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U.S. Manufacturing in International Perspective

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Summary

The health of the U.S. manufacturing sector has long been of great concern to Congress. The decline in manufacturing employment since the start of the 21st century has stimulated particular congressional interest, leading Members to introduce hundreds of bills over many sessions of Congress intended to support domestic manufacturing activity in various ways. The proponents of such measures frequently contend that the United States is by various measures falling behind other countries in manufacturing, and they argue that this relative decline can be mitigated or reversed by government policy.

This report is designed to inform the debate over the health of U.S. manufacturing through a series of charts and tables that depict the position of the United States relative to other countries according to various metrics. Understanding which trends in manufacturing reflect factors that may be unique to the United States and which are related to broader changes in technology or consumer preferences may be helpful in formulating policies intended to aid firms or workers engaged in manufacturing activity. This report does not describe or discuss specific policy options.

The main findings are the following:

- The United States' share of global manufacturing activity declined from 28% in 2002, following the end of a U.S. recession, to 16.5% in 2011. By 2016, the U.S. share rose to over 18%, the largest share since 2009. These estimates are based on the value of each country's manufacturing in U.S. dollars; part of the decline in the U.S. share was due to a 23% decline in the value of the dollar between 2002 and 2011, and part of the subsequent rise is attributable to a stronger dollar.
- China displaced the United States as the largest manufacturing country in 2010. Again, part of China's rise by this measure has been due to the appreciation of its currency, the renminbi, against the U.S. dollar. The reported size of China's manufacturing sector decreased in 2015 and 2016 due to currency adjustments.
- Manufacturing output, measured in each country's local currency adjusted for inflation, has been growing more slowly in the United States than in China, South Korea, Germany, and Mexico, but more rapidly than in many European countries and Canada.
- Employment in manufacturing has fallen in most major manufacturing countries over the past quarter-century. In the United States, manufacturing employment since 1990 has declined in line with the changes in Western Europe and Japan, although the timing of the decline has differed from country to country.
- U.S. manufacturers' spending for research and development (R&D) rose 10.5% from 2010 to 2015, adjusted for inflation. Manufacturers' R&D spending rose more rapidly in several other countries.
- Manufacturers in many countries have increased spending on R&D, relative to value added in the manufacturing sector, but U.S. manufacturers' R&D intensity has changed little since 2008. A large proportion of U.S. manufacturers' R&D takes place in high-technology sectors such as pharmaceutical, electronics, and aircraft manufacturing, whereas in most other countries the largest share of R&D occurs in medium-technology sectors such as automotive and machinery manufacturing.

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Introduction

The health of the U.S. manufacturing sector has long been of great concern to Congress. The large decline in manufacturing employment since the start of the 21st century has stimulated particular congressional interest. Over the years, Members have introduced hundreds of bills intended to support domestic manufacturing activity in various ways. The proponents of such measures frequently contend that the United States is in some way falling behind other countries in manufacturing and argue that this relative decline can be mitigated by government policy.

Examining U.S. manufacturing in isolation sheds little light on the causes of changes in the manufacturing sector. While some of those changes may be a result of factors specific to the United States, others may be attributable to technological advances, shifting consumer preferences, or macroeconomic forces such as exchange-rate movements. This report is designed to inform the debate over manufacturing policy by examining changes in the manufacturing sector in comparative perspective. It does not describe or discuss specific policy options.

The charts and tables on the pages that follow depict the position of the United States relative to other major manufacturing countries according to various metrics. Not all countries compile information on each subject. This report draws on data from a number of sources, and has certain unavoidable statistical problems of which the reader should be aware.

Despite meaningful progress in standardization, countries define "manufacturing" in different ways. Some associate manufacturing with factory production, while others may label a self-employed artisan as a manufacturing worker. Some countries have sophisticated sampling systems to collect data about production and employment from firms and households, whereas others rely heavily on estimates drawn from macroeconomic models or collect data only from a non-random subset of enterprises. International comparisons of compensation data are especially difficult because of national differences in taxation and employee benefits. Complicating matters further, the organizations that compile statistics obtained from national governments may adjust the raw data in different ways to improve compatibility, such that certain figures used to prepare this report may not be identical to those published by national statistical services.

Additionally, analysis of trends in manufacturing is complicated by often arbitrary distinctions between manufacturing and non-manufacturing activity. If, for example, a manufacturing firm owns the trucks that deliver its goods, statisticians may count the truck drivers as manufacturing-sector workers, and their wages may be included in manufacturing value added. If the manufacturer instead contracts with a separate trucking company to deliver its goods, statisticians will consider the truck drivers to be transport-sector workers and their wages will be included in transport-sector value added, making the manufacturing sector appear smaller—even though there has been no change in the total amount of labor or the tasks performed.

All of these factors argue for caution in the use of these data, and warn against unwarranted assumptions of precision.

How the U.S. Manufacturing Sector Ranks

The standard measure of the size of a nation's manufacturing sector is not manufacturers' sales, but rather their value added. Value added attempts to capture the economic contribution of manufacturers in designing, processing, and marketing the products they sell.

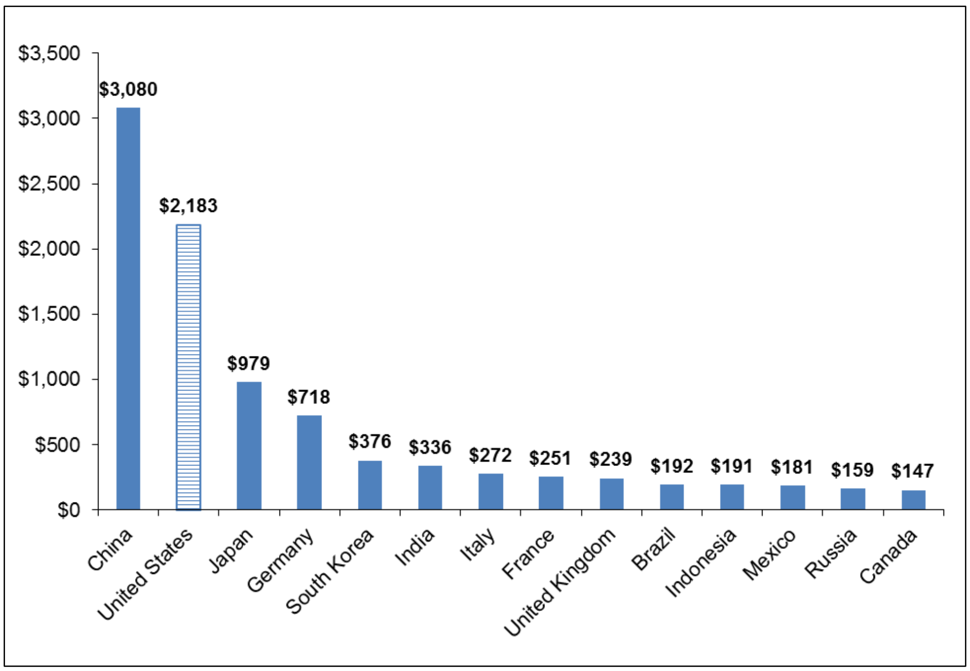
At the level of an individual firm, value added can be calculated as total sales less the total cost of purchased inputs, such as raw materials and electricity. Thus, a firm that purchases raw materials and processes them only slightly may have substantial sales, but will produce little value added. Alternatively, a firm's value added can be measured as the sum of its employee compensation, business taxes (less subsidies), and profits.

The size of a country's manufacturing sector cannot be determined simply by adding up the value added of its manufacturers. If a domestic manufacturer uses inputs from its plants abroad, those inputs contain value added by the firm, but not domestically. Calculating total value added in manufacturing thus requires adjustments for imported parts and components incorporated into the output of domestic factories, and also for domestic goods and services that were exported and used in another country to make products that were subsequently imported.

According to U.N. estimates, China displaced the United States as the largest manufacturing nation in 2010. In 2016, according to the U.N. figures, China's value added in manufacturing exceeded $3 trillion, compared to $2.2 trillion for the United States. These estimates are calculated in U.S. dollars, and the reported manufacturing value added of some countries, including China, Mexico, and Russia, declined in 2016 due to the declines of those countries' currencies against the dollar.[1] Japan, which ranked third in manufacturing value added at $979 billion in 2016 (see **Figure 1**), saw its reported manufacturing value added fall 27% between 2012 and 2015, a period in which its currency fell 40% in dollar terms, before rising 10% as the yen steadied against the dollar in 2016.[2]

Figure 1. Leading Countries, Value Added in Manufacturing

Billion dollars, 2016



Source: U.N. National Accounts Main Aggregates Database, value added by economic activity, at current prices—U.S. dollars.

[1] The trade weighted value of the dollar rose approximately 4.6% in 2016; see Federal Reserve Board H.10 release.

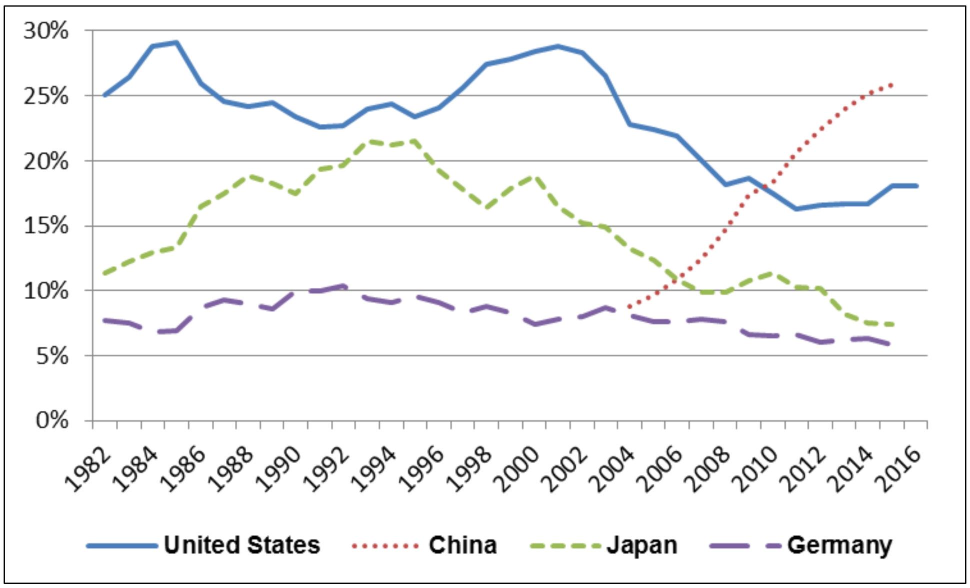
[2] U.N. National Accounts Main Aggregates Database, value added by economic activity at current prices—U.S. dollars, http://unstats.un.org/unsd/snaama/resQuery.asp (accessed January 17, 2018).

The U.S. share of global manufacturing value added has declined over time, from 29% in the early 1980s to 18.1% in 2015 and 2016 (see **Figure 2**). Similarly, the global shares of Japan and Germany have contracted significantly from their peaks in the 1990s. The declining shares of these and other wealthy economies are a consequence of the very rapid increase in manufacturing activity in emerging economies, notably China. However, China's share of global manufacturing output has steadied in the range of 25% to 26% since 2014, according to U.N. data. It is important to note that global shares are measured in U.S. dollars, so each country's share in a given year is greatly affected by the strength of its currency against the dollar.

Manufacturing value added in the United States, as measured by the U.S. Bureau of Economic Analysis in inflation-adjusted 2009 dollars, rose 41% from 1997 to 2016.[3]

Figure 2. Selected Countries' Shares of Global Manufacturing Value Added

Calculated in current U.S. dollars



Source: U.N. National Accounts Main Aggregates Database, value added by economic activity, at current prices—U.S. dollars.

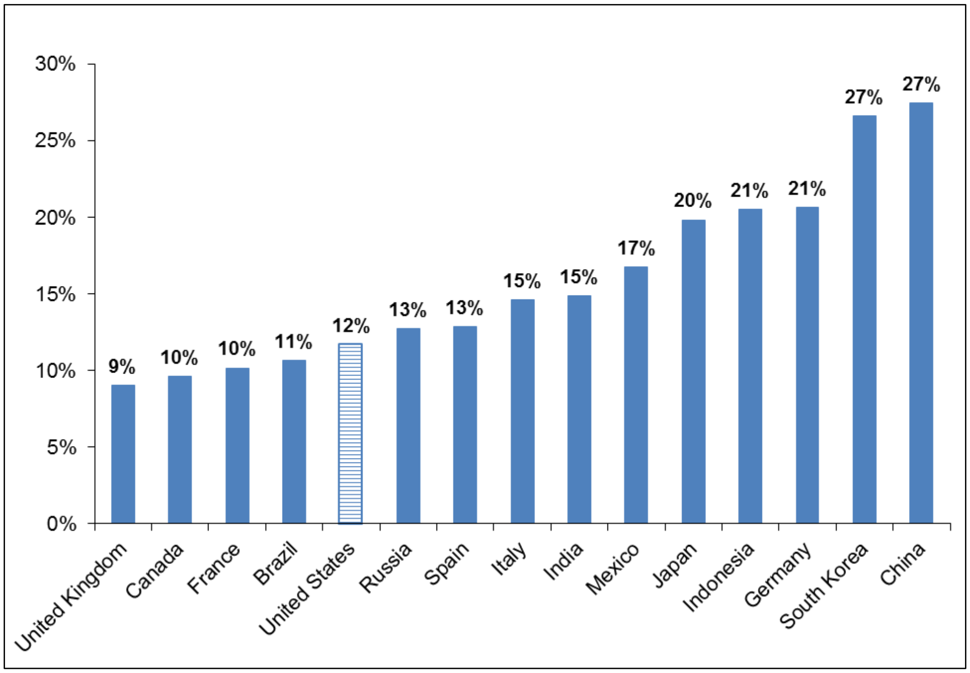
Globally, manufacturing contributed 17% of all economic value added, according to U.N. calculations. This figure has changed little in recent years. Manufacturing value added amounted to 12% of total U.S. gross domestic product (GDP) in 2016. Manufacturing is more significant in the United States, relative to the size of the economy, than in the United Kingdom, France, and Canada, but much less important than in Japan, Indonesia, Germany, China, and South Korea (see **Figure 3**). The manufacturing share of total economic output in China declined from 32% in 2010 to 27% in 2016, while the share of manufacturing in the U.S. economy remained relatively stable.

In this respect, it is important to note that a high ratio of manufacturing value added to GDP is not necessarily a sign of economic vibrancy. To the contrary, a high ratio may indicate that various policies or practices, such as labor regulations, credit subsidies, or protection from imports, are standing in the way of a reallocation of capital and labor from manufacturing to other sectors in which they might contribute more to economic growth.

[3] Bureau of Economic Analysis, real value added by industry (accessed January 17, 2018).

Figure 3. Share of Manufacturing in National Economies

Manufacturing value added as percentage of Gross Domestic Product, 2016



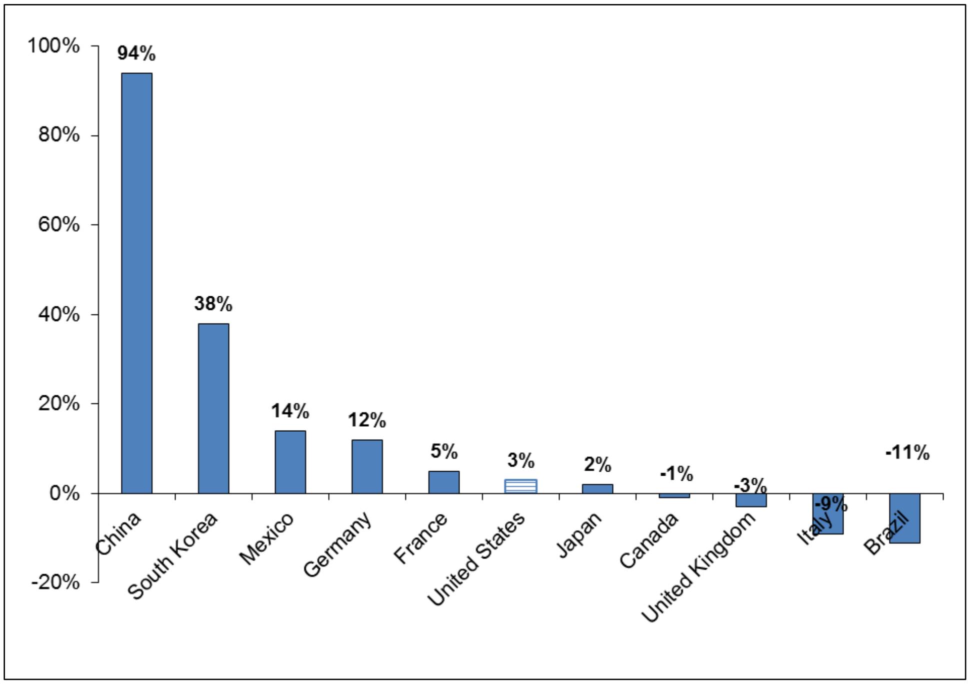
Source: U.N. National Accounts Main Aggregates Database, value added by economic activity and Gross Domestic Product, at current prices—national currency.

Despite its relatively low rank in manufacturing as a share of GDP, the United States appears to have outperformed many other wealthy countries in the growth of manufacturing value added in recent years. Between the recession year of 2008 and 2016, U.S. value added in manufacturing, adjusted for inflation, rose 2.7%, according to U.N. data. This was faster than the growth of manufacturing value added over the same period in Canada, Brazil, Italy, Japan, and the United Kingdom. China, South Korea, Mexico, and Germany had much faster growth in manufacturing value added than the United States over the same period, after adjusting for inflation (see **Figure 4**). These data are expressed in terms of each country's currency, adjusted for its domestic inflation, so exchange-rate changes play no role.[4]

[4] U.N. National Accounts Main Aggregates Database, Value Added by Economic Activity at constant 2005 prices, national currency, http://unstats.un.org/unsd/snaama/selbasicFast.asp.

Figure 4. Change in Value Added in Manufacturing, 2008-2016

Adjusted for inflation in each respective country



Source: U.N. National Accounts Main Aggregates Database, value added by economic activity at constant 2005 prices, national currency.

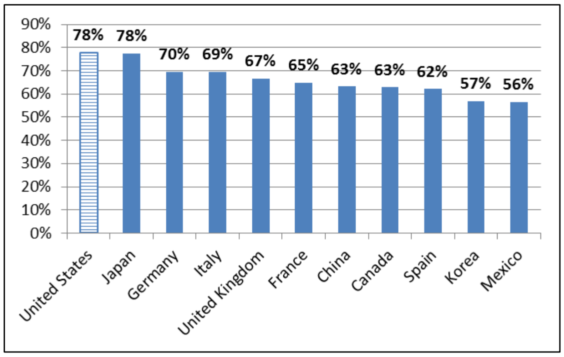
U.S. manufacturers, like those in other countries, rely on and participate in international supply chains. However, U.S.-made goods appear to have less foreign content than goods produced in most other major manufacturing countries, with the exception of Japan. Some 78% of the value of U.S. exports in 2014 was added in the United States, according to estimates by the Organisation for Economic Co-operation and Development (OECD). By contrast, less than 65% of the value of manufactured goods exported by China, Canada, South Korea, and Mexico was added in those countries (see **Figure 5**).[5]

The proportion of domestic content varies considerably by product, depending mainly on the extent of international supply chains. For example, an estimated 66% of the value of U.S. exports of motor vehicles in 2014 was added in the United States. This was on a par with South Korea and far more than Canada and Mexico, but considerably less than Japan (see **Figure 6**). With respect to exports of computers and electrical and optical equipment, on the other hand, the share of value added domestically was greater for the United States (89%) than for any other country. Although China is by far the largest exporter of such products, less than half the value of its exports is Chinese in origin.[6]

[5] Calculated from Organisation for Economic Co-operation and Development (OECD), Trade in Value Added, Origin of Value Added in Gross Exports, nowcast estimates (accessed January 24, 2018).

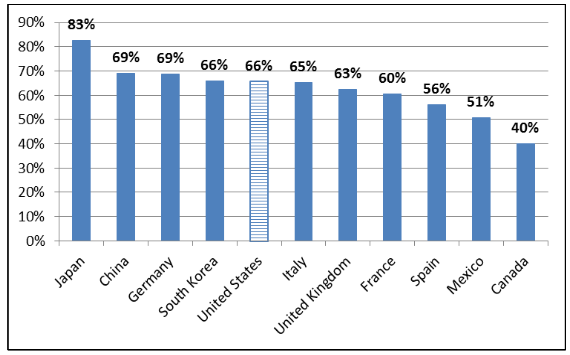
[6] Ibid.

Figure 5. Domestic Value in Exports of Manufactured Goods, 2014



Source: OECD-WTO Trade in Value Added, Value Added in Gross Exports by Source.

Figure 6. Domestic Value in Exports of Motor Vehicles, 2014



Source: OECD-WTO Trade in Value Added, Value Added in Gross Exports by Source.

The United States has performed well in manufacturing, compared to other high-income economies, when viewed over a longer time period. From 1990 through 2016, the only high-income countries with faster growth in manufacturing value added were a handful of smaller economies including Austria, Finland, Israel, and Sweden, as well as South Korea.

Additionally, data on inflows of foreign investment suggest that the United States has been an attractive manufacturing location relative to other high-income countries in recent years. In 2016, according to OECD data, 45% of foreign direct investment coming into the United States went into the manufacturing sector. Of this, some $89 billion, or 44%, involved investment in pharmaceutical manufacturing.[7] The limited data on other wealthy countries show much smaller flows of foreign investment into manufacturing.[8] However, it is possible that recent data on foreign investment in U.S. manufacturing have been affected by "inversions," in which U.S. corporations become wholly owned subsidiaries of foreign corporations for tax reasons. If a U.S. manufacturer moves its headquarters abroad as the result of an inversion, its stock of fixed capital in the United States is reclassified as foreign-owned, and any future capital investment will be counted as foreign direct investment rather than domestic investment.[9]

Data permitting international comparisons of capital investment in manufacturing are available for only a few countries. These indicate that U.S. gross investment in fixed manufacturing capital, such as factories and equipment, is in about the same range as in West European economies, but much lower than in South Korea (see **Figure 7**).[10]

Interpreting these data on investment in manufacturing is problematic. A high ratio of gross fixed capital formation to output is not necessarily positive from an economic point of view; if such investment is generating a low return, then high capital investment could indicate inefficient use of capital. The relatively low level of gross investment in the United States might therefore

[7] U.S. Bureau of Economic Analysis, "New Foreign Direct Investment in the United States, 2014 and 2015," July 13, 2016, https://www.bea.gov/newsreleases/international/fdi/2016/pdf/fdi0716.pdf, Table 1.2.

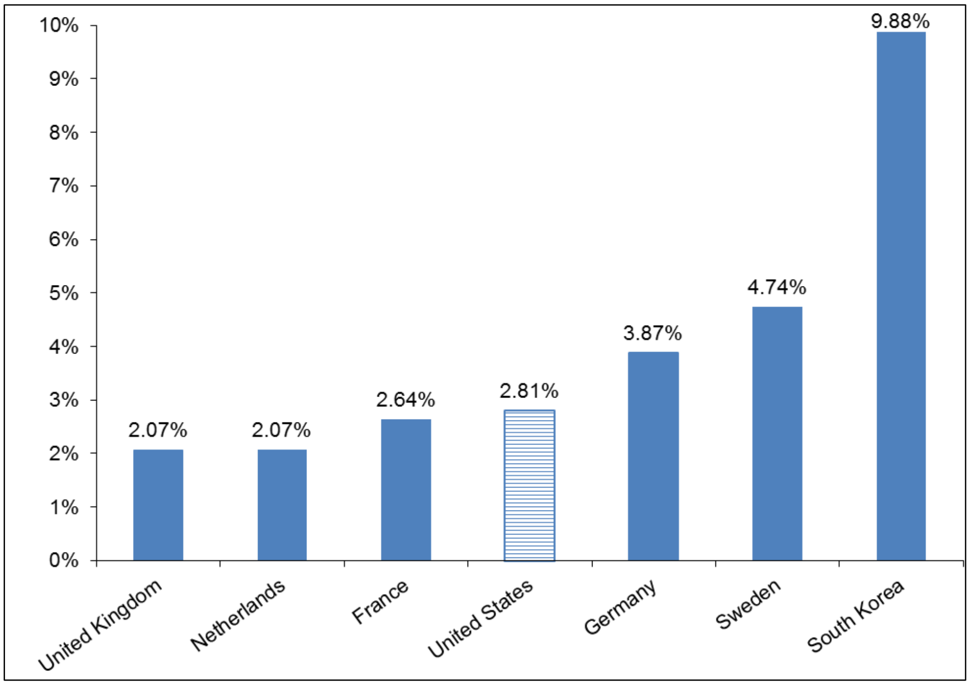
[8] OECD International Direct Investment Statistics, "FDI financial flows by industry BMD4: Inward FDI by instrument and by industry" (accessed January 24, 2018).

[9] Jessica M. Hanson, Howard I. Krakower, Raymond J. Mataloni Jr., and Kate L.S. Pinard, "The Effects of Corporate Inversions on the International and National Economic Accounts," *Survey of Current Business*, February 2015.

[10] OECD National Accounts Statistics, "Capital formation by activity – ISIC Rev. 4" (accessed January 24, 2018).

indicate that U.S. manufacturers pay greater attention to return on capital than their counterparts in other countries. Another explanation might be that U.S. manufacturers face comparatively few obstacles to contracting fabrication or assembly work to manufacturers abroad, whereas other nations may have policies in place to promote domestic fabrication and assembly or to discourage foreign sourcing.

Figure 7. Investment in Manufacturing Fixed Capital as Share of GDP, 2015



Source: OECD, National Accounts Statistics, Capital Formation by Activity – ISIC Rev. 4.

Note: Data for Spain and South Korea pertain to 2014.

The Role of Services in Manufacturing

Measuring manufacturing activity is not without challenges, largely because of the imperfect line between manufacturing and services. U.S. statistical agencies, for example, consider work performed at establishments whose principal business is manufacturing to be manufacturing, regardless of the specific tasks involved. Similarly, all activities occurring at establishments whose principal business is services are considered service activities.

The following three examples illustrate the statistical confusion that can result.

- If workers at a manufacturing establishment design and fabricate a product, the design activities generally will be counted as value added in manufacturing and the workers engaged will be tabulated as manufacturing employees.
- If the design is created within the manufacturing firm but at a location where no physical production occurs, it could conceivably be counted as either a manufacturing-sector product or a service-sector product.
- If the manufacturer purchases the design from a specialist design firm, the value added in the design process will be credited to the service sector, and the workers involved will be considered service-sector employees.

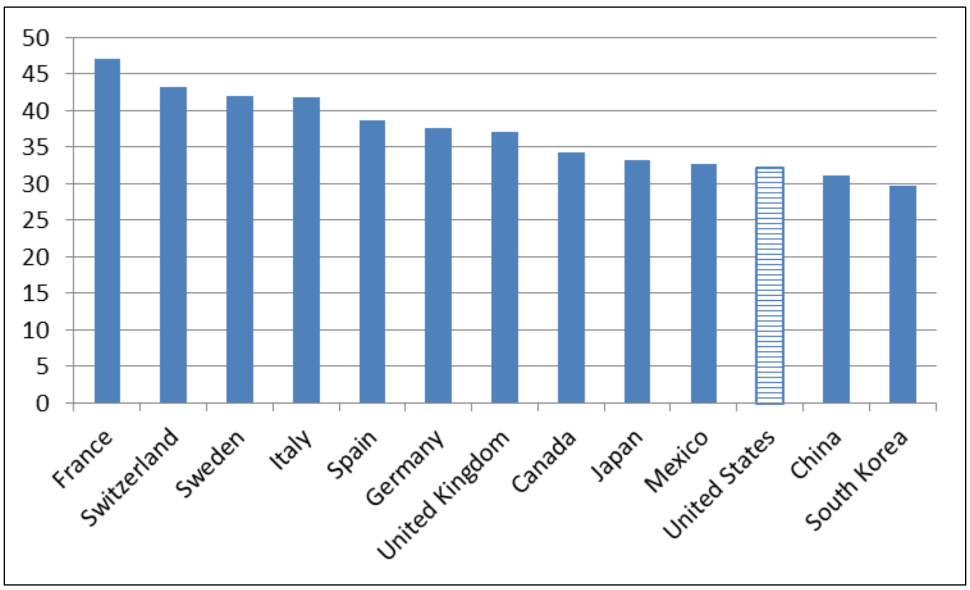
In all three cases, total employment and total value added are identical; all that differs is the economic sector to which the employment and value added are attributed.

Identifying manufacturing work has become even more difficult in recent years for a variety of reasons. As of May 2016, more than 760,000 people engaged in production occupations typical of manufacturing, such as assemblers and fabricators, were employed by employment services firms in the United States; they were likely counted as service-sector workers, as they were not employed directly by the manufacturing establishments in which they labored. Similarly, more than 28,000 workers at U.S. warehousing and storage facilities were engaged in manufacturing production activities such as assembly, fabrication, and packaging in May 2016. Although these workers were engaging in traditional manufacturing tasks, their output is unlikely to have been captured as value added in manufacturing.[11]

Moreover, determining the location at which value is added to a service that is used in a manufactured product can be all but impossible. Manufacturers frequently procure components from many suppliers in lengthy international supply chains, and each of those suppliers is likely to purchase service inputs to at least a limited extent. The service providers themselves may be international firms, and their involvement in a given production process may involve workers on several continents.

Figure 8. Service-Sector Inputs into Manufacturing Exports

Service-sector value added as percentage of total value added in of manufactured exports, 2011



Source: Organisation for Economic Co-operation and Development (OECD), Trade in Value Added database, https://stats.oecd.org/Index.aspx?DataSetCode=TIVA_2016_C1 (accessed January 25, 2018).

Efforts to measure the value of manufacturing-related services more accurately are still in their infancy. According to 2011 data, U.S. exports of manufactured products include a lesser proportion of services content than exports of most other advanced economies (see **Figure 8**). As a result, only 5% of U.S. service sector jobs depended on manufacturing exports in 2015,

[11] U.S. Bureau of Labor Statistics, Occupational Employment Statistics Query System, data.bls.gov/oes (accessed January 25, 2018).

compared with nearly 8% in Japan and 10%-23% in European Union states.[12] However, U.S. manufacturers made comparatively little use of imported services content in exports. For example, 17.8% of the value of Chinese manufactured exports and 16.4% of the value of South Korean manufactured exports in 2011 comprised imported services, according to the Organisation for Economic Co-operation and Development (OECD), compared with 8.0% of the value of U.S. manufactured exports.

The figures illustrated in **Figure 8** show only the importance of services purchased by manufacturers from outside firms. One possible interpretation of these data is that U.S. manufacturers may be more vertically integrated than those in other countries and therefore less reliant on services purchased from other firms. A partial explanation is that a comparatively efficient transportation system requires U.S. exporters to spend less on purchasing transportation than their competitors in other countries: the cost of transportation and communications services came to only 5.0% of the value of U.S. manufactured exports in 2011, compared with 6.1% in Germany and 6.4% in China.[13]

The steps involved in producing goods such as electrical equipment and automobiles may be dispersed across many countries, forming what economists refer to as "global value chains." Attempts to study this phenomenon on a global basis suggest that activities that are close to the producer, such as design and finance, or close to the consumer, such as marketing and sales, tend to be located in high-wage countries and to pay relatively high wages wherever they occur, whereas activities in between those two stages—such as physical production—tend to be located in lower-wage countries and to pay lower wages no matter where they are located. This finding reinforces the general conclusion that services account for an increasing share of the value of products that are sold to end users as manufactured goods.[14]

Manufacturing Work

International comparisons of manufacturing employment trends are hampered by inadequate data, particularly for emerging economies. Some major manufacturing countries, notably China and India, do not report complete information on manufacturing employment at the national level. Mexico has had consistent nationwide data available only since 2005.

All the advanced economies for which data are available have experienced long-term declines in manufacturing employment. Manufacturing employment in the United States, measured on a basis compatible with internationally agreed definitions, fell by 4% from 2008 through 2016, despite the economic recovery that began in 2009. Canada, France, Italy, Japan, the Netherlands, Sweden, and the United Kingdom all saw larger declines over that period (see **Figure 9** for data on selected countries). Over the quarter-century between 1990 and 2016, manufacturing employment fell by a much lower percentage in the United States than in the United Kingdom, France, Sweden, and Japan and by about the same percentage as in Germany, the Netherlands, and Canada (see **Figure 10**).[15] The number of manufacturing workers also has declined in some

[12] OECD, Business Sector Service Jobs Sustained by Foreign Final Demand for Manufactured Goods, 2011, *OECD Science, Technology and Industry Scoreboard 2015* (accessed January 17, 2017).

[13] OECD, Services Value Added in Manufacturing Exports, by Type of Service, 2011, *OECD Science, Technology and Industry Scoreboard 2015* (accessed April 11, 2018).

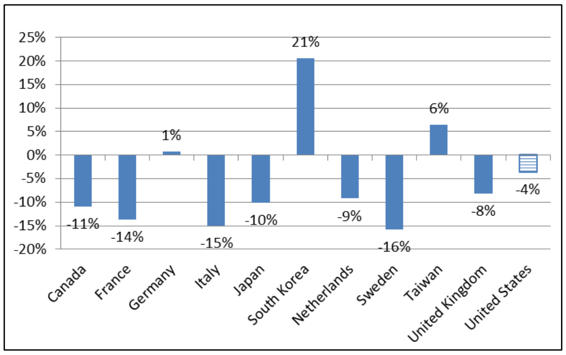
[14] Christophe Degain, Bo Meng, and Zhi Wang, "Recent trends in global trade and global value chains," in *Measuring and Analyzing the Impact of GVCs on Economic Development* (Washington, DC: World Bank, 2017), pp. 54-60.

[15] Conference Board International Labor Comparisons Program, "International Comparisons of Manufacturing Productivity & Unit Labor Cost Trends, Update to 2016," 2017, http://www.conference-board.org/ilcprogram/. The (continued...)

countries with less advanced economies, and has declined as a share of the labor force in many countries, including Mexico and Brazil.[16] These figures indicate that the diminished importance of manufacturing as a source of jobs is not limited to the United States.[17]

Figure 9. Manufacturing Employment

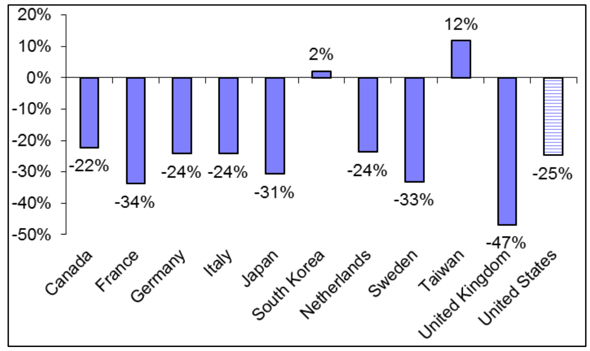
Percentage change, 2008-2016



Source: The Conference Board, "International Comparisons of Manufacturing Productivity & Unit Labor Cost Trends," 2017.

Figure 10. Manufacturing Employment

Percentage change, 1990-2016



Source: The Conference Board, "International Comparisons of Manufacturing Productivity & Unit Labor Cost Trends," 2017.

The international comparison of manufacturing employment is somewhat different if viewed in terms of hours worked rather than by the number of workers. By this metric, Germany experienced a similar decline in manufacturing work to that of the United States over the 1990-2016 period, while the declines in France, Japan, and the United Kingdom were larger. The timing differed among countries, with manufacturing work hours falling faster in other countries during the 1990s and the United States experiencing a comparatively steep drop in the 2000-2010 period. Since 2010, hours worked in manufacturing (as defined internationally) have grown 8% in the United States; among the countries for which the Conference Board maintains data, only South Korea and the Czech Republic have shown faster growth in manufacturing work hours.[18]

The long-term reduction in demand for labor in manufacturing is directly related to improved labor productivity. From 2002 to 2016, manufacturing labor productivity, measured in terms of output per worker hour, increased much more rapidly in the United States than in Canada, most West European countries, and Japan (see **Figure 11**). Since 2010, however, U.S. labor

(...continued)

data published by the Conference Board in 2017 reflect changes in reporting by Canada, Japan, and the United States to improve international compatibility, and thus are not directly comparable either to data published by the Conference Board in prior years or to data published by those countries' statistical services for other purposes.

[16] International Labour Organization, *Key Indicators of the Labour Market 2015*, http://www.ilo.org/global/statistics-and-databases/research-and-databases/kilm/lang--en/index.htm, Tables 4b and 4c. For examples of countries where manufacturing employment has peaked as a share of total employment, see International Labour Organization, *World Employment and Social Outlook Trends 2015* (Geneva, 2015), p. 63.

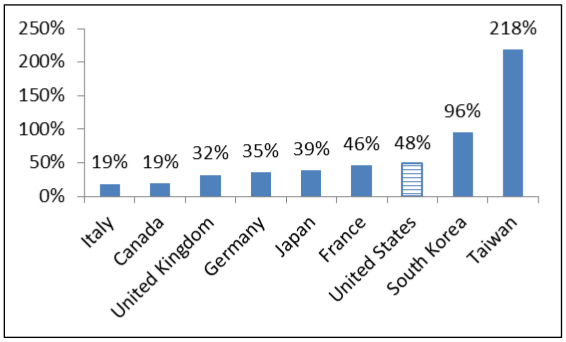
[17] These data were compiled by the Conference Board International Labor Comparisons Program.

[18] Conference Board International Labor Comparisons Program, "International Comparisons of Manufacturing Productivity & Unit Labor Cost Trends," 2017, http://www.conference-board.org/ilcprogram/ (accessed January 29, 2018).

productivity in manufacturing has declined, whereas it has improved in several other major manufacturing countries (**Figure 12**).

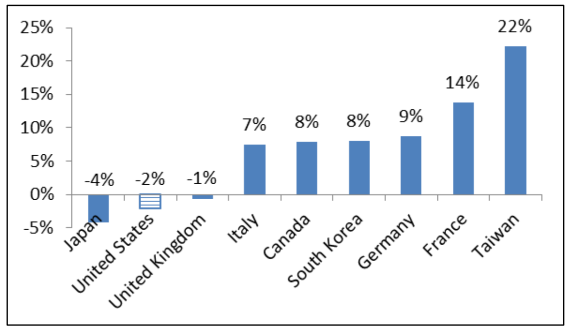
The comparatively poor U.S. performance by this metric may indicate that U.S. manufacturers are slower to invest in labor-saving technology than those in other countries. A recent report by the International Federation of Robotics, for example, estimated that Korea used 621 industrial robots per 10,000 manufacturing workers in 2016, Germany 309, Japan 303, and the United States 189.[19]

Figure 11. Output per Labor Hour in Manufacturing, Change 2002-2016



Source: The Conference Board, "International Comparisons of Manufacturing Productivity & Unit Labor Cost Trends," 2017.

Figure 12. Output per Labor Hour in Manufacturing, Change 2010-2016



Source: The Conference Board, "International Comparisons of Manufacturing Productivity & Unit Labor Cost Trends," 2017.

Average compensation per employee in U.S. manufacturing, measured on an internationally comparable basis, was $39.01 per hour in 2016. This figure, which is not adjusted for taxes and social insurance benefits, was in the same range as hourly costs in most northern and central European countries and considerably higher than average manufacturing compensation in Japan, South Korea, and southern Europe (**Table 1**).[20]

Accurate nationwide data on manufacturing compensation costs in China are not available. Chinese government statistics point to an average wage in urban manufacturing of approximately $4.26 per hour in 2016.[21] This figure, which is consistent with Conference Board estimates, is not comparable to the direct pay in other countries shown in **Table 1**, as it excludes workers in rural areas, where wages generally are lower than in urban areas. For India, the Conference Board estimates average wages at formally registered manufacturing enterprises to have been $1.47 per

[19] International Robotics Federation, "Executive Summary World Robotics 2017 Industrial Robots," p. 20.

[20] Figures calculated from estimates of total compensation and hours worked in manufacturing, as reported by the Conference Board and converted to U.S. dollar terms with the annual average exchange rates reported in the Federal Reserve Board H.10 release.

[21] The average annual wage reported for urban manufacturing workers in 2016 was 59,404 yuan; National Bureau of Statistics of China, *China Statistical Yearbook 2017*, http://www.stats.gov.cn/tjsj/ndsj/2017/indexeh.htm, table 4-15. Conversion to U.S. dollars at a rate of 6.64 yuan per dollar, the average exchange rate for 2016 as published by the Federal Reserve Board, yields an annual wage of approximately $8,946. Assuming the average Chinese manufacturing worker works 2,100 hours per year—official figures on hours worked are not published—produces an average hourly rate of $4.26. However, the average varies considerably within the country; using the same methodology, the reported average hourly manufacturing wage was $7.00 per hour in Beijing, but only $3.13 in the interior province of Henan.

hour in 2014. However, these figures probably overstate Indian manufacturing labor costs, as they do not cover workers in unorganized or informal manufacturing.[22]

Table 1. Hourly Compensation Costs in Manufacturing

U.S. dollar basis, 2016

	Direct Pay	Total Compensation Costs	Change Relative to United States, 2000-2016 (percentage points)
Brazil	$5.48	$7.98	18
Canada	$23.99	$30.08	5
France	$26.26	$37.72	13
Germany	$33.71	$43.18	10
Italy	$23.08	$32.49	25
Japan	$21.67	$26.46	-33
Korea	$18.59	$22.98	53
Mexico	$2.74	$3.91	-30
Switzerland	$49.25	$60.36	43
Taiwan	$8.35	$9.82	-14
United Kingdom	$24.28	$28.41	-12
United States	$29.65	$39.03	NA

Source: The Conference Board, "International Comparisons of Hourly Compensation Costs in Manufacturing and Sub-Manufacturing Industries," 2018, https://www.conference-board.org/ilcprogram.

Notes: "Direct Pay" includes vacation pay, bonus payments, and employer contributions to employees' savings funds. "Total Compensation Costs" additionally includes pensions, disability insurance, sick leave, health insurance, severance pay, other social insurance expenditures, and taxes on payrolls or employment. "Change in Compensation Costs Relative to United States" incorporates the effects of exchange-rate changes.

The data on hourly compensation costs can be misleading, as they are not adjusted for differences in the industrial mix. In most countries, including the United States, labor costs vary greatly among industries; the average hourly wage of production workers at U.S. sawmills is around $18.60, whereas the average in aircraft manufacturing exceeds $40. The most recent data, from 2016, show total U.S. labor costs to be similar to those in the major economies of continental Europe, although well above those in emerging economies (see **Table 2**).

[22] Data from the Conference Board, "International Comparisons of Hourly Compensation Costs in Manufacturing and Submanufacturing Industries," 2018.

Table 2. Hourly Compensation Costs in Selected Manufacturing Industries

U.S. dollar basis, 2016

	Paper	Textiles	Chemicals	Machinery	Motor Vehicles
Brazil	$9.19	$5.19	$14.02	$9.69	$12.91
France	$37.05	$30.56	$48.29	$40.05	$40.42
Germany	$38.28	$29.80	$53.96	$48.08	$54.93
Italy	$30.65	$29.74	$40.48	$35.21	$36.07
Korea	$17.49	$15.19	$28.86	$20.65	$27.02
Mexico	$4.29	$2.99	$7.16	$6.16	$4.65
Taiwan	$7.94	$7.72	NA	NA	$9.95
United Kingdom	$28.87	$22.03	$33.41	$30.08	$34.43
United States	$41.15	$26.47	$45.39	$41.51	$40.17

Source: The Conference Board, "International Comparisons of Hourly Compensation Costs in Manufacturing and Submanufacturing Industries," 2018. Brazil data are for 2015.

Technology and Research in Manufacturing

High-technology manufacturing has been a particular focus of public-policy concern for many years. There is no standard definition of high-tech manufacturing, but commentators have long asserted that high-technology production has especially beneficial economic spillovers.[23] Although definitions of "high-tech industry" vary, the OECD considers that manufacturing of pharmaceuticals; office, accounting, and computing machinery; radio, television, and communications equipment; medical, precision, and optical instruments; and aircraft and spacecraft is particularly technology-intensive, based on those industries' research and development (R&D) expenditures and on the amount of R&D embodied in their products.[24] It is important to note in this context that some industries that may have a considerable technological component, such as automobile and machinery manufacturing, are not considered high-technology industries by the OECD.

Manufacturers in the United States spend far more on research than those in any other country save China (see **Figure 13**).[25] Adjusted for differences in purchasing power, Chinese manufacturers' R&D spending has grown more rapidly than that of manufacturers in the United States, and as of 2015 was 18% larger.

[23] For a recent statement of this view, see Gregory Tassey, "Competing in Advanced Manufacturing: The Need for Improved Growth Models and Policies," *Journal of Economic Perspectives*, vol. 28 (2014), p. 29. Similar arguments were made in earlier decades in Stephen S. Cohen and John Zysman, *Manufacturing Matters: The Myth of the Post-Industrial Economy* (New York, 1987), p. 106, and Lester Thurow, *Head to Head: The Coming Economic Battle Among Japan, Europe, and America* (New York, 1992), pp. 45-51.

[24] These sectors correspond to U.N. International Standard Industrial Classifications 2423, 30, 32, 33, and 353. For details, see OECD, "ISIC Rev. 3 Technology Intensity Definition," July 7, 2011, p. 1, http://www.oecd.org/dataoecd/43/41/48350231.pdf.

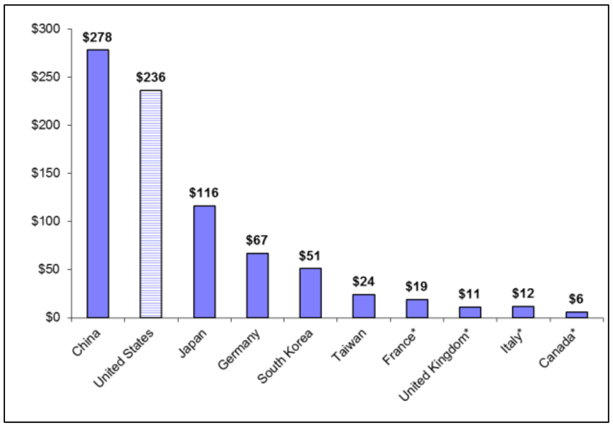
[25] These figures include expenditures by manufacturers, whatever the original source of the funds.

Manufacturing R&D in the United States and other high-income economies lagged during the international financial crisis of the last decade, but has grown more rapidly since 2010. R&D spending by manufacturers has increased much more quickly in some Asian economies, notably China, South Korea, and Taiwan, than in the United States and Europe (see **Figure 14**).

Manufacturers have been responsible for around 68% of all R&D conducted by businesses in the United States in recent years. This is far lower than in Germany, Japan, South Korea, and China, where manufacturers account for 85%-90% of all business-financed R&D. Conversely, the service sector is relatively more important in undertaking R&D in the United States than in many other countries. The most notable exception is the United Kingdom, where service companies account for nearly three-fifths of all business R&D spending.[26]

Figure 13. R&D in Manufacturing, 2015

$ billions at purchasing power parity

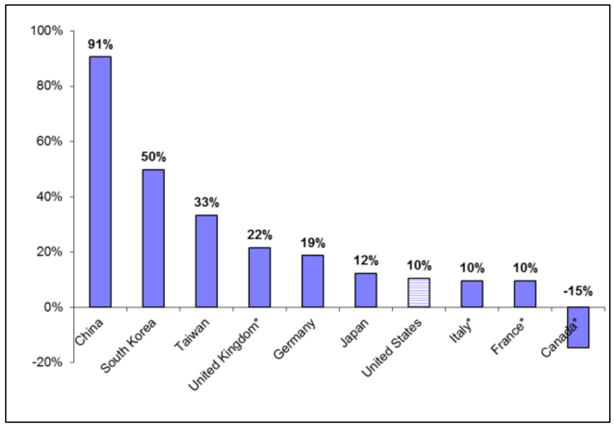


Source: OECD STAN R&D database, "Research and development expenditures by industry," Rev. 4.

Note: * Data for 2013 or 2014.

Figure 14. Growth in Manufacturing R&D

Change at constant purchasing power parity, 2010-2015



Source: OECD STAN R&D database, "Research and development expenditures by industry," Rev. 4.

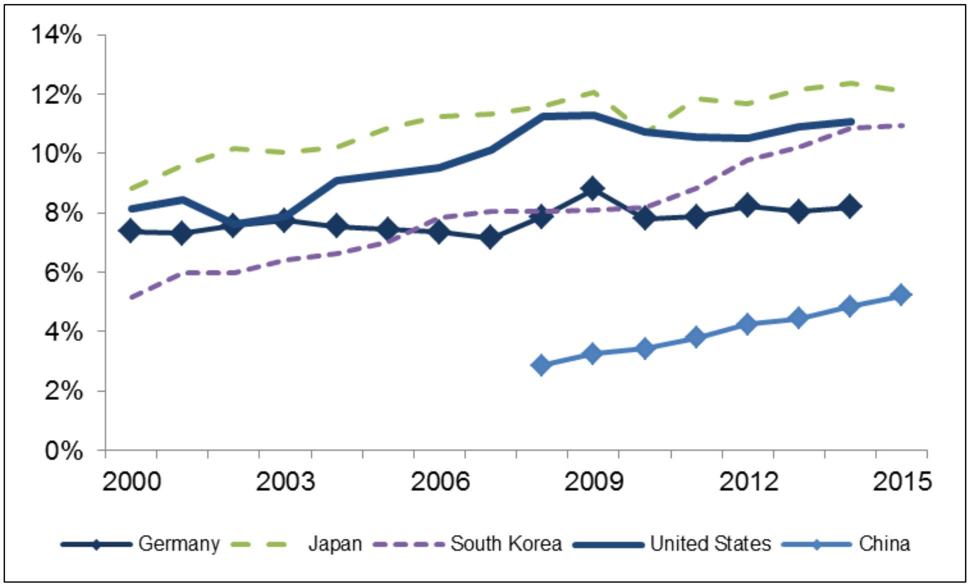
Note: * Data for 2013 or 2014.

The research intensity of U.S. manufacturing increased significantly in the years leading up to the most recent recession, but data measuring R&D relative to manufacturing value added indicate that U.S. manufacturers' research intensity has not increased since 2008. In 2000, U.S. manufacturers spent 8% of sales on R&D; this figure has varied between 10.5% and 11.3% since 2008. A similar trend is evident in most other countries with substantial R&D in manufacturing. U.S. manufacturers spend more on R&D, relative to value added, than those in other large manufacturing countries, with the exceptions of Japan and South Korea (see **Figure 15**).

[26] OECD, Science, Technology and R&D Statistics, "Business enterprise R-D expenditure by industry (ISIC 4)," (accessed February 20, 2018).

Figure 15. Manufacturing R&D as Share of Manufacturing Value Added

Local currency basis, 2000-2015



Source: CRS, from OECD STAN R&D expenditures in industry and Value added and its components by activity-ISIC Rev. 4; U.N. National Accounts Main Aggregates Database (accessed February 20, 2018).

One reason for national differences in R&D intensity is variation in the composition of the manufacturing sector. Industries such as aircraft, spacecraft, and electronic instrument manufacturing are among the most research-intensive in every country, and, all other things equal, countries in which these sectors are relatively large may be expected to have greater R&D intensity in manufacturing than countries in which they are less important. As **Table 3** confirms, a very large proportion of U.S. manufacturers' R&D takes place in high-technology sectors, particularly pharmaceuticals, electronics, and aircraft manufacturing, whereas in most other countries save South Korea, a far greater proportion of manufacturers' R&D outlays occur in medium-technology sectors such as motor vehicle and machinery manufacturing.

Table 3. Manufacturers' R&D Spending by Sector

Percentage of total R&D spending by manufacturers, 2014

Country	Chemicals	Pharmaceuticals	Computers, Electronics, Optical	Motor Vehicles	Other Transport Equipment
China	9.3%	4.4%	17.6%	8.9%	4.8%
France	6.1%	5.2%	23.5%	12.2%	21.7%
Germany	7.3%	8.2%	15.2%	39.7%	4.2%
Italy	4.4%	5.9%	15.0%	20.0%	11.1%
Japan	6.4%	12.7%	24.6%	29.1%	0.8%
South Korea	5.4%	2.5%	59.8%	13.3%	1.7%
United Kingdom	4.7%	5.1%	12.9%	25.9%	20.4%
United States	4.2%	24.3%	31.7%	7.9%	12.2%

Source: OECD, Research and development expenditure in industry-ISIC Rev. 4 (accessed February 20, 2018).

Note: Not all manufacturing sectors are included. Data for France pertain to 2013.

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