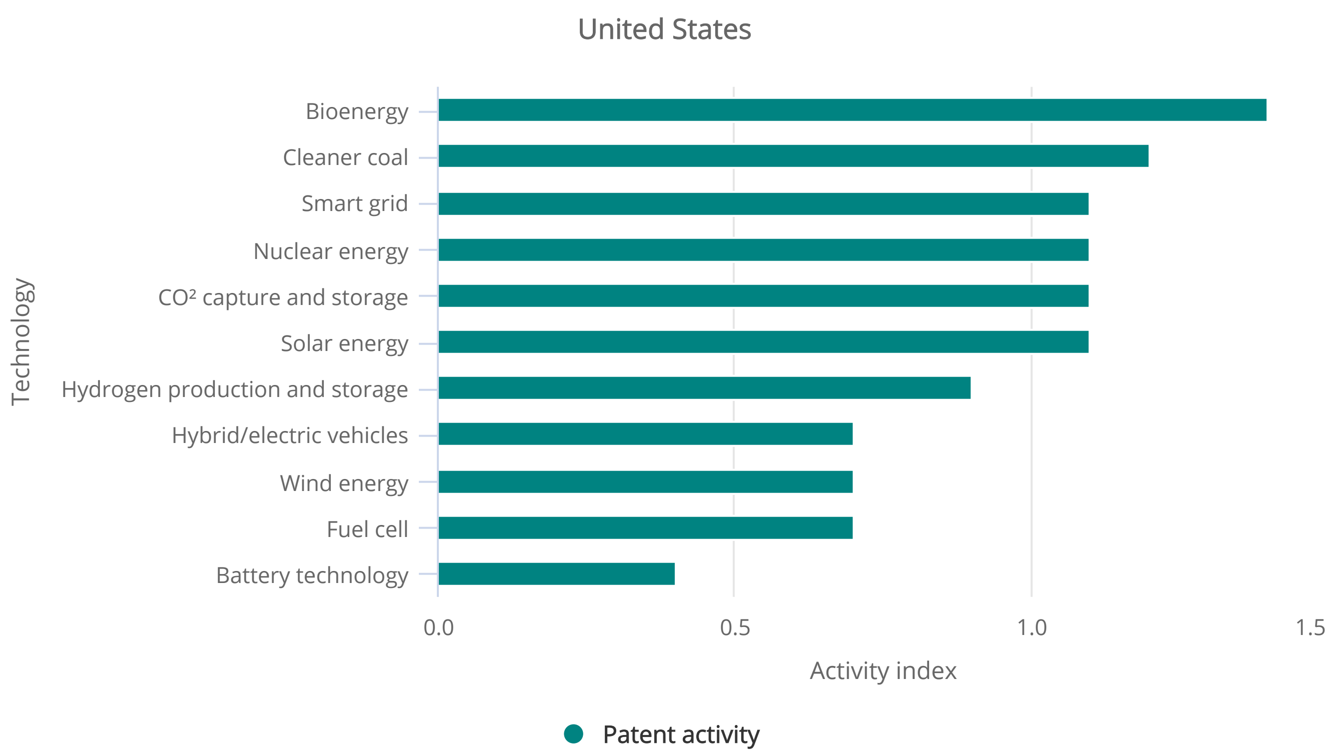
South Korea's patents more than quadrupled to reach 1,000 resulting in its global share nearly doubling to reach 9% (Figure 6-45). Growth was very rapid in energy storage, solar, hybrid/electric, and battery technologies (Appendix Table 6-58, Appendix Table 6-63, Appendix Table 6-64, and Appendix Table 6-67). Patents granted to China and Taiwan have increased rapidly, though from a very low base (Figure 6-46; Appendix Table 6-56).

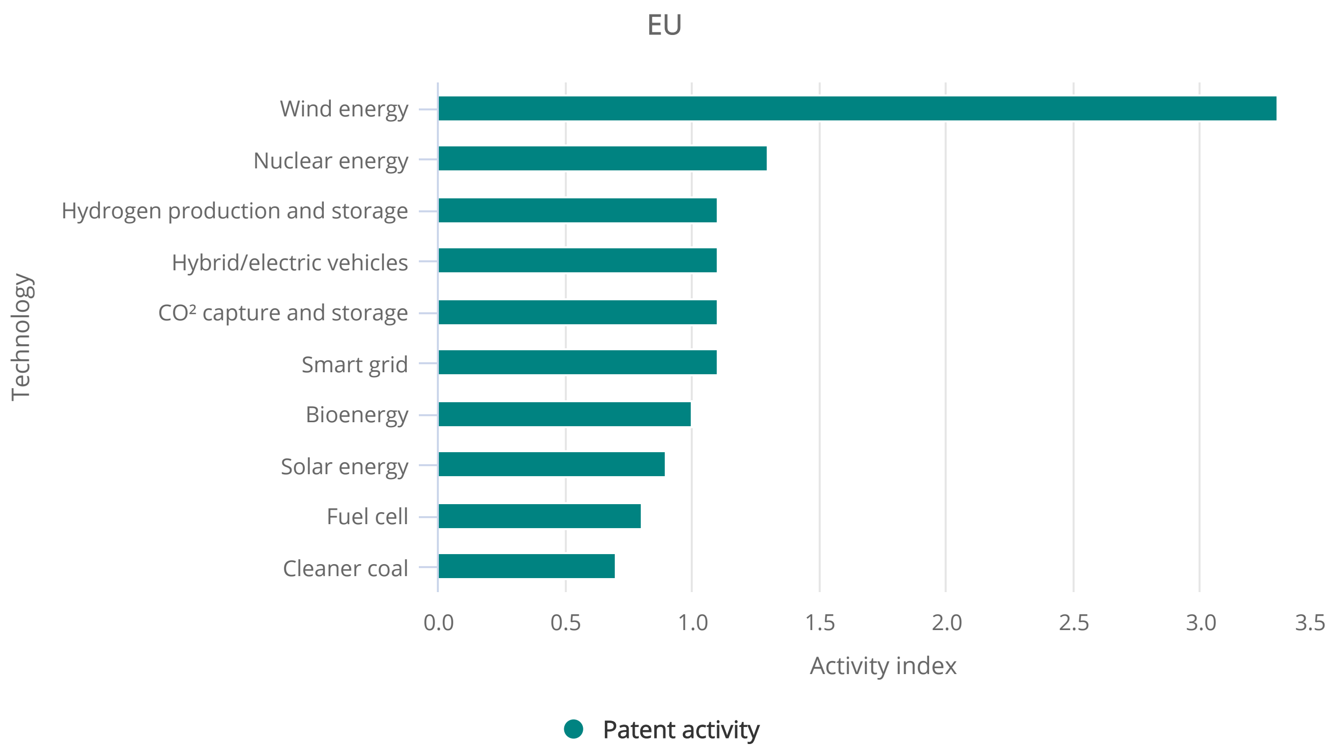
The patenting technology activity index indicates the extent to which a country specializes in that area. This indicator is indexed to 1.00, which represents the world level, meaning that a score above 1.00 shows that a country produces more of its patent output in the given technological area than the global proportion, whereas a score below 1.00 shows that a country produces fewer patents in this technological area than the global proportion. Technologies with an activity index of 1.2 or more are defined here as relatively more concentrated. (See Chapter 8 for a discussion on the limitations of using the patenting technology activity index.)

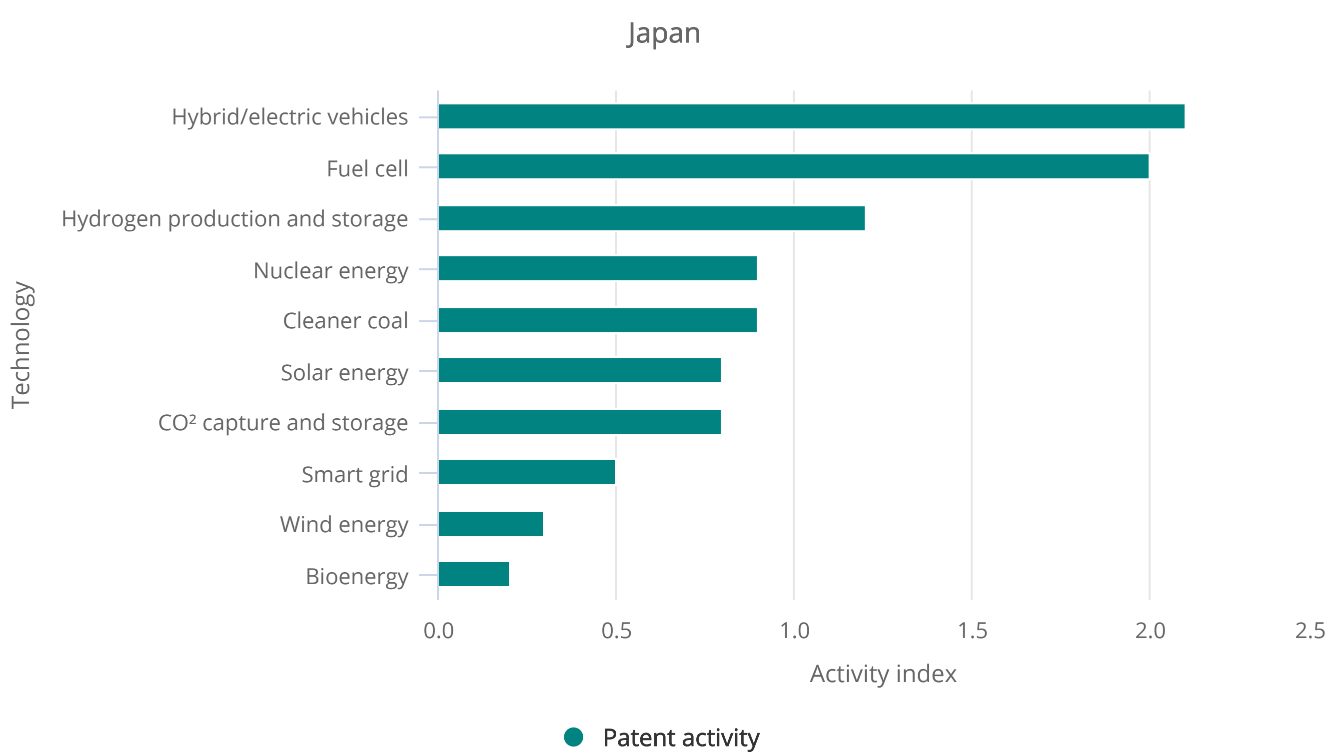
The United States has a relatively high concentration of patenting in bioenergy and cleaner coal (Figure 6-48; Appendix Table 6-62 and Appendix Table 6-69). The EU has a relatively high concentration in wind and nuclear energy (Figure 6-48; Appendix Table 6-65 and Appendix Table 6-66). Japan has a relatively high concentration in hybrid and electric vehicles, fuel cells, and hydrogen production and storage (Figure 6-48; Appendix Table 6-61, Appendix Table 6-64, and Appendix Table 6-68). South Korea has an extremely high concentration in batteries (6.3) and fuel cells (2.4) and a relatively high concentration in solar, hybrid and electric vehicles, and nuclear energy (Figure 6-48; Appendix Table 6-61, Appendix Table 6-63, Appendix Table 6-64, Appendix Table 6-66, and Appendix Table 6-67).

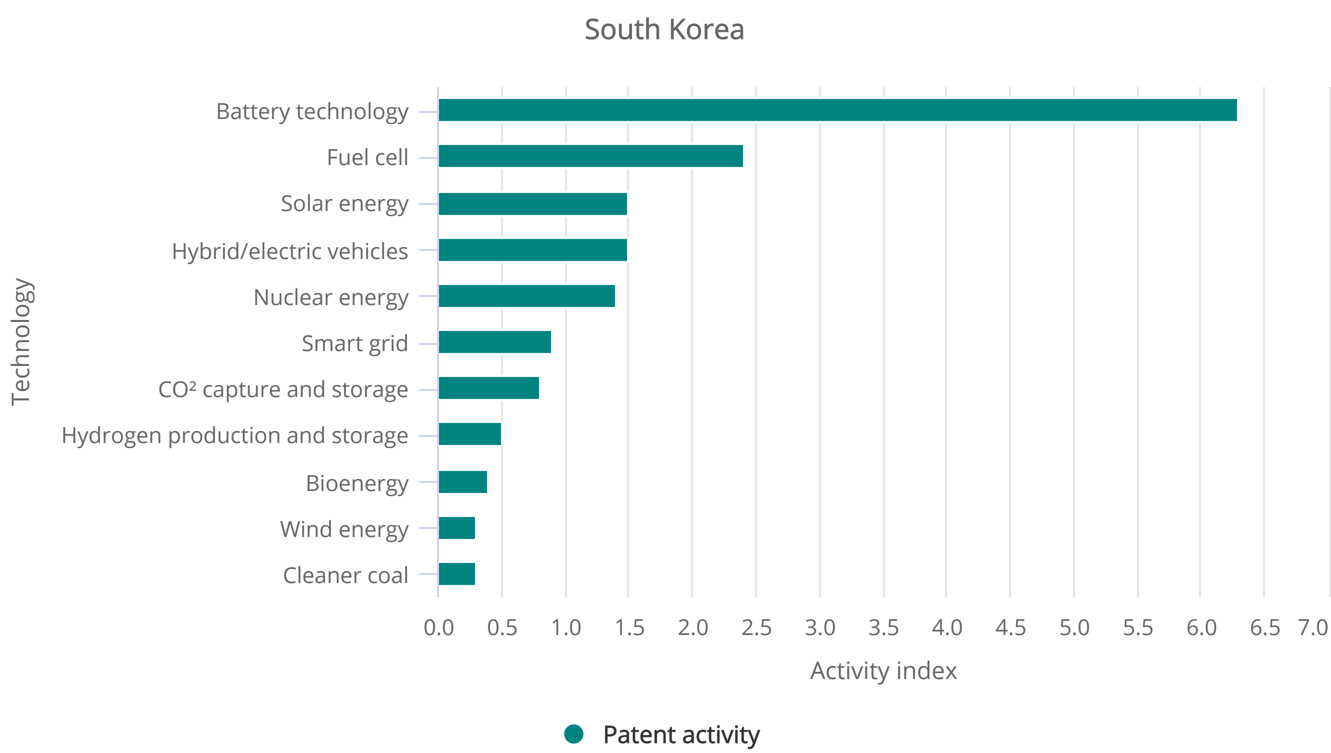
FIGURE 6-48

Patent activity index of selected sustainable energy technologies for the United States, the EU, Japan, and South Korea: 2014–16




EU
Technology
Wind energy
Nuclear energy
Hydrogen production and storage
Hybrid/electric vehicles
CO² capture and storage
Smart grid
Bioenergy
Solar energy
Fuel cell
Cleaner coal
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Activity index
Patent activity


Japan
Technology
Hybrid/electric vehicles
Fuel cell
Hydrogen production and storage
Nuclear energy
Cleaner coal
Solar energy
CO² capture and storage
Smart grid
Wind energy
Bioenergy
0.0
0.5
1.0
1.5
2.0
2.5
Activity index
Patent activity



EU = European Union.

Note(s)

A patent activity index is the ratio of a country's share of a technology area to its share of all patents. A patent activity index greater (less) than 1.0 indicates that the country is relatively more (less) active in the technology area. 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. Technologies are based on a classification developed by The Patent Board. Data were extracted in April 2017.

Source(s)

Science-Metrix, PatentsView, and USPTO patent data.

Science and Engineering Indicators 2018

---

[1] The International Energy Agency (IEA) manual states: "The IEA concept of Energy RD&D differs from the Frascati concept of R&D, in that (i) it focuses on energy related programmes only; (ii) it includes 'demonstration projects'; and (iii) it includes state owned companies.... The energy RD&D data collected by the IEA should not be confused with the data on government budget appropriations or outlays on R&D (GBAORD) collected by the OECD Directorate for Science, Technology, and Industry for the socio-economic objective 'Production, distribution and rational utilisation of energy'" (IEA 2011:16–17).

[2] Energy smart covers a wide range of technologies, from digital energy applications to efficient lighting, electric vehicles, and the smart grid that maximize the energy efficiency of existing energy sources and networks.

[3] Small distributed capacity consists largely of installation of solar photovoltaics on commercial and residential structures

[4]Bloomberg's data include investment in renewable energy, biofuels, energy efficiency, smart grid and other energy technologies, CO_2 capture and storage, and infrastructure investments targeted purely at integrating clean energy. Investment in solar hot water, combined heat and power, renewable heat, and nuclear are excluded, as are the proceeds of mergers and acquisitions (which do not contribute to new investment).

[5] BNEF (2017). In the first half of 2016, 21% of wind power in China went to waste and 12% of solar power in northern China was curtailed according to the World Resources Institute. See http://www.wri.org/blog/2017/01/china-leaving-us-behind-clean-energy-investment.

[6] The PTC and ITC lapsed at the end of 2013, and were reinstated briefly in December 2014. After being unavailable for most of 2015, Congress extended the PTC and ITC for a full 5 years.

[7] "Third party" financing has become a popular method of financing residential solar installation in the United States that is less expensive than purchasing a residential solar system. Under this type of financing, a customer can sign a traditional lease and pay for the use of a solar system or a customer can sign a power purchase agreement to pay a specific rate for the electricity that is generated each month. For more information, see http://www.seia.org/policy/finance-tax/third-party-financing.

[8] One gigawatt is a unit of electric power equal to one billion watts.

[9] BNEF, https://about.bnef.com/clean-energy-investment/. Accessed 28 February 2017.

[10] This discussion includes public research, development, and demonstration in energy efficiency, renewable energy, nuclear, hydrogen and fuel cells, CO_2 capture and storage, and other power and storage technologies.

[11] See D'Amato, Hamilton, and Hill (2015) for more information on NSF's classification of clean energy patents.

[12] The USPTO initiated a green technology pilot program on 7 December 2009 that expedites processing of some applications related to green technologies. For more information, see http://www.uspto.gov/patents/init_events/green_tech.jsp.

Conclusion

The global science and technology landscape is changing rapidly. Knowledge-intensive production and trade account for increasing shares of global output and are closely related to country and regional investment in S&E education and in R&D activity (Chapter 2 and Chapter 4 provide information on S&E higher education and R&D activity). While the United States and the EU continue to be leading global producers in many knowledge-intensive industries, the production and assembly of many high-technology goods have shifted to the developing world, particularly in China, where ICT and pharmaceutical manufacturing have become large shares of global production. Exports of high-technology products are centered in Asia, where China accounts for 24% of global exports, but smaller nations such as Vietnam are expanding rapidly. Although this production activity often represents the final phase of the global supply chain, where components designed or produced in other countries are transformed into final products, there is increasing evidence that China is moving from final assembly into higher-value activities, including R&D and manufacture of sophisticated products. Overall, the United States is the largest producer of high-technology manufacturing output with China being the largest global producer in the ICT manufacturing industries. China is by far the world's largest global producer in medium-high-technology industries. In commercial knowledge-intensive services (such as banking, finance insurance, R&D services), the United States and the EU lead in the volume of output while China is growing rapidly and now the third largest producer.

China is the world's largest global exporter in high-technology manufactured products and the second largest in medium-high-technology products. China has substantial trade surpluses in most of these products. However, conventional trade statistics likely exaggerate China's position because China's exports contain substantial content supplied by other countries, including the United States. China's exports of commercial knowledge-intensive services are growing rapidly and are in surplus.

The United States continues to have a strong competitive position in some technology-based industries. The United States remains the global leader in commercial knowledge-intensive services, which include many sophisticated industries such as R&D and civil engineering. The commercial knowledge-intensive industries account for nearly a fifth of global economic activity. The United States is the global leader in the high-technology manufacturing industries of aerospace and scientific measuring and control instruments. U.S. KTI industries have grown robustly compared to weak or negative growth of the EU and Japan following the global recession. Despite the strong recovery of U.S. KTI output, gains in employment have been limited and confined to commercial knowledge-intensive services.

The United States has a weaker position than other major economies in trade of technology-intensive goods. The United States is the world's third and fourth largest exporter of high-technology and medium-high-technology goods, respectively, and has substantial trade deficits in most of these goods. In high-technology goods, the United States remains the world's largest exporter of aerospace products and has a substantial surplus. However, conventional trade statistics likely overstate the weakness of the United States because U.S. exports of sophisticated intermediate goods to China and other countries are not included in the value of U.S. exports.

In sustainable energy research and technology, the United States is the global leader in attracting early-stage investment and is the largest investor in public RD&D in these technologies. Large-scale public investment in RD&D is important because many sustainable energy research and technology require costly large-scale testing and demonstration plants that are too risky for the private sector to finance entirely. The EU and Japan are major investors in public RD&D. China is the leading recipient of commercial-scale private investment and is leading the world in increasing its renewable energy capacity. In addition, China is the world's largest solar manufacturer and is a major wind manufacturer.

Glossary

Definitions

Commercial knowledge-intensive (KI) services: Knowledge-intensive services that are generally privately owned and compete in the marketplace without public support. These services are business, information, and financial services.

Company or firm: A business entity that is either in a single location with no subsidiaries or branches or the topmost parent of a group of subsidiaries or branches.

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

Foreign direct investment: Financial investment by which a person or an entity acquires a lasting interest in and a degree of influence over the management of a business enterprise in a foreign country.

Gross domestic product (GDP): The market value of all final goods and services produced within a country within a given period of time.

High-technology manufacturing industries: Industries formerly classified by the OECD that spend a high proportion of their revenue on R&D. These industries consist of aerospace; pharmaceuticals; computers and office machinery; semiconductors and communications equipment; and measuring, medical, navigation, optical, and testing instruments.

Information and communications technologies (ICT) industries: A subset of knowledge- and technology-intensive industries, consisting of two high-technology manufacturing industries, computers and office machinery and communications equipment and semiconductors, and two knowledge-intensive services industries, information and computer services, which is a subset of business services.

Intellectual property: Intangible property resulting from creativity that is protected in the form of patents, copyrights, trademarks, and trade secrets.

Intra-EU exports: Exports from European Union (EU) countries to other EU countries.

Knowledge- and technology-intensive (KTI) industries: Those industries that have a particularly strong link to science and technology. These industries are five service industries—financial, business, communications, education, and health care; five high-technology manufacturing industries—aerospace; pharmaceuticals; computers and office machinery; semiconductors and communications equipment; and measuring, medical, navigation, optical, and testing instruments; and five medium-high-technology industries—motor vehicles and parts, chemicals excluding pharmaceuticals, electrical machinery and appliances, machinery and equipment, and railroad and other transportation equipment.

Knowledge-intensive services industries: Those industries that incorporate science, engineering, and technology into their services or the delivery of their services, consisting of business, information, education, financial, and health care.

Medium-high-technology manufacturing industries: Industries formerly classified by the OECD that spend a relatively high proportion of their revenue on R&D. These industries consist of motor vehicles and parts, chemicals excluding pharmaceuticals, electrical machinery and appliances, machinery and equipment, and railroad and other transportation equipment.

Productivity: The efficiency with which resources are employed within an economy or industry, measured as labor or multifactor productivity. Labor productivity is measured by gross domestic product (GDP) or output per unit of labor. Multifactor productivity is measured by GDP or output per combined unit of labor and capital.

Public knowledge-intensive services: An industry category consisting of education and healthcare. These are publicly regulated or provided and remain relatively more location bound than the commercial knowledge-intensive services.

Value added: A measure of industry production that is the amount contributed by a country, firm, or other entity to the value of the good or service. It excludes the country, industry, firm, or other entity's purchases of domestic and imported supplies and inputs from other countries, industries, firms, and other entities.

Value chain: A chain of activities to produce goods and services that may extend across firms or countries. These activities include design, production, marketing and sales, logistics, and maintenance.

Venture capital Venture capitalists manage the pooled investments of others (typically wealthy investors, investment banks, and other financial institutions) in a professionally managed fund. In return, venture capitalists receive ownership equity and almost always participate in managerial decisions.

Key to Acronyms and Abbreviations

EU: European Union

GDP: gross domestic product

GHG: greenhouse gas

HS: Harmonized Commodity Description and Coding System, or Harmonized System

HT: high technology

ICT: information and communications technologies

IEA: International Energy Agency

IMF: International Monetary Fund

IoT: Internet of Things

IT: information technology

ITC: Investment Tax Credit

KI: knowledge intensive

KTI: knowledge- and technology-intensive

MHT: medium-high technology

MNC: multinational company

NAFTA: North American Free Trade Agreement

NSF: National Science Foundation

OECD: Organisation for Economic Co-operation and Development

PTC: Production Tax Credit

R&D: research and development

RD&D: research, development, and demonstration

ROW: rest of world

S&E: science and engineering

S&T: science and technology

UK: United Kingdom

UN: United Nations

USPTO: U.S. Patent and Trademark Office

WTO: World Trade Organization

References

AmChamChina. 2015. *Sector snapshots: Automotive*. https://business-center.amchamchina.org/sector-snapshot/automotive. Accessed 5 June 2017.

Balke NS, Ma J, Wohar ME. 2013. The contribution of economic fundamentals to movements in exchange rates. *Journal of International Economics* 90(1):1–16. https://doi.org/10.1016/j.jinteco.2012.10.003.

Bloomberg New Energy Finance (BNEF). 2017. *Record $30bn year for offshore wind but overall investment down*. https://about.bnef.com/blog/record-30bn-year-offshore-wind-overall-investment/. Accessed 7 February 2017.

Bresnahan T, Trajtenberg M. 1995. General purpose technologies: "Engines of growth?" *Journal of Econometrics* 65:83–108.

Cao, Y. 2014. *Health system and policies of China.* Presentation at the Health System and Policies Symposium, China Pharmaceutical Industry. https://regulatory.usc.edu/files/2014/11/015YC_Health_System_and_Policies_Symposium_20143.pdf. Accessed 2 February 2017.

China Daily. 2016. China's service outsourcing grows in 2015. *China Daily* 20 January. http://www.chinadaily.com.cn/business/chinadata/2016-01/20/content_23167866.htm. Accessed 4 February 2017.

D'Amato T, Hamilton K, Hill D. 2015. *Identifying Clean Energy Supply and Pollution Control Patents*. Working Paper NCSES 15-200. Arlington, VA: National Science Foundation, National Center for Science and Engineering Statistics. https://www.nsf.gov/statistics/2015/ncses15200/. Accessed 12 June 2017.

DeLong JB, Summers LH. 2001. *How important will the information economy be? Some simple analytics.* https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.503.7654&rep=rep1&type=pdf. Accessed 12 June 2017.

Dizoli A, Hunt B, Maliszewski W. 2016*. Spillovers from the Maturing of China's Economy*. IMF Working Paper WP/16/212. https://www.imf.org/external/pubs/ft/wp/2016/wp16212.pdf. Accessed 29 January 2017.

Donofrio N, Whitefoot K, editors. 2015. *Making Value for America: Embracing the Future of Manufacturing, Technology, and Work*. Washington, DC: National Academy of Engineering. The National Academies Press.

Economist. 2013. Coming home, Special report: Outsourcing and offshoring. *Economist* 19 January. https://www.economist.com/news/special-report/21569570-growing-number-american-companies-are-moving-their-manufacturing-back-united. Accessed 12 June 2017.

Feldman M. 2017. Putting the rise of Chinese supercomputing in perspective. *TOP500* 4 January. https://www.top500.org/news/putting-the-rise-of-chinese-supercomputing-in-perspective/. Accessed 15 February 2017.

Fuchs ERH, Kirchain R. 2010. Design for location: The impact of manufacturing offshore on technology competitiveness in the optoelectronics industry. *Management Science* 56(12):2323–49. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1545027.

Funabashi Y, Kushner B, editors. 2015. *Examining Japan's Lost Decades*. NY: Routledge.

Goodrich A, Powell D, James T, Woodhouse M, Buonassisi T. 2013. Assessing the drivers of regional trends in solar photovoltaic manufacturing. *Energy & Environmental Science* 6:2811-21.

Godin B. 2004. The new economy: What the concept owes to the OECD. *Research Policy* 33:679–90.

Green W. 2014. Electronic manufacturers bet big on Vietnam. *Techonomy* 24 July. http://techonomy.com/2014/07/electronics-manufacturers-bet-big-vietnam/. Accessed 5 June 2017.

Hsu S. 2015. China's health care reforms. *The Diplomat* 25 May. https://thediplomat.com/2015/05/chinas-health-care-reforms/. Accessed 2 February 2017.

Indian Brand Equity Foundation. 2017. *Pharmaceutical industry in India*. https://www.ibef.org/industry/pharmaceutical-india.aspx. Accessed 5 June 2017.

Industrial Research Institute. 2016. *2016 Global R&D Funding Forecast* Winter. https://www.iriweb.org/sites/default/files/2016GlobalR%26DFundingForecast_2.pdf. Accessed 4 June 2017.

International Energy Agency (IEA). 2011. *IEA guide to reporting energy RD&D budget/expenditure statistics*. Paris: Organisation for Economic Co-operation and Development, International Energy Agency. https://www.iea.org/stats/RDD%20Manual.pdf. Accessed 12 June 2017.

Jensen JB. 2012. U.S. should focus on business services. *Washington Post* 23 February. https://www.washingtonpost.com/opinions/us-should-focus-on-business-services/2012/02/22/gIQAm1MZWR_story.html. Accessed 12 June 2017.

Kavilanz P. 2013. Dreamliner: Where in the world its parts come from. *CNN Money* 18 January. http://money.cnn.com/2013/01/18/news/companies/boeing-dreamliner-parts/. Accessed 1 June 2017.

Klier T, Rubenstein J. 2013. Restructuring of the U.S. auto industry in the 2008-2009 recession. *Economic Development Quarterly* 27(2):144–59.

KPMG. 2009. *A new dawn: China's emerging role in global outsourcing*. https://assets.kpmg.com/content/dam/kpmg/pdf/2009/10/china-global-outsourcing-O-0904.pdf. Accessed 4 February 2017.

Mandel M. 2013. *Can the Internet of everything bring back the high-growth economy?* Washington, DC: Progressive Policy Institute. http://www.progressivepolicy.org/wp-content/uploads/2013/09/09.2013-Mandel_Can-the-Internet-of-Everything-Bring-Back-the-High-Growth-Economy-1.pdf. Accessed 5 June 2017.

Manyika J, Chui M, Bisson P, Woetzel J, Dobbs R, Bughin J, Aharon D. 2015. *The Internet of things: Mapping the value beyond the hype*. McKinsey Global Institute. http://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/the-internet-of-things-the-value-of-digitizing-the-physical-world. Accessed 31 May 2017.

Mudambi R. 2008. Location, control, and innovation in knowledge-intensive industries. *Journal of Economic Geography* 8(5): 699–725.

National Science Foundation, National Center for Science and Engineering Statistics (NSF/NCSES). 2014. *U.S. Knowledge-Intensive Services Industries Employ 18 Million and Pay High Wages*. NSF 15-300. Arlington, VA. https://www.nsf.gov/statistics/2015/nsf15300/.

Nie J, Palmer A. 2016. Consumer spending in China: The past and the future. *Federal Reserve Bank of Kansas City Economic Review* Q(III): 25-49.

Organisation for Economic Co-operation and Development (OECD). 2001. *Knowledge-Based Industries*. Paris: Directorate for Science, Technology, and Industry, Economic Analysis Statistics.

Organisation for Economic Co-operation and Development (OECD). 2007. *Science, Technology and Industry Scoreboard 2007, Annex 1*. Paris: Directorate for Science, Technology, and Industry. http://www.oecd.org/sti/inno/oecdsciencetechnologyandindustryscoreboard2007.htm Accessed 12 June 2017.

Organisation for Economic Co-operation and Development (OECD)/World Trade Organisation (WTO). 2013. *Aid for Trade at a Glance: Connecting to Value Chains.* http://www.oecd-ilibrary.org/development/aid-for-trade-at-a-glance-2013_aid_glance-2013-en. Accessed 13 October 2017.

Organisation for Economic Co-operation and Development (OECD), World Trade Organization (WTO), World Bank Group. 2014. *Global Value Chains: Challenges, Opportunities, and Implications for Policy*. https://www.oecd.org/tad/gvc_report_g20_july_2014.pdf. Accessed 12 June 2017.

Prasad E. 2015. *The path to sustainable growth in China.* Brookings Institution. https://www.brookings.edu/testimonies/the-path-to-sustainable-growth-in-china/. Accessed 12 June 2017.

PricewaterhouseCoopers (PwC). 2014. *China's impact on the semiconductor industry: 2016 update.* https://www.pwc.com/gx/en/technology/chinas-impact-on-semiconductor-industry/index.jhtml. Accessed 12 June 2017.

Reynolds E. 2010*. Institutions, public policy and the product life cycle: The globalization of biomanufacturing and implications for Massachusetts*. Working Paper Series MIT-IPC-10-001. Cambridge, MA: Industrial Performance Center, Massachusetts Institute of Technology. https://dspace.mit.edu/handle/1721.1/58380. Accessed 12 June 2017.

Sturgeon T. 2016. *Measuring knowledge intensive trade flows in goods and services*. Workshop on the Classification of High-Technology/Knowledge-Intensive Industries. Arlington, VA: National Science Foundation, National Center for Science and Engineering Statistics. 2–3 June.

Tomiyama A. 2015. Vietnam becoming device production hub. *Nikkei Asian Review.* http://asia.nikkei.com/Business/Trends/Vietnam-becoming-device-production-hub. Accessed 5 June 2017.

Treuner F, Hübner D, Baur S, Wagner SM. 2014. A survey of disruptions in aviation and aerospace supply chains and recommendations for increasing resilience. *Supply Chain Management*. https://www.ethz.ch/content/dam/ethz/special-interest/study-programme-websites/mba-eth-scm-dam/documents/publications/practitioner/2014-Supply_Chain_Management.pdf. Accessed 12 June 2017.

UN Broadband Commission for Sustainable Development. 2016. *Harnessing the Internet of things for global development*. http://www.itu.int/en/action/broadband/Documents/Harnessing-IoT-Global-Development.pdf. Accessed 1 June 2017.

Van Alstyne M. 2016. Platform shift: How new biz models are changing the shape of industry. April 24, 2014. Massachusetts Industrial Liason Program, Massachusetts Institute of Technology. http://ilp.mit.edu/images/conferences/2015/rd/presentations/Vanalstyne.2015.RD.pdf. Accessed 13 October, 2017.

Watt L, Wong A. 2017. First large Chinese-made passenger jet makes its maiden flight. *Phys.Org* 5 May. https://phys.org/news/2017-05-large-chinese-made-passenger-jet-maiden.html. Accessed 2 June 2017.

Williamson PJ, Raman AP. 2011. The globe: How China reset its global acquisition agenda. *Harvard Business Review* April. Available at https://hbr.org/2011/04/the-globe-how-china-reset-its-global-acquisition-agenda/ar/6. Accessed 12 June 2017.

World Trade Organization (WTO) and Institute of Developing Economies-Japan External Trade Organization (IDE-JETRO). 2011. *Trade Patterns and Global Value Chains in East Asia: From Trade in Goods to Trade in Tasks*. IDE-JETRO. https://www.wto.org/english/res_e/booksp_e/stat_tradepat_globvalchains_e.pdf. Accessed 12 June 2017.

World Trade Organization (WTO). 2016. *World trade statistical review*. https://www.wto.org/english/res_e/statis_e/wts2016_e/wts16_toc_e.htm. Accessed 28 January 2017.