NIST Advanced Manufacturing Series 100-20

Annual Manufacturing Review: 2018

Douglas S. Thomas

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https://doi.org/10.6028/NIST.AMS.100-20

National Institute of Standards and Technology
U.S. Department of Commerce

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Engineering Laboratory

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January 2019

U.S. Department of Commerce
Wilbur L. Ross, Jr., Secretary

National Institute of Standards and Technology
Walter Copan, NIST Director and Undersecretary of Commerce for Standards and Technology

Preface

This study was conducted by the Applied Economics Office (AEO) in the Engineering Laboratory (EL) at the National Institute of Standards and Technology (NIST). The study provides aggregate manufacturing industry data and industry subsector data to develop a quantitative depiction of the US manufacturing industry.

Disclaimer

Certain trade names and company products are mentioned in the text in order to adequately specify the technical procedures and equipment used. In no case does such identification imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the products are necessarily the best available for the purpose.

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Acknowledgements

The author wishes to thank all those who contributed so many excellent ideas and suggestions for this report. Special appreciation is extended to Simon Frechette, Katherine Morris, and Vijay Srinivasan of EL's Systems Integration Division for their technical guidance, suggestions, and support. Special appreciation is also extended to Anand Kandaswamy and David Butry of EL's AEO and to Shaw Feng of EL's Systems Integration Devision for their thorough reviews and many insights. The author also wishes to thank Nicos Martys, of the Materials and Structural Systems Division for his review.

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List of Acronyms

ASE: Annual Survey of Entrepreneurs
ASM: Annual Survey of Manufactures
BEA: Bureau of Economic Analysis
GDP: Gross Domestic Product
IBRD: International Bank for Reconstruction and Development
IDA: International Development Association
ISIC: International Standard Industrial Classification
MAPI: Manufacturers Alliance for Productivity and Innovation
NAICS: North American Industry Classification System
NIST: National Institute of Standards and Technology
PPP: Purchasing Power Parity
SIC: Standard Industrial Classification
UNSD: United Nations Statistics Division

Executive Summary

This annual report characterizes US innovation and industrial competitiveness in manufacturing. It includes tracking domestic manufacturing activity and its domestic supply chain in order to develop a quantitative depiction of US manufacturing in the context of the domestic economy and global industry. This depiction provides change agents, such as public entities and trade groups that invest in advancing the current state of manufacturing, insight into the current state and recent trends in US manufacturing. The report further identifies areas of manufacturing that can have large impacts on costs.

The US remains a major manufacturing nation; however, production and innovation is increasing rapidly in other countries. US manufacturing was significantly impacted by the previous recession and has only recently returned to pre-recession levels of production and remains below pre-recession levels of employment.

Companies compete based on cost competitiveness and differentiation (e.g., quality or brand recognition). The US has advantages in technological prowess, innovation, productivity, and research and development, which suggests that the US tends to be more of a differentiator; therefore, research and development efforts in this area are likely to have a significantly positive impact. While the US ranks high in measures of innovation, several countries still outrank it by some measures. The Annual Survey of Entrepreneurs identified that more than a third of firms indicated negative impacts in finding qualified labor, taxes, slow business or lost sales, nonpayment from customers, and unpredictability of business conditions. Approximately 17 % indicated negative impacts from changes or updates in technology.[1]

Research has shown that costs are not distributed equally within the manufacturing supply chain. Approximately 20 % of the supply chain represents 80 % of the cost, which is a phenomenon referred to as the Pareto Principle.[2] Additionally, a majority of the cost is frequently in the supply chain. For example, 83 % of the cost of the value added for an automobile is in the supply chain, occurring in establishments other than where the final assembly takes place. Research and development expenditures in these high cost areas tend to have a higher return on investment.[3] The logic behind this tendency is that a larger cost suggests that there is more of a particular type of activity occurring; thus, an increase in productivity has a larger impact. An input-output analysis of US manufacturing reveals that management is a significant cost along with a number of other

[1] US Census Bureau. Annual Survey of Entrepreneurs. https://www.census.gov/programs-surveys/ase.html
[2] Thomas, Douglas S. and Anand Kandaswamy. (2017) "Identifying high resource consumption areas of assembly-centric manufacturing in the United States." Journal of Technology Transfer. https://link.springer.com/article/10.1007%2Fs10961-017-9577-9
[3] Thomas, Douglas. "The Effect of Flow Time on Productivity and Production." National Institute of Standards and Technology. Unpublished Article – Currently In Review.

non-production costs such as wholesale trade. The US also tends to have high labor costs, which is often associated with the advantage of having high productivity.[4]

The number of injuries and the injury rate in US manufacturing has a general downward trend, benefiting employees and others; meanwhile, labor compensation has had robust growth.

Competitiveness – Manufacturing Growth: US compound real (i.e., controlling for inflation) annual growth between 1991 and 2016 (i.e., 25-year growth) was 2.4 %, which places the US in the 51st percentile of all countries (see Figure 2.1). This growth exceeded that of Germany, France, Canada, Japan, and Australia; however, it is slower than the global average (3.3 %) and that of many emerging economies. The compound annual growth for the US between 2011 and 2016 (i.e., 5-year growth) was 1.0 % (see Figure 2.2). This puts the US at the 34th percentile below Canada and Germany.

Competitiveness – Manufacturing Industry Size: US manufacturing value added, as measured in constant 2010 dollars, is the second largest behind that of China (See Figure 2.3). In current dollars, the US produced $1.9 trillion in manufacturing valued added while China produced $3.0 trillion. Among the ten largest manufacturing countries, the US is the 4th largest manufacturing value added per capita (see Figure 2.4). Out of all countries the most recent US rank is 18th, as illustrated in Figure 2.5.

Competitiveness – Productivity: For US manufacturing, multifactor productivity, a measure of economic performance that compares the amount of goods and services produced (output) to the amount of combined inputs used to produce those goods and services, declined from 2015 to 2016 (see Figure 4.7). For all US industries, data from the Conference Board puts the US as 5th out of 67 countries (see Figure 4.8) with a compound annual growth rate of 0.8 %. In recent years, productivity growth has been negative or has come to a plateau in many countries and the US seems to be following this pattern of slow growth. There are competing explanations for why productivity has slowed, such as an aging population, inequality, or it could be the result of the economic recovery. A number of the explanations equate to low levels of capital investment. It is also important to note that productivity is difficult to measure and even more difficult to compare across countries. Moreover, the evidence does not seem to support any particular explanation over another as to why productivity appears to have stalled.

Competitiveness – Economic Environment: The US frequently ranks high on issues for economic environment, including issues related to research and development; however, it does not always rank as the highest. The US ranked 3rd in 2016 in resident patent applications per million people (see Figure 5.1) which puts it above the 95th percentile. The US ranked 9th in research and development expenditures as a percent of GDP in 2015, which puts it at the 88th percentile (see Table 5.1); however, China outspends the US in 10 of 12 manufacturing subsectors. In terms of researchers per million people, the

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[4] Bureau of Labor Statistics. Beyond the Numbers: Productivity. June 2017. https://www.bls.gov/opub/btn/volume-6/pdf/understanding-the-labor-productivity-and-compensation-gap.pdf

US ranked 14th, putting it at the 78th percentile in 2014. In journal articles per million people it ranked 21st in 2016, putting it at the 90th percentile.

The International Institute for Management Development (IMD) Competitiveness Index ranked the US 1st among 63 countries in competitiveness for conducting business. In 2018, the US ranked low in public finance, prices, societal framework, and attitudes and values, as seen in Figure 5.3.

The Competitive Industrial Performance Index, published by the United Nations Industrial Development Organization, ranked the US 3rd in its economic performance in 2014. This index assesses an economy's ability to competitively produce and export manufactured goods.

The Deloitte Global Manufacturing Competitiveness Index uses a survey of CEOs to rank countries based on managerial perception. The US was ranked 2nd out of 40 nations. High-cost labor, high corporate tax rates, and increasing investments outside of the US were identified as challenges to the US industry. Manufacturers indicated that companies were building high-tech factories in the US due to rising labor costs in China, shipping costs, and low-cost shale gas in the US.

The World Economic Forum's 2017-2018 Global Competitiveness Report uses 12 items to assess the competitiveness of 138 economies. The US was ranked 2nd overall with low rankings in macroeconomic environment, health and primary education, and institutions (Figure 5.4).

Domestic Specifics – Types of Goods Produced: The largest manufacturing subsector in the US is chemical manufacturing followed by computer/electronic products, followed by food, beverage, and tobacco products (see Figure 2.12). The 5-year compound annual growth rates, calculated using the PPI, for these sectors are 1.7 %, 3.3 %, and 4.2 %, respectively.

Domestic Specifics – Economic Recovery: Manufacturing declined significantly in 2008 and has only recently returned to its pre-recession peak level, which occurred in 2007. The percentage decline in manufacturing value added was greater than that for total US GDP, creating a persistent gap. The result is that first quarter GDP in 2018 is 15.9 % above its pre-recession peak level while manufacturing is at 1.6 % above its peak level. In the 3rd quarter of 2017, manufacturing finally surpassed its pre-recession peak.

Between January 2006 and January 2010, manufacturing employment declined by 19.4 %, as seen in Figure 4.1. As of August 2018, employment is still 10.3 % below its 2006 level.

Domestic Specifics – Manufacturing Supply Chain Costs: High cost areas have a disproportional impact on productivity; thus, research in these areas have been shown to have a higher return on investment. Using BEA Input Output data on value added, wholesale trade, the management of companies and enterprises, and oil and gas extraction are a major supply chain cost for discrete high-tech manufacturing as a whole and among selected subsectors (see Table 3.5). Input-output analysis estimates the total contribution that each industry makes to finished goods. Discrete high-tech manufacturing includes manufacturing of machinery, computers, electronics, and transportation equipment. General and operations managers, sales representatives (wholesale), first-line supervisors of production and operating workers, accountants and auditors, industrial production managers, and financial managers are listed as a top 20 labor cost in every industry category (see Table 3.6). Manufacturing as a whole also has team assemblers; industrial engineers; heavy and tractor-trailer truck drivers; and laborers/freight, stock, and material movers listed among the top ten. In 2016, the US imported approximately 17.0 % of its intermediate imports (see Table 3.3). As a proportion of output and imports (i.e., a proportion of the total inputs), intermediate imports represented 9.5 %.

Using data from the Annual Survey of Manufactures, payroll is equivalent to 12.0 % of the revenue (i.e., shipments) that manufacturers receive (see Figure 3.2). Materials, parts, containers, and packaging are 49.7 %, which reaffirms that a large portion of the cost is in the supply chain rather than in the final assembly. Moreover, reducing the need for these items (e.g., light weighting, reducing material waste, and reducing defects) are likely to have a significant impact on cost. It is not clear what the defect rate is in manufacturing; however, the USGS estimates that 15 % of steel mill products end up as scrap in the manufacturing process.[5] Other sources cite that at least 25 % of liquid steel and 40 % of liquid aluminum does not make it into a finished product due primarily to metal quality (25 % of steel loss and 40 % of aluminum loss), the shape produced[6] (10 % to 15 % of loss), and defects in the manufacturing processes (5 % of loss). Fuels and electricity amount to 1.6 % of revenue. Annual expenditures on machinery amount to 2.8 % of revenue and buildings amounts to 1.0 %; however, the gross value of depreciable assets was $2.8 trillion in 2012 with machinery and equipment accounting for an estimated $2.3 trillion. Payroll and capital (i.e., machinery and buildings) are wasted when production is unexpectedly stopped. Estimates from survey data in Sweden show that 13.3 % of planned production time is downtime (there are limited estimates for the US downtime). This suggests that approximately 13.3 % of capital and labor are wasted or underutilized.

Domestic Specifics – Manufacturing Safety and Compensation: In addition to the personal pain and suffering, an injured worker is also a lost asset for society. Fatalities, injuries, and the injury rate has been on an overall downward trend since 2000 (see Figure 4.2). Nonfatal injuries per 100 full-time workers has declined from 6.4 in 2002 to 3.3 in 2016. Employee compensation, which includes benefits, has had a 5-year compound annual growth of 3.0 % (see Figure 4.5). Labor productivity is up while multifactor productivity is down.

[5] Fenton, M. D. (2001) "Iron and Steel Recycyling in the United States in 1998." Report 01-224. US Geological Survey: 3. https://pubs.usgs.gov/of/2001/of01-224/
[6] The steel and aluminum industry often produce standard shapes rather than customized shapes tailored to specific products. This results in needing to cut away some portion of material, which ends up as scrap.

1 Introduction

1.1 Background

Public entities have a significant role in the US innovation system.[7] The federal government has had a substantial impact in developing, supporting, and nurturing numerous innovations and industries, including the Internet, telecommunications, aerospace, semiconductors, computers, pharmaceuticals, and nuclear power among others, many of which may not have come to fruition without public support.[8] Although the Defense Advanced Research Projects Agency (DARPA), Small Business Innovation Research Program (SBIR), and Advanced Technology Program (ATP) have received attention in the scholarly community, there is generally limited awareness of the government's role in US innovation. The vastness and diversity of US federal research and development programs along with their changing nature make them difficult to categorize and evaluate,[9] but their impact is often significant. For instance, the origins of Google are rooted in a public grant through the National Science Foundation.[10, 11] One objective of public innovation is to enhance economic security and improve our quality of life[12], which is achieved in part by advancing efficiency in which resources are consumed or impacted by production. This includes decreasing inputs and negative externalities (e.g., environmental impacts) while increasing output and the function of the product, as seen in Figure 1.1. In pursuit of this goal, the National Institute of Standards and Technology (NIST) has expended resources on a number of projects, such as support for the development of the International Standard for the Exchange of Product Model Data (STEP),[13] which reduces the need for duplicative efforts such as re-entering design data. Another effort to advance efficiency is the development of the Core Manufacturing Simulation Data (CMSD) specification, which enables data exchange for manufacturing simulations.[14]

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[7] Block, Fred L and Matthew R. Keller. State of Innovation: The US Government's Role in Technology Development. New York, NY; Taylor & Francis; 2016.

[8] Wessner CW and Wolff AW. Rising to the Challenge: US Innovation Policy for the Global Economy. National Research Council (US) Committee on Comparative National Innovation Policies: Best Practice for the 21st Century. Washington (DC): National Academies Press (US). 2012. http://www.ncbi.nlm.nih.gov/books/NBK100307/

[9] Block at 27.

[10] National Science Foundation. "On the Origins of Google." https://www.nsf.gov/discoveries/disc_summ.jsp?cntn_id=100660

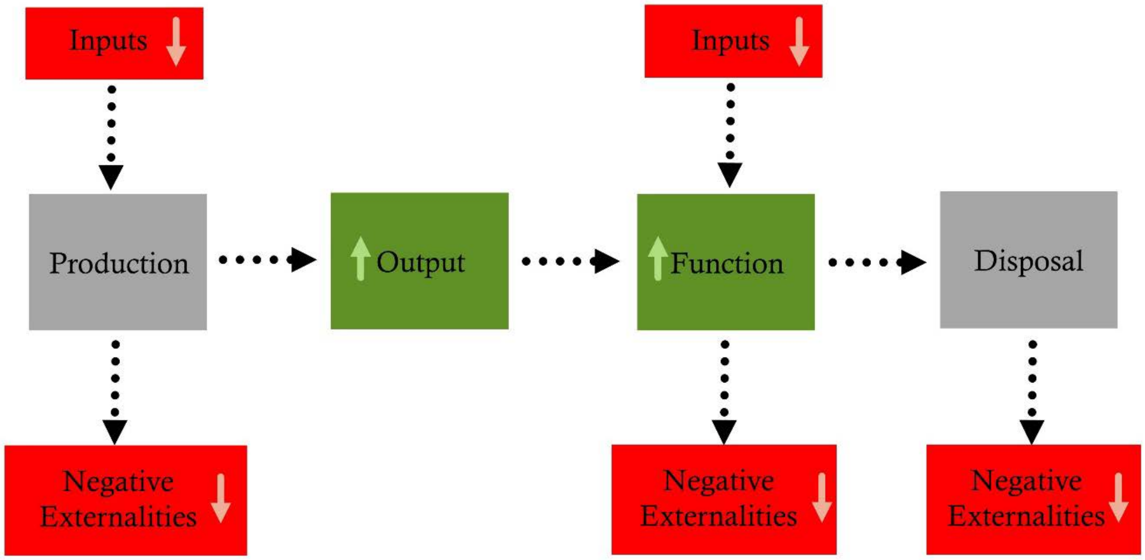
[11] Block, Fred L and Matthew R. Keller. State of Innovation: The US Government's Role in Technology Development. New York, NY; Taylor & Francis; 2016: 23.

[12] National Institute of Standards and Technology. "NIST General Information." http://www.nist.gov/public_affairs/general_information.cfm

[13] Robert D. Niehaus, Inc. Reassessing the Economic Impacts of the International Standard for the Exchange of Product Model Data (STEP) on the US Transportation Equipment Manufacturing Industry. November 26, 2014. Contract SB1341-12-CN-0084.

[14] Lee, Yung-Tsun Tina, Frank H. Riddick, and Björn Johan Ingemar Hohansson (2011). "Core Manufacturing Simulation Data – A Manufacturing Simulation Integration Standard: Overview and Case Studies." International Journal of Computer Integrated Manufacturing. vol 24 issue 8: 689-709.

Figure 1.1: Illustration of Objectives



1.2 Purpose of this Report

The purpose of this report is to characterize US innovation and industrial competitiveness in manufacturing, as it relates to the objectives illustrated in Figure 1.1. It includes tracking domestic manufacturing activity and its supply chain in order to develop a quantitative depiction of US manufacturing in the context of the domestic economy and global industry. There are five aspects that encapsulate the information discussed in this report:

- **Growth and Size**: The size of the US manufacturing industry and its growth rate as compared to other countries reveals the relative competitiveness of the industry.
    - ***Metrics***: Value added, value added per capita, compound annual growth

- **Productivity**: It is necessary to use resources efficiently to have a competitive manufacturing industry. Productivity is a major driver of the growth and size of the industry.
    - ***Metrics***: Labor productivity index, multifactor productivity index, output per hour, output per hour index

- **Economic Environment**: A number of factors, including research, policies, and societal trends, can affect the productivity and size of the industry.
    - ***Metrics***: Research and development expenditures as a percent of GDP, journal articles per capita, researchers per capita, competitiveness indices

- **Stakeholder Impact**: Owners, employees, and other stakeholders invest their resources into manufacturing with the purpose of receiving some benefit. The costs and return that they receive can drive industry productivity and growth. However, data is limited on this topic area.

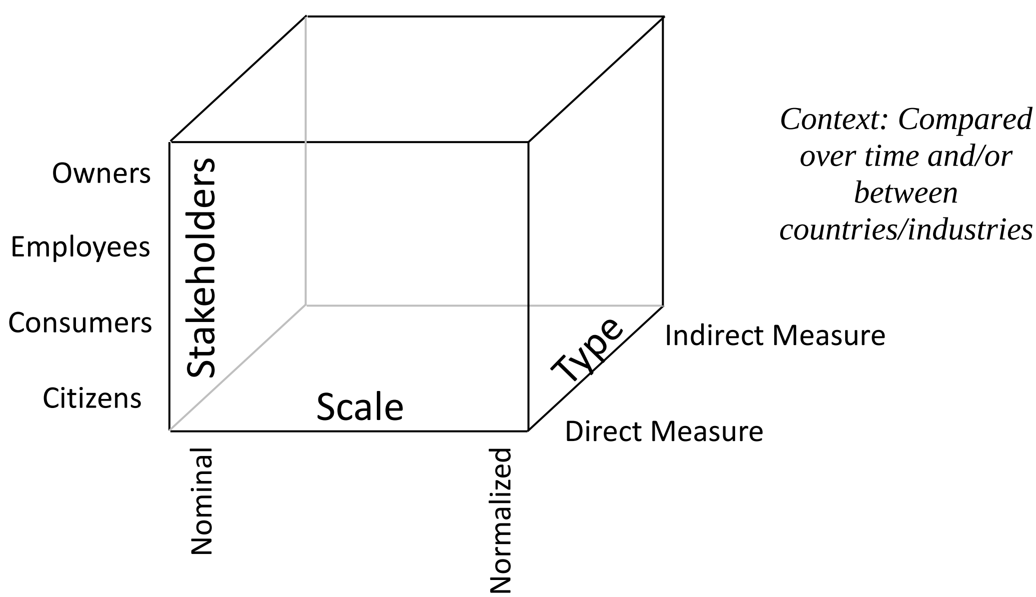
- ***Metrics***: Number of employees, compensation, net income, safety incidents

- **Areas for Advancement**: It is important to identify areas of investment that have the potential to have a high return, which can facilitate productivity and growth in manufacturing.
  - ***Metrics***: High cost supply chain components, low ranking factors for the economic environment

Currently, this annual report discusses items related to inputs for production and outputs from production. It does not discuss negative externalities, the inputs that are used in the function of a product (e.g., gasoline for an automobile), or the function of the product; however, these items might be included in future reports.

Manufacturing metrics can be categorized by stakeholder, scale, and metric type (see Figure 1.2). Stakeholders include the individuals that have an interest in manufacturing. All the metrics in this report relate directly or indirectly to all or a selection of stakeholders. The benefits for some stakeholders are costs for other stakeholders. For instance, the price of a product is a cost to the consumer but represents compensation and profit for the producers. The scale indicates whether the metric is nominal (e.g., the total US manufacturing revenue) or is adjusted to a notionally common scale (e.g., revenue per capita). The metric type distinguishes whether the metric measures manufacturing activities directly (e.g., total employment) or measures those things that affect manufacturing (e.g., research and development). These metrics are then compared over time and/or between industries to provide context to US manufacturing activities.

Figure 1.2: Data Categorization for Examining the Economics of Manufacturing



1.3 Scope and Approach

There are numerous aspects one could examine in manufacturing. This report discusses a subset of stakeholders and focuses on US manufacturing. Among the many datasets available, it utilizes those that are prominent and are consistent with economic standards. These criteria are further discussed below.

Stakeholders: This report focuses on the employees and the owners/investors, as the data available facilitates examining these entities. Future work may move toward examining other stakeholders in manufacturing, such as the consumers and general public.

Geographic Scope: Many change agents are concerned with a certain group of people or organizations. Since NIST is concerned with "US innovation and competitiveness," this report focuses on activities within national borders. In a world of globalization, this effort is challenging, as some of the parts and materials being used in US-based manufacturing activities are imported. The imported values are a relatively small percentage of total activity. The US imported 10.8 % of its supply chain, as measured in terms of 2009 imported value added (i.e., supply chain value added used by a nation's manufacturing industry as a percent of all value added associated with that nation's manufacturing industry).[15] These imports have environmental impacts, require natural resources, and utilize labor; thus, they are important in regards to a firm's production. NIST, however, promotes US innovation and industrial competitiveness; therefore, consideration of these imported goods and services are outside of the scope of this report.

Standard Data Categorization: US domestic data tends to be organized using the NAICS, which is the standard used by federal statistical agencies classifying business establishments in the United States. NAICS was jointly developed by the US Economic Classification Policy Committee, Statistics Canada, and Mexico's Instituto Nacional de Estadística y Geografía, and was adopted in 1997. NAICS has several major categories each with subcategories. Historic data and some organizations continue to use the predecessor of NAICS, which is the Standard Industrial Classification system (SIC). NAICS codes are categorized at varying levels of detail. The broadest level of detail is the two-digit NAICS code, which has 20 categories. More detailed data is reported as the number of digits increase; thus, three-digit NAICS provide more detail than the two-digit and the four-digit provides more detail than the three-digit. The maximum is six digits. Sometimes a two, three, four, or five-digit code is followed by zeros, which do not represent categories. They are null or place holders. For example, the code 336000 represents NAICS 336. International data tends to be in the International Standard Industrial Classification (ISIC) version 3.1, a revised United Nations system for classifying economic data. Manufacturing is broken into 23 major categories (ISIC 15 through 37), with additional subcategorization. This data categorization works similar to NAICS in that additional digits represent additional detail.

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[15] Thomas, Douglas S. The US Manufacturing Value Chain: An International Perspective. February 2014. NIST Technical Note 1810. http://www.nist.gov/customcf/get_pdf.cfm?pub_id=914022

Data Sources: Thomas (2012) explores a number of data sources for examining US manufacturing activity.[16] This report selects from sources that are the most prominent and reveal the most information about the US manufacturing industry. These data include the United Nations Statistics Division's National Accounts Main Aggregates Database and the US Census Bureau's Annual Survey of Manufactures, among others.[17] Because the data sources are scattered across several resources, there are differences in what yearly data is available for a particular category or topic. In each case, the most-up-to-date and available information is provided for the relevant category.

[16] Thomas, Douglas S. The Current State and Recent Trends of the US Manufacturing Industry. NIST Special Publication 1142. http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1142.pdf

[17] See http://unstats.un.org/unsd/snaama/dnlList.asp and http://www.census.gov/manufacturing/asm/

2 Value Added

Value added is the primary metric used to measure economic activity. It is defined as the increase in the value of output at a given stage of production; that is, it is the value of output minus the cost of inputs from other establishments.[18] The primary elements that remain after subtracting inputs is taxes, compensation to employees, and gross operating surplus; thus, the sum of these also equal value added. Gross operating surplus is used to calculate profit, which is gross operating surplus less the depreciation of capital such as buildings and machinery. The sum of all value added for a country is that nation's Gross Domestic Product (GDP).

2.1 International Comparison

There are a number of sources of international estimates of value added for manufacturing. The United Nations Statistics Division National Accounts Main Aggregates Database has a wide-ranging dataset that covers a large number of countries over a significant period of time. In 2016, there was $12.6 trillion in value added (i.e., GDP) by global manufacturing in constant 2010 dollars, which is 17 % of the value added by all industries ($72.8 trillion), according to the United Nations Statistics Division.[19] Since 1970, manufacturing ranged between 14.2 % and 17.4 % of global GDP. The top 10 manufacturing countries accounted for $8.8 trillion or 69.8 % of global manufacturing value added: China (23.6 %), United States (15.3 %), Japan (10.0 %), Germany (6.3 %), India (3.3 %), South Korea (2.9 %), Italy (2.4 %), France (2.3 %), Brazil (2.0 %), and the United Kingdom (1.8 %).[20]

As seen in Figure 2.1, US compound real (i.e., controlling for inflation) annual growth between 1991 and 2016 was 2.4 %, which places the US in the 51st percentile of all countries reported. This growth exceeded that of Germany, France, Canada, Japan, and Australia; however, it is slower than the global average (3.3 %) and that of many emerging economies. It is important to note that emerging economies can employ idle or underutilized resources and adopt technologies that are already proven in other nations to achieve high growth rates. Developed countries are already utilizing resources and are employing advanced technologies; thus, comparing US growth to the high growth rates in China or India has limited meaning. As seen in Figure 2.2, the compound annual growth for the US between 2011 and 2016 was 1.0 %. This puts the US at the 34th percentile below Canada and Germany among others.

As see in Figure 2.3, US manufacturing value added, as measured in constant 2010 dollars, is the second largest behind that of China. In current dollars, the US produced $1.9 trillion in manufacturing valued added while China produced $3.0 trillion. Among the ten largest manufacturing countries, the US has the 4th largest manufacturing

[18] Dornbusch, Rudiger, Stanley Fischer, adn Richard Startz. 2000. Macroeconomics. 8th ed. London, UK: McGraw-Hill.
[19] In current prices, global manufacturing accounts for $11.7 trillion and global value added is $70.6 trillion
[20] United Nations Statistics Division. "National Accounts Main Aggregates Database." http://unstats.un.org/unsd/snaama/Introduction.asp

Figure 2.1: National 25-Year Compound Annual Growth, by Country (1991 to 2016): Higher is Better

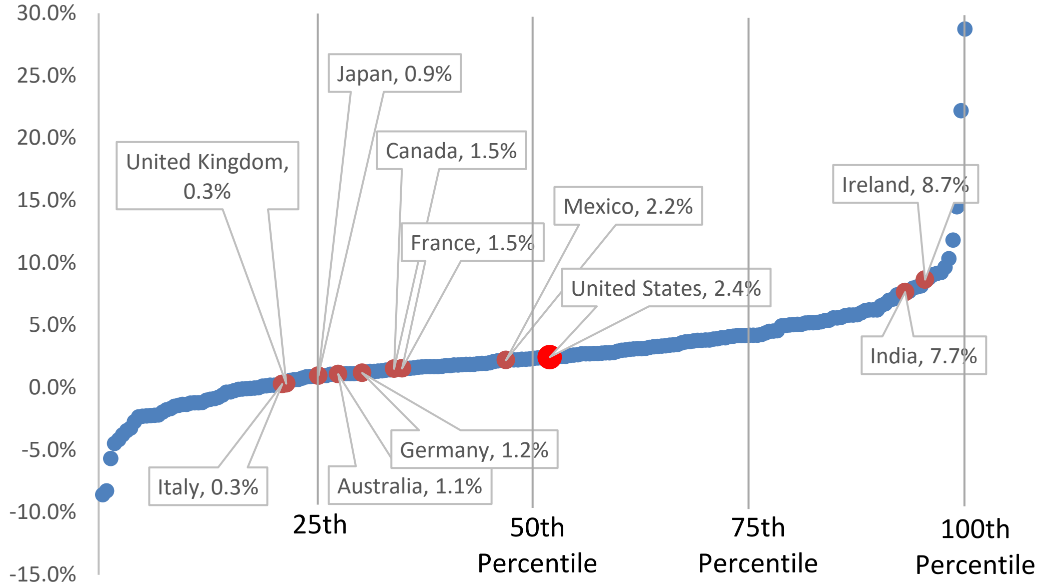
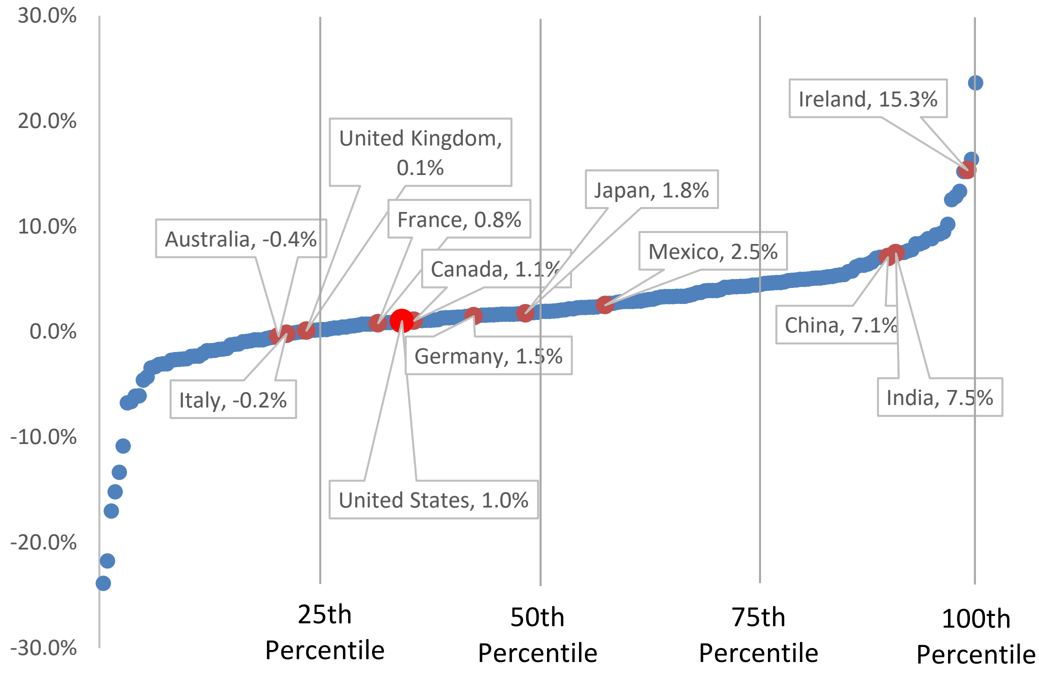


Figure 2.2: National 5-Year Compound Annual Growth, by Country (2011 to 2016): Higher is Better



value added per capita, as seen in Figure 2.4. Out of all countries the US ranks 18th, as seen in Figure 2.5. This ranking is improved from the early 1990's where it was ranked as low as the 21st largest. Since 1970, the US ranking has ranged between 16th and 24th. It is important to note that there are varying means for adjusting data that can change the rankings. The UNSD data uses market exchange rates while others might use purchasing power parity (PPP) exchange rates. PPP is the rate that a currency in one country would

Figure 2.3: Manufacturing Value Added, Top 10 Manufacturing Countries (1970 to 2015)

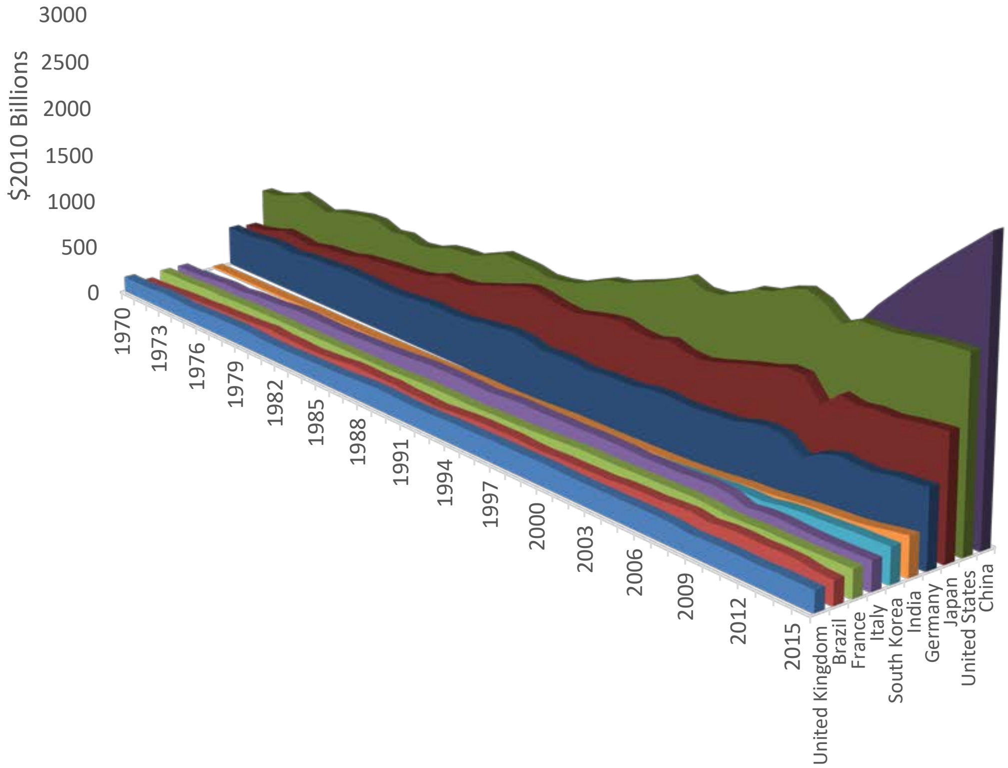


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Figure 2.4: Manufacturing Value Added Per Capita, Top 10 Manufacturing Countries (1970 to 2015): Higher is Better

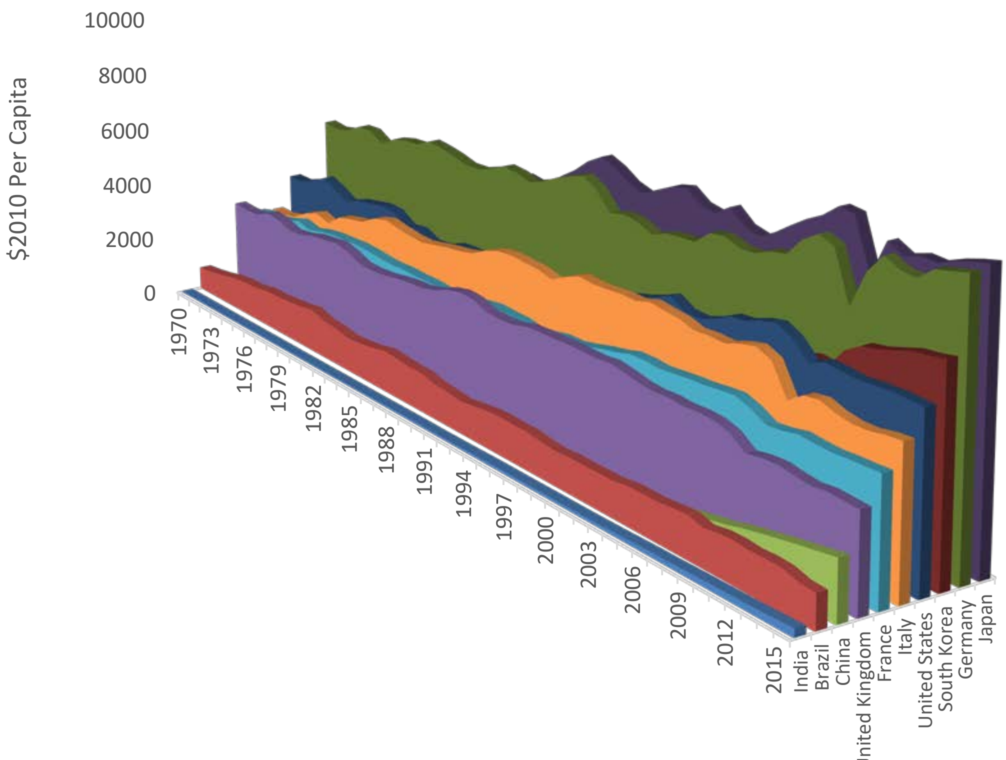
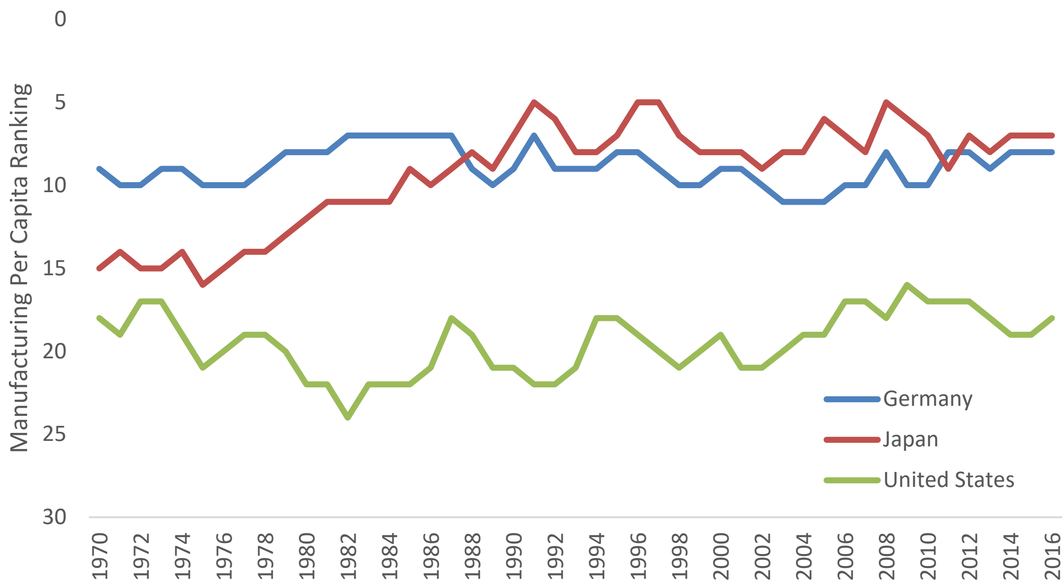


Figure 2.5: Manufacturing Per Capita Ranking, 1970-2015: Lower is Better



have to be converted to purchase the same goods and services in another country. The drawback of PPP is that it is difficult to measure and methodological questions have been raised about some surveys that collect data for these calculations.[21] Market based rates tend to be relevant for internationally traded goods;[22] therefore, this report utilizes these rates.

2.2 Domestic Details

Annual Survey of Manufactures: According to the 2016 Annual Survey of Manufactures (ASM) data shown in Table 2.1, the manufacturing sector produced $2409 billion in value added in 2016, up 0.2 % from $2405 billion in 2015.[23] Value added in machinery manufacturing (NAICS 333), computer and electronic product manufacturing (NAICS 334), electrical equipment (NAICS 335), and transportation equipment (NAICS 336) grew -6.9 %, -1.8 %, 1.1 %, and -2.2 % respectively. The ASM calculation of value added is equal to the value of shipments less the cost of materials, supplies, containers, fuel, purchased electricity, and contract work. It is adjusted by the addition of value added by merchandising operations plus the net change in finished goods and work-in-process goods:

$$ASM\ Value\ Added = shipments - net\ inventories\ shipped - suppliers\ of\ materials + merchandising\ operations$$

[21] Callen, Tim. March 2007. PPP Versus the Market: Which Weight Matters? Finance and Development. Vol 44 number 1. http://www.imf.org/external/pubs/ft/fandd/2007/03/basics.htm
[22] Ibid.
[23] Census Bureau. "Annual Survey of Manufactures." February 2015. Accessed from the American FactFinder. http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml and Census Bureau. "Economic Census." March 2015. Accessed from the American FactFinder. http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml

Value added avoids the duplication caused from the use of products of some establishments as materials. It is important to note that the Bureau of Economic Analysis (BEA) and the ASM calculate value added differently. The BEA, which follows the more traditional method, calculates value added as “gross output (sales or receipts and other operating income, plus inventory change) less intermediate inputs (consumption of goods and services purchased from other industries or imported).” Moreover, the difference is that ASM’s calculation of value added includes purchases from other industries such as mining and construction while BEA’s does not include it. Table 2.1 has both the ASM’s calculation and a calculation that follows the more traditional approach.

Net income, which could also be referred to as profit, for manufacturing was $798 billion in 2016, which equates to 18.2 % of expenditures. Net income as a percent of expenditures for machinery manufacturing (NAICS 333), computer and electronic product manufacturing (NAICS 334), electrical equipment (NAICS 335), and transportation equipment (NAICS 336) was 14.1 %, 12.2 %, 19.4 %, and 11.0 %.

Table 2.1: Manufacturing Activity by Economic Measure by Subsector

	2015 ($Billions 2015)	2016 ($Billions 2016)	Percent Change
I. Manufacturing Shipments and Value Added			
a. TOTAL MANUFACTURING			
i. Net Inventories Shipped	-0.41	2.82	782.0%
ii. Depreciation of Capital	176.23	170.98	-3.0%
iii. Net Income	786.43	796.76	1.3%
iv. Expenditures	4,556.78	4,384.14	-3.8%
a. Suppliers of Materials	3,114.22	2,942.56	-5.5%
v. Shipments (i + ii + iii + iv)	**5,519.02**	**5,354.69**	**-3.0%**
vi. ASM Value Added = v - i - iv.a + adjustment[1]	**2,404.70**	**2,409.00**	**0.2%**
vii. Value Added = v - i - iv + Compensation [2]	**1,792.40**	**1,806.76**	**0.8%**
viii. BEA Value Added	**2,185.00**	**2,183.00**	**-0.1%**
b. NAICS 324: Petroleum & coal products mfg			
i. Net Inventories Shipped	7.36	-3.17	-143.1%
ii. Depreciation of Capital	6.52	5.52	-15.3%
iii. Net Income	44.54	29.49	-33.8%
iv. Expenditures	449.37	398.49	-11.3%
a. Suppliers of Materials	398.58	347.54	-12.8%
v. Shipments (i + ii + iii + iv)	**507.79**	**430.33**	**-15.3%**
vi. ASM Value Added = v - i - iv.a + adjustment	**101.84**	**85.97**	**-15.6%**
vii. Value Added = v - i - iv + Compensation	**64.91**	**49.36**	**-23.9%**
c. NAICS 325: Chemical mfg			
i. Net Inventories Shipped	0.89	-1.54	-273.9%
ii. Depreciation of Capital	28.36	27.82	-1.9%
iii. Net Income	190.47	205.23	7.7%
iv. Expenditures	517.57	491.76	-5.0%
a. Suppliers of Materials	351.84	324.48	-7.8%
v. Shipments (i + ii + iii + iv)	**737.29**	**723.27**	**-1.9%**
vi. ASM Value Added = v - i - iv.a + adjustment	**384.56**	**400.33**	**4.1%**
vii. Value Added = v - i - iv + Compensation	**291.87**	**307.89**	**5.5%**
d. NAICS 326: Plastics & rubber products mfg			
i. Net Inventories Shipped	0.39	-0.14	-136.6%
ii. Depreciation of Capital	10.25	10.21	-0.3%
iii. Net Income	26.51	30.11	13.6%
iv. Expenditures	199.38	195.53	-1.9%
a. Suppliers of Materials	124.33	117.58	-5.4%
v. Shipments (i + ii + iii + iv)	**236.53**	**235.71**	**-0.3%**
vi. ASM Value Added = v - i - iv.a + adjustment	**111.81**	**118.27**	**5.8%**
vii. Value Added = v - i - iv + Compensation	**81.39**	**86.12**	**5.8%**

	2015 ($Billions 2015)	2016 ($Billions 2016)	Percent Change
e. NAICS 327: Nonmetallic mineral product mfg			
i. Net Inventories Shipped	-0.10	-0.29	-200.9%
ii. Depreciation of Capital	9.08	9.46	4.3%
iii. Net Income	13.41	15.15	13.0%
iv. Expenditures	95.80	98.92	3.2%
a. Suppliers of Materials	51.22	52.10	1.7%
v. Shipments (i + ii + iii + iv)	**118.19**	**123.23**	**4.3%**
vi. ASM Value Added = v - i - iv.a + adjustment	**67.07**	**71.43**	**6.5%**
vii. Value Added = v - i - iv + Compensation	**46.79**	**50.02**	**6.9%**
f. NAICS 331: Primary metal mfg			
i. Net Inventories Shipped	2.79	1.30	-53.3%
ii. Depreciation of Capital	7.63	6.90	-9.6%
iii. Net Income	19.17	19.30	0.7%
iv. Expenditures	198.85	179.10	-9.9%
a. Suppliers of Materials	144.02	125.43	-12.9%
v. Shipments (i + ii + iii + iv)	**228.43**	**206.60**	**-9.6%**
vi. ASM Value Added = v - i - iv.a + adjustment	**81.63**	**79.87**	**-2.2%**
vii. Value Added = v - i - iv + Compensation	**58.71**	**56.94**	**-3.0%**
g. NAICS 332: Fabricated metal product mfg			
i. Net Inventories Shipped	0.18	0.32	81.8%
ii. Depreciation of Capital	13.86	13.33	-3.8%
iii. Net Income	35.63	33.67	-5.5%
iv. Expenditures	299.40	288.44	-3.7%
a. Suppliers of Materials	162.57	152.45	-6.2%
v. Shipments (i + ii + iii + iv)	**349.06**	**335.76**	**-3.8%**
vi. ASM Value Added = v - i - iv.a + adjustment	**186.31**	**182.99**	**-1.8%**
vii. Value Added = v - i - iv + Compensation	**141.10**	**137.77**	**-2.4%**
h. NAICS 333: Machinery mfg			
i. Net Inventories Shipped	1.25	2.01	60.9%
ii. Depreciation of Capital	10.29	9.49	-7.7%
iii. Net Income	47.38	41.70	-12.0%
iv. Expenditures	318.63	295.24	-7.3%
a. Suppliers of Materials	192.08	174.87	-9.0%
v. Shipments (i + ii + iii + iv)	**377.55**	**348.45**	**-7.7%**
vi. ASM Value Added = v - i - iv.a + adjustment	**184.22**	**171.56**	**-6.9%**
vii. Value Added = v - i - iv + Compensation	**138.86**	**129.59**	**-6.7%**
i. NAICS 334: Computer & electronic product mfg			
i. Net Inventories Shipped	-1.84	1.60	186.8%
ii. Depreciation of Capital	14.25	13.98	-1.9%
iii. Net Income	27.79	30.37	9.3%
iv. Expenditures	258.95	247.63	-4.4%
a. Suppliers of Materials	127.25	121.39	-4.6%
v. Shipments (i + ii + iii + iv)	**299.14**	**293.59**	**-1.9%**
vi. ASM Value Added = v - i - iv.a + adjustment	**173.73**	**170.60**	**-1.8%**
vii. Value Added = v - i - iv + Compensation	**123.35**	**125.12**	**1.4%**

	2015 ($Billions 2015)	2016 ($Billions 2016)	Percent Change
j. NAICS 335: Electrical equipment, appliance, & component mfg			
i. Net Inventories Shipped	-0.20	0.21	203.3%
ii. Depreciation of Capital	3.52	3.49	-1.0%
iii. Net Income	18.15	19.58	7.9%
iv. Expenditures	103.96	100.91	-2.9%
a. Suppliers of Materials	64.79	62.48	-3.6%
v. Shipments (i + ii + iii + iv)	**125.43**	**124.18**	**-1.0%**
vi. ASM Value Added = v - i - iv.a + adjustment	**60.84**	**61.49**	**1.1%**
vii. Value Added = v - i - iv + Compensation	**46.61**	**48.02**	**3.0%**
k. NAICS 336: Transportation equipment mfg			
i. Net Inventories Shipped	-8.21	5.24	163.9%
ii. Depreciation of Capital	26.65	26.64	0.0%
iii. Net Income	95.34	90.57	-5.0%
iv. Expenditures	835.57	826.81	-1.0%
a. Suppliers of Materials	619.46	613.44	-1.0%
v. Shipments (i + ii + iii + iv)	**949.34**	**949.28**	**0.0%**
vi. ASM Value Added = v - i - iv.a + adjustment	**337.95**	**330.59**	**-2.2%**
vii. Value Added = v - i - iv + Compensation	**255.51**	**252.42**	**-1.2%**
l. NAICS 339: Miscellaneous mfg			
i. Net Inventories Shipped	-0.87	-0.66	23.7%
ii. Depreciation of Capital	5.04	5.10	1.3%
iii. Net Income	31.77	32.45	2.1%
iv. Expenditures	117.27	118.38	0.9%
a. Suppliers of Materials	57.63	58.01	0.7%
v. Shipments (i + ii + iii + iv)	**153.21**	**155.27**	**1.3%**
vi. ASM Value Added = v - i - iv.a + adjustment	**96.45**	**97.92**	**1.5%**
vii. Value Added = v - i - iv + Compensation	**72.79**	**74.52**	**2.4%**
m. Food mfg			
i. Net Inventories Shipped	-0.48	-0.88	-82.8%
ii. Depreciation of Capital	17.16	16.95	-1.2%
iii. Net Income	122.18	129.32	5.8%
iv. Expenditures	635.27	619.40	-2.5%
a. Suppliers of Materials	493.60	472.84	-4.2%
v. Shipments (i + ii + iii + iv)	**774.13**	**764.79**	**-1.2%**
vi. ASM Value Added = v - i - iv.a + adjustment	**280.91**	**292.82**	**4.2%**
vii. Value Added = v - i - iv + Compensation	**216.49**	**227.24**	**5.0%**
n. Other: Apparel, wood product, and printing mfg			
i. Net Inventories Shipped	-1.56	-1.17	24.9%
ii. Depreciation of Capital	30.18	30.20	0.0%
iii. Net Income	107.56	111.69	3.8%
iv. Expenditures	526.75	523.54	-0.6%
a. Suppliers of Materials	326.85	319.95	-2.1%
v. Shipments (i + ii + iii + iv)	**662.93**	**664.25**	**0.2%**
vi. ASM Value Added = v - i - iv.a + adjustment	**337.38**	**345.17**	**2.3%**
vii. Value Added = v - i - iv + Compensation	**254.02**	**261.76**	**3.0%**

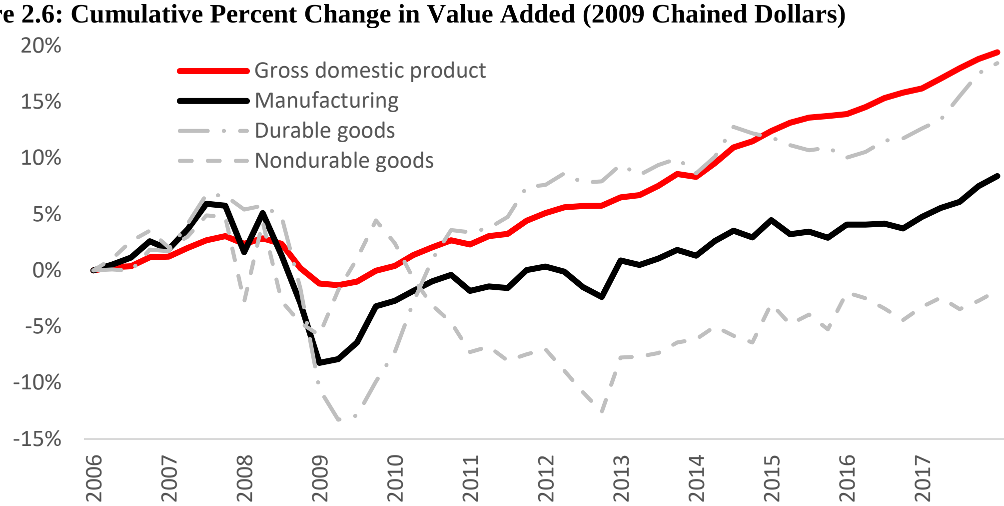
[1] It is adjusted by the addition of value added by merchandising operations plus the net change in finished goods and work-in-process goods.
[2] Compensation includes payroll and fringe benefits (not shown)

Bureau of Economic Analysis – Chained Dollars: There are two primary methods for adjusting value added for inflation. The first is using chained dollars, which uses a changing basket of goods to adjust for inflation. The second uses an unchanging basket of goods to adjust for inflation. [24] Both are discussed in this report, as there has been some dispute about the accuracy of chained dollars for some goods. The BEA estimate for manufacturing value added in 2016 was $2183 billion. Using chained dollars from the BEA shows that manufacturing increased by 0.8 % in the first quarter of 2018.[25]

As illustrated in Figure 2.6, manufacturing declined significantly in 2008 and has only recently returned to its pre-recession peak level, which occurred in 2007. Manufacturing value added declined more than total US GDP, creating a persistent gap. The result is that first quarter GDP in 2018 is 15.9 % above its pre-recession peak level while manufacturing is at 1.6 % above its peak level. In the 3rd quarter of 2017, manufacturing finally surpassed its pre-recession peak.[26]

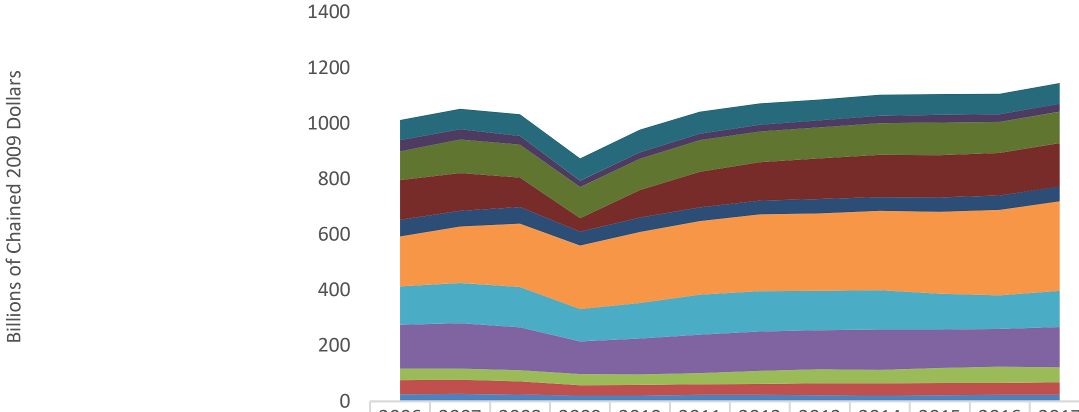
Figure 2.7 and Figure 2.8 provide more detailed data on durable and nondurable goods. As seen in Figure 2.7, value added for a number of durable goods is higher in 2017 than it was in 2006, including computer and electronic products and motor vehicles. The growth in durable goods is largely driven by computer and electronic products, which should be viewed with some caution, as there has been some dispute regarding the price adjustments for this sector, which affects the measured growth. As seen in Figure 2.8, in 2016 only two non-durable sectors were above their 2006 value. The largest manufacturing subsector in the US is chemical manufacturing, followed by computer and electronic products and food, beverage, and tobacco products, as seen in Figure 2.9.

Figure 2.6: Cumulative Percent Change in Value Added (2009 Chained Dollars)



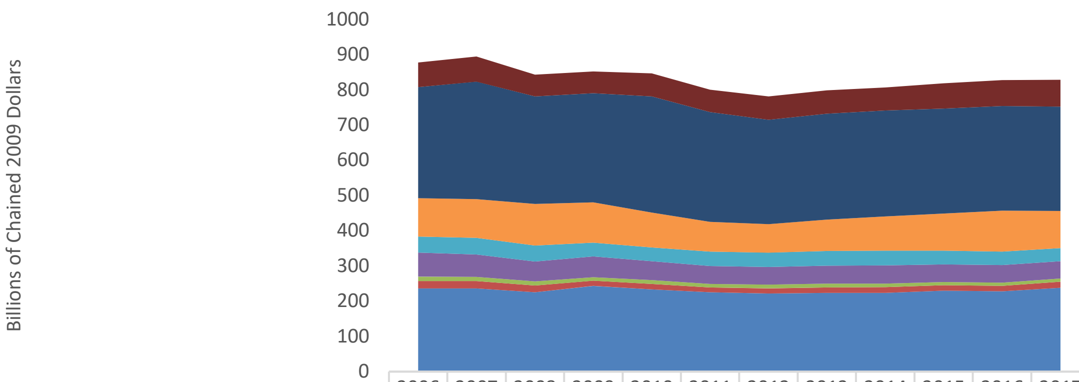
[24] Dornbusch, Rudiger, Stanley Fischer, and Richard Startz. Macroeconomics. Eighth Edition. (Boston, McGraw Hill, 2001): 32.
[25] Billions of chained dollars seasonally adjusted at annual rates
[26] Bureau of Economic Analysis. "Industry Economic Accounts Data." http://www.bea.gov/iTable/index_industry_gdpIndy.cfm

Figure 2.7: Value Added for Durable Goods by Type (chained dollars), 2006-2015



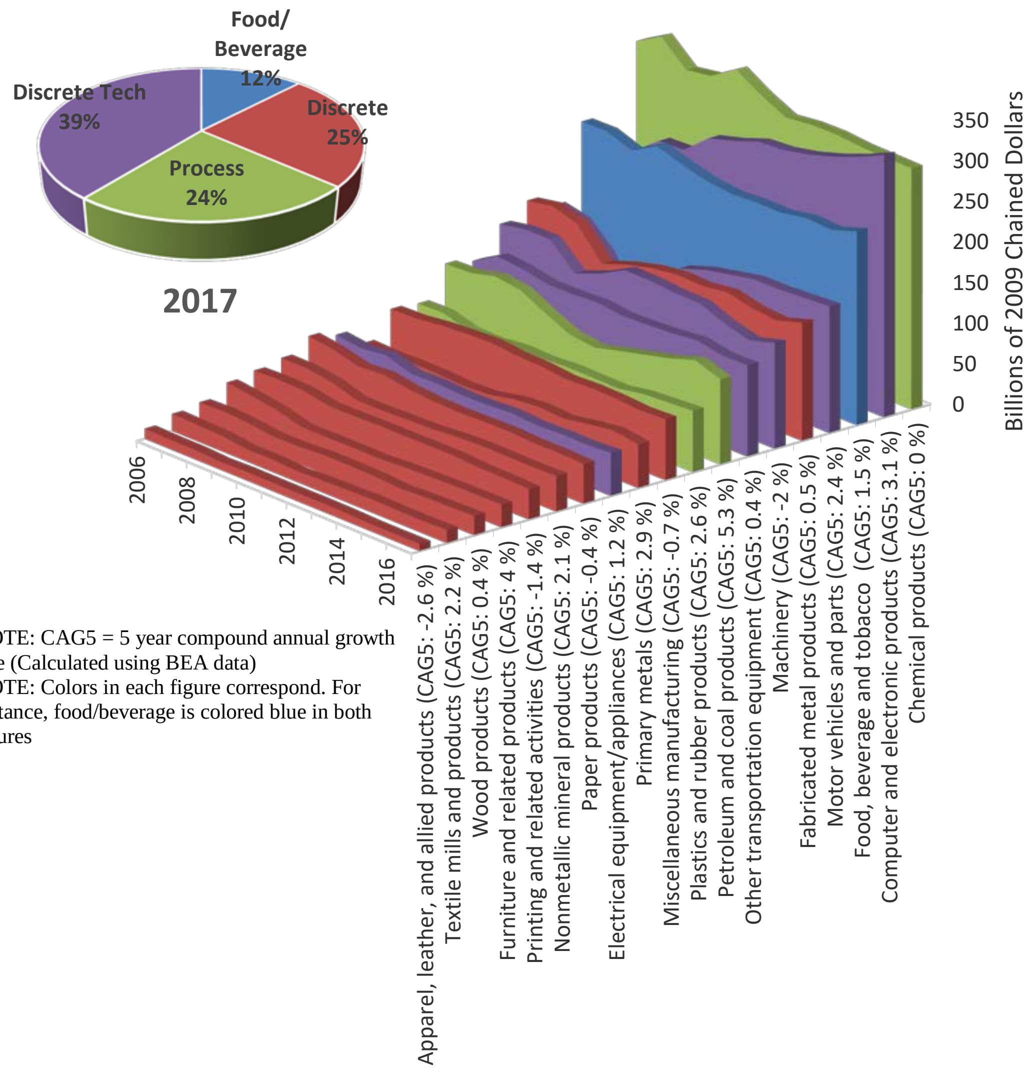
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Miscellaneous manufacturing	73	74	78	80	82	79	78	75	76	76	74	75
Furniture and related products	40	37	32	23	23	24	23	25	27	28	28	28
Other transportation equipment	103	121	118	112	112	114	111	112	114	118	112	113
Motor vehicles and parts	143	136	107	48	100	127	138	145	151	152	154	156
Electrical equipment/appliances	60	57	60	50	51	49	50	52	50	51	51	53
Computer and electronic products	180	203	228	229	256	265	276	279	286	296	308	323
Machinery	139	145	145	116	128	145	144	142	141	129	121	130
Fabricated metal products	158	164	154	118	129	137	142	141	145	138	136	146
Primary metals	41	39	41	40	38	40	47	50	48	54	59	54
Nonmetallic mineral products	51	51	47	37	37	39	40	42	44	44	43	44
Wood products	26	27	25	21	21	23	23	23	21	22	23	24

Figure 2.8: Value Added for Nondurable Goods by Type (chained dollars), 2006-2015: Higher is Better



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Plastics and rubber products	70	71	62	62	65	64	67	66	66	72	74	76
Chemical products	315	334	305	310	330	311	296	300	301	298	297	297
Petroleum and coal products	109	111	119	115	99	85	81	90	98	106	116	105
Printing and related activities	45	47	46	39	40	41	41	41	41	39	39	38
Paper products	69	64	56	59	53	51	50	51	52	50	50	49
Apparel, leather, and allied products	13	12	12	10	11	11	10	11	10	9	9	9
Textile mills and products	21	20	19	15	16	13	15	16	17	16	16	17
Food, beverage and tobacco	236	236	225	243	233	225	222	224	224	230	228	239

Figure 2.9: Manufacturing Value Added by Subsector (chained dollars)

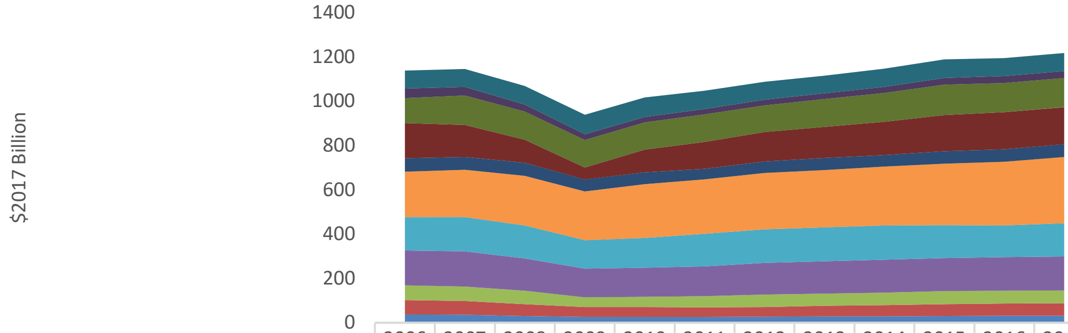


NOTE: CAG5 = 5 year compound annual growth rate (Calculated using BEA data)
NOTE: Colors in each figure correspond. For instance, food/beverage is colored blue in both figures

Bureau of Economic Analysis – Constant Dollars: Some concerns have been raised regarding the use of chained dollars to adjust for inflation[27]; therefore, it is prudent to examine manufacturing value added using the producer price index. Figure 2.10 and Figure 2.11 presents value added for durable and nondurable goods adjusted using the producer price index from the Bureau of Labor Statistics. The general trends are similar to those calculated using chained dollars; however, there are some differences. For instance, chemical products went down when calculated using chained dollars while the other went up. A similar situation occurred for petroleum and coal products. As seen in Figure 2.12, the five-year compound annual growth in computer and electronic manufacturing is 3.3 % while it is 3.1 % using chained dollars.

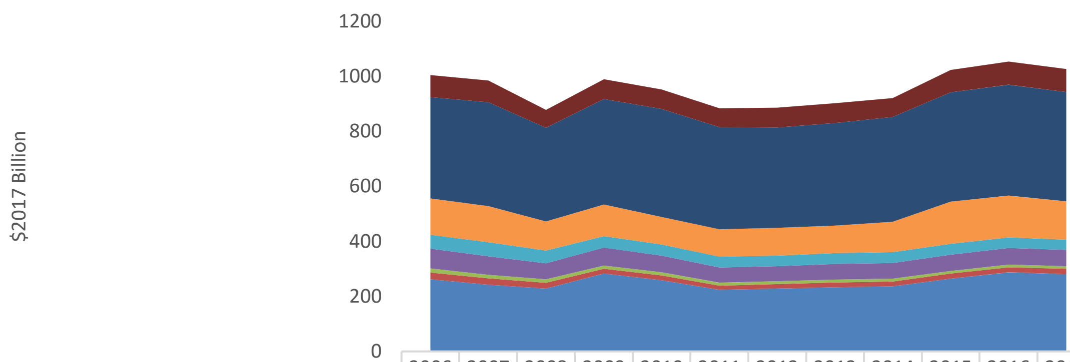
[27] Bureau of Economic Analysis. BEA's Chain Indexes, Time Series, and Measures of Long-Term Economic Growth. https://www.bea.gov/scb/account_articles/national/0597od/maintext.htm

Figure 2.10: Value Added for Durable Goods by Type (constant dollars), 2006-2015



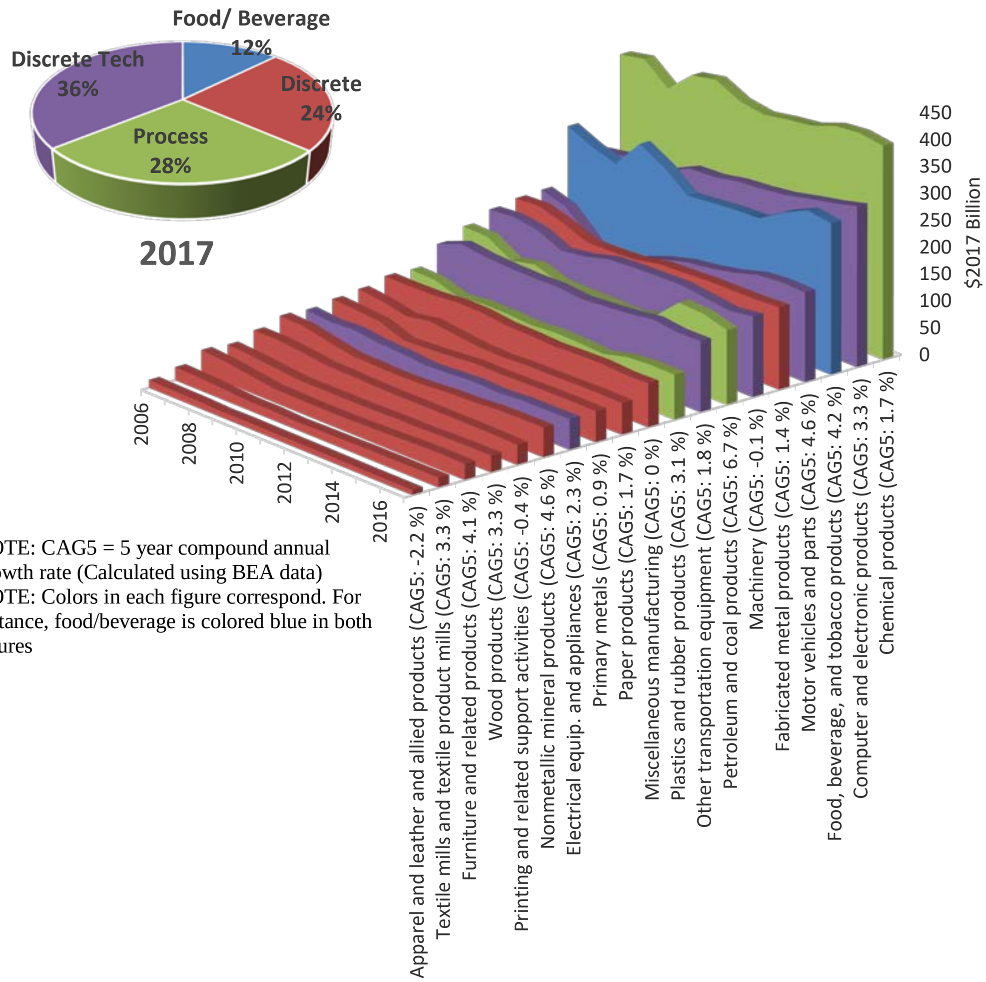
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Miscellaneous manufacturing	82	82	83	88	88	82	82	80	82	83	81	82
Furniture and related products	42	39	32	26	25	25	25	26	28	30	31	30
Other transportation equipment	113	132	126	124	124	125	121	125	129	137	131	132
Motor vehicles and parts	159	145	104	54	102	120	133	140	150	164	168	167
Electrical equip. and appliances	61	57	60	54	53	48	51	54	53	56	57	57
Computer and electronic products	205	214	224	220	242	245	255	259	266	277	287	299
Machinery	150	154	148	128	135	148	151	153	155	149	143	151
Fabricated metal products	157	160	146	129	131	134	143	146	149	150	150	154
Primary metals	67	65	61	44	47	51	56	55	56	58	59	58
Nonmetallic mineral products	64	62	53	44	43	43	44	48	50	54	55	56
Wood products	38	36	31	26	27	27	27	29	29	31	32	32

Figure 2.11: Value Added for Nondurable Goods by Type (constant dollars), 2006-2015



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Plastics and rubber products	80	79	65	71	71	68	72	71	69	81	84	84
Chemical products	368	377	341	383	393	371	365	374	380	398	403	397
Petroleum and coal products	132	132	105	116	101	100	101	100	111	154	152	139
Printing and related support activities	51	51	47	41	40	39	38	39	39	39	39	38
Paper products	72	67	58	66	60	55	54	57	58	59	60	59
Apparel and leather and allied products	15	13	13	11	11	11	11	11	10	10	10	10
Textile mills and textile product mills	24	23	20	17	17	15	16	17	18	18	18	19
Food, beverage, and tobacco products	263	243	229	284	259	224	229	234	236	265	288	281

Figure 2.12: Manufacturing Value Added by Subsector, BEA (constant dollars)



NOTE: CAG5 = 5 year compound annual growth rate (Calculated using BEA data)
NOTE: Colors in each figure correspond. For instance, food/beverage is colored blue in both figures

In addition to value added, the BEA provides estimates for real private fixed investment, which can be a leading indicator of future manufacturing activity. As seen in Figure 2.13, Fixed investment in manufacturing structures has decreased from $75.9 billion in 2015 to $53.1 billion in 2018. In recent years there has been modest increases in industrial equipment; however, the last estimate was a decrease of 1.4 %.

Construction Put in Place: Similar to real private fixed investment, construction of new manufacturing facilities can be indicative of future manufacturing activities. In June 2018, chemical manufacturing accounted for 41 % of construction for manufacturing, as illustrated in Figure 2.14. The "food/beverage/tobacco" category is the next largest (16 %) with the "other" category being the third (15 %).[28] Since June of 2015, construction spending on manufacturing facilities has decreased 42 %.

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[28] Census Bureau. Construction Spending. Construction put in place. https://www.census.gov/construction/c30/c30index.html

Figure 2.13: Real Private Fixed Investment (Seasonally Adjusted at Annual Rates), BEA

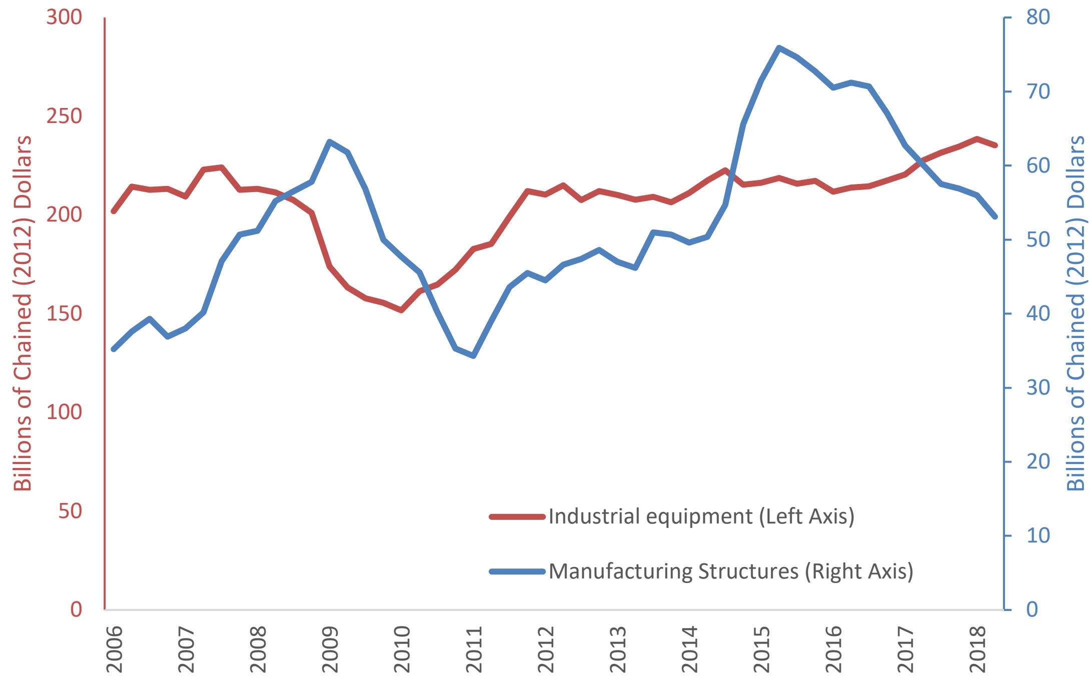
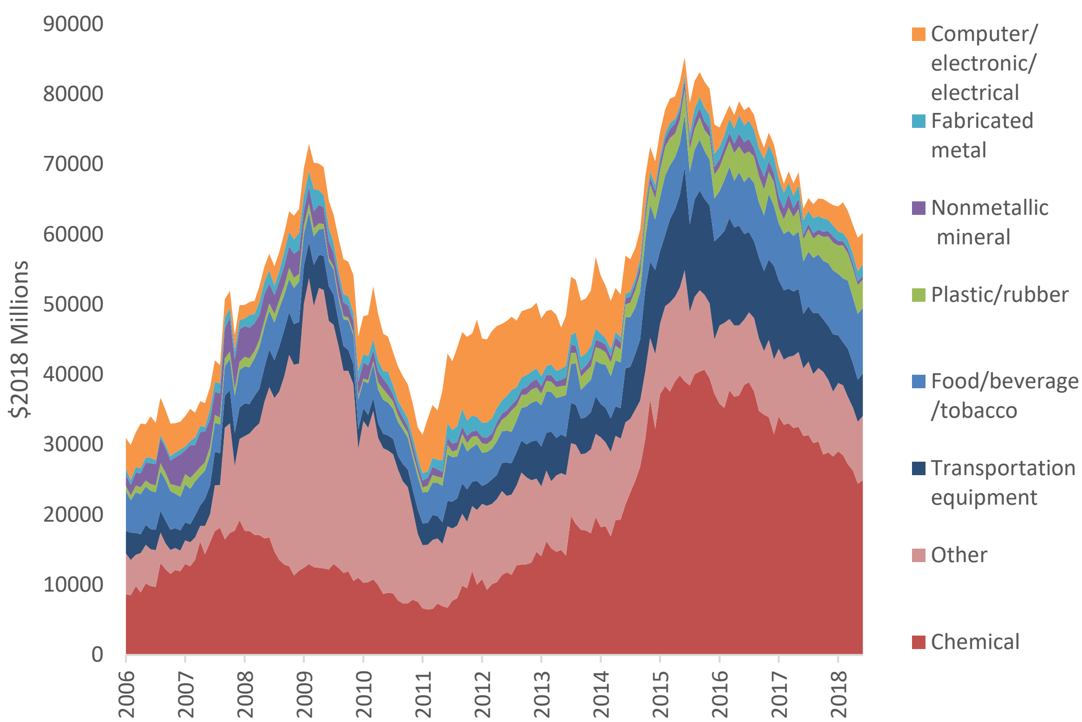
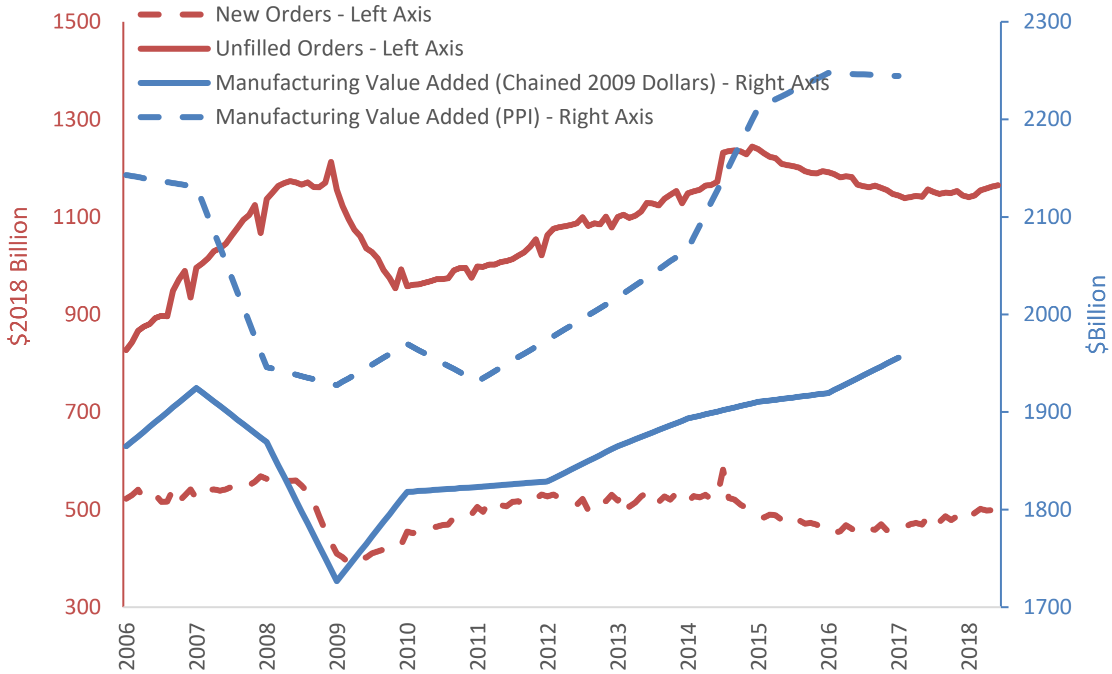


Figure 2.14: Construction Put in Place for Manufacturing Facilities, 2006-2018



Orders: New and unfilled orders tend to be available sooner than value added figures, making them leading indicators. As seen in Figure 2.15, both are currently in positive territory suggesting positive growth in 2018.[29] As can be seen in the figure, orders (shown in red) and value added (shown in blue) correlate loosely. The Industrial Machinery Stock Outlook is also in positive territory.[30]

Figure 2.15: New and Unfilled Orders Compared to Value Added



[29] Census Bureau. Manufacturers' Shipments, Inventories, and Orders. https://www.census.gov/manufacturing/m3/historical_data/index.html
[30] NASDAQ. Industrial Machinery Stock Outlook – Sept 2015. September 8, 2015. http://www.nasdaq.com/article/industrial-machinery-stock-outlook-sept-2015-cm517732

3 US Manufacturing Supply Chain

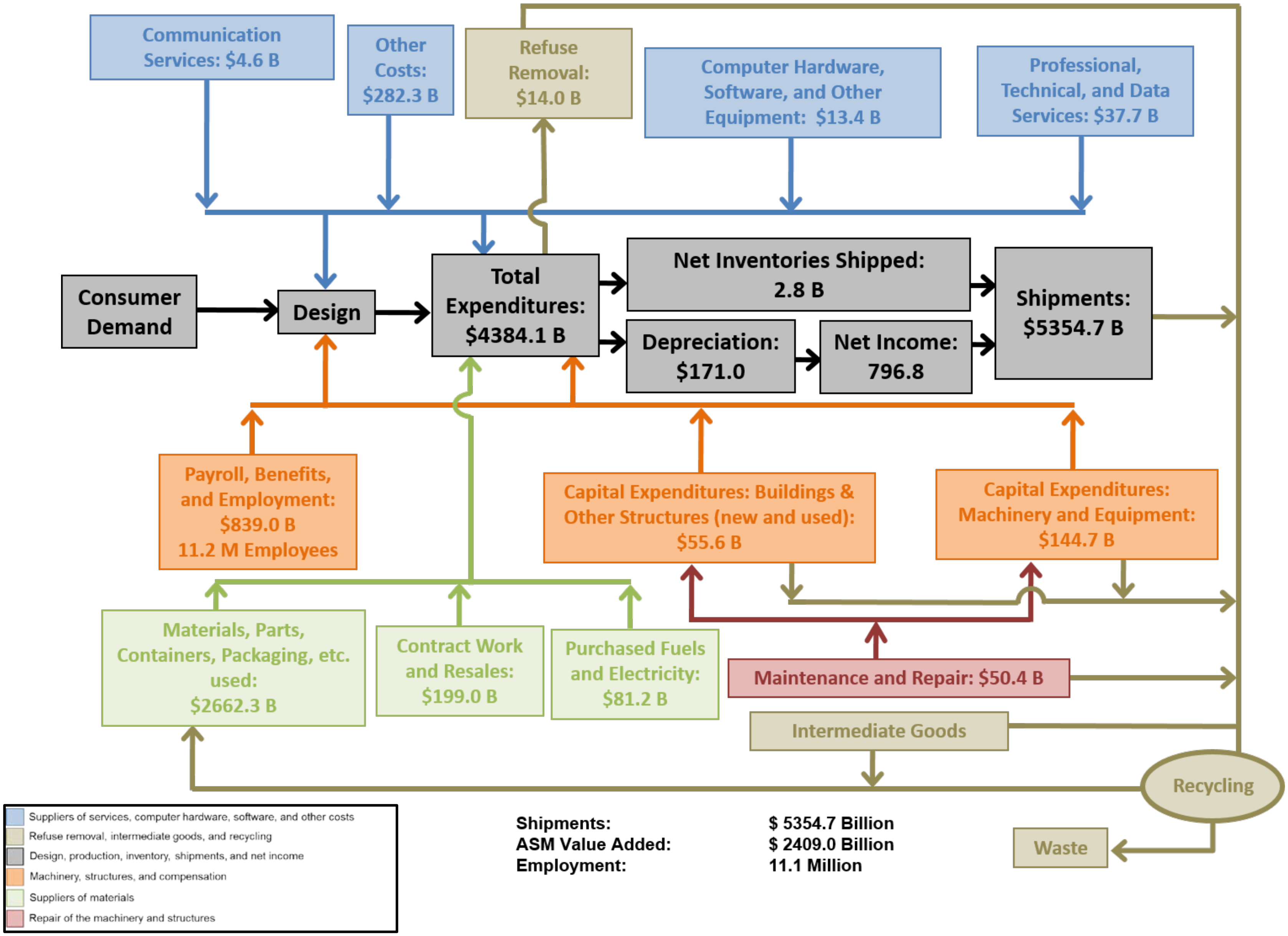
There are many suppliers of goods and services that have a stake in manufacturing; these include resellers, providers of transportation and warehousing, raw material suppliers, suppliers of intermediate goods, and suppliers of professional services. Using data from the Annual Survey of Manufactures,[31] Table 3.1 presents and Figure 3.1 maps, the purchases that the manufacturing industry made for production, which is disaggregated into five categories: suppliers of services, computer hardware, software, and other costs (blue), refuse removal, intermediate goods, and recycling (gold), machinery, structures, and compensation (orange), repair of the machinery and structures (red), and suppliers of materials (green). These items all feed into the design and production of manufactured goods which are inventoried and/or shipped (gray). The depreciation of capital and net income is also included in Figure 3.1, which affects the market value of shipments. In addition to the stakeholders, there are also public vested interests, the end users, and financial service providers to be considered.

Table 3.1: Supply Chain Entities and Contributions

	2015 ($Billions 2015)	**2016 ($Billions 2016)**	**Percent Change**
I. Services, Computer Hardware, Software, and Other Expenditures			
a. Communication Services	4.61	4.55	-1.2%
b. Computer Hardware, Software, and Other Equipment	12.74	13.40	5.2%
c. Professional, Technical, and Data Services	37.79	37.70	-0.2%
d. Other Expenditures	285.14	282.31	-1.0%
e. TOTAL	**340.27**	**337.96**	**-0.7%**
II. Refuse Removal Expenditures	**14.09**	**13.98**	**-0.8%**
III. Machinery, Structures, and Compensation Expenditures			
a. Payroll, Benefits, and Employment	829.74	839.03	1.1%
b. Capital Expenditures: Structures (including rental)	59.94	55.55	-7.3%
c. Capital Expenditures: Machinery/Equipment (including rental)	149.01	144.65	-2.9%
d. TOTAL	**1038.69**	**1039.23**	**0.1%**
IV. Suppliers of Materials Expenditures			
a. Materials, Parts, Containers, Packaging, etc… Used	2,815.14	2,662.33	-5.4%
b. Contract Work and Resales	213.12	199.01	-6.6%
c. Purchased Fuels and Electricity	85.97	81.22	-5.5%
d. TOTAL	**3,114.22**	**2,942.56**	**-5.5%**
V. Maintenance and Repair Expenditures	**49.51**	**50.42**	**1.8%**
VI. Shipments			
a. Expenditures	4,556.78	4,384.14	-3.8%
b. Net Inventories Shipped	-0.41	2.82	782.0%
c. Depreciation	176.23	170.98	-3.0%
d. Net Income	786.43	796.76	1.3%
E. TOTAL	**5,519.02**	**5,354.69**	**-3.0%**

Note: Colors correspond with those in Figure 3.1

[31] Census Bureau. "Annual Survey of Manufactures." February 2015. Accessed from the American FactFinder. http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml



Shipments:	**$ 5354.7 Billion**
ASM Value Added:	**$ 2409.0 Billion**
Employment:	**11.1 Million**

Figure 3.1: Manufacturing Supply Chain

Direct and Indirect Manufacturing: As previously mentioned, to achieve economy-wide efficiency improvements, researchers have suggested that "the supply chain must become the focus of policy management, in contrast to the traditional emphasis on single technologies/industries." [32] As seen in Table 3.2, there is an estimated $2081 billion in manufacturing value added with an additional $905 billion in indirect value added from other industries for manufacturing, as calculated using input-output analysis.[33]

In 2014, the US imported approximately 20.8 % of its intermediate imports, as seen in Table 3.3. As a proportion of output and imports (i.e., a proportion of the total inputs), intermediate imports represented 11.4 %. As can be seen in Table 3.3, these proportions have not changed dramatically in recent years.

Table 3.2: Direct and Indirect Manufacturing Value Added ($millions 2014)

	Value Added	Indirect Value Added	Total
a. TOTAL MANUFACTURING	2 080 659	904 990	2 985 649
b. NAICS 333: Machinery mfg	153 534	131 272	284 805
c. NAICS 334: Computer & electronic product mfg	204 853	67 840	272 693
d. NAICS 335: Electrical equipment, appliance, & component mfg	50 228	17 722	67 949
e. NAICS 336: Transportation equipment mfg	296 465	275 118	571 583
f. NAICS 337: Furniture	28 011	33 146	61 157
g. NAICS 339: Miscellaneous mfg	81 112	49 643	130 755
h. NAICS 311-312: Food, beverage, and Tobacco mfg	255 940	362 431	618 371
i. NAICS 313-323: Textiles, apparel, leather, wood, and paper mfg	134 951	28 444	163 395
j. NAICS 324-332: Chemicals, materials and energy mfg	875 565	212 522	1 088 087

Table 3.3: Imported Intermediate Manufacturing

Year	Intermediate Manufacturing	Intermediate Imports for Manufacturing	Total Manufacturing Output	Intermediate Imports as a Percent of Intermediates	Intermediate imports as a Percent of Total Industry Output
2006	3 247 782	659 800	5 052 761	20.3%	11.5%
2007	3 463 140	691 536	5 354 410	20.0%	11.4%
2008	3 573 053	792 707	5 457 834	22.2%	12.7%
2009	2 713 744	488 704	4 469 326	18.0%	9.9%
2010	3 088 872	631 125	4 992 521	20.4%	11.2%
2011	3 528 087	798 994	5 581 944	22.6%	12.5%
2012	3 665 614	813 348	5 841 607	22.2%	12.2%
2013	3 721 728	776 492	5 953 299	20.9%	11.5%
2014	3 784 226	786 304	6 098 370	20.8%	11.4%
2015	3 542 101	645 391	5 784 980	18.2%	10.0%
2016	3 513 858	598 668	5 712 567	17.0%	9.5%

[32] Tassey Gregory. (2010) "Rationales and Mechanisms for Revitalizing US Manufacturing R&D Strategies." *Journal of Technology Transfer*. 35. 283-333.
[33] This analysis uses an Input-Output model discussed in Thomas, Douglas and Anand Kandaswamy. "Identifying High Resource Consumption Areas of Assembly-Centric Manufacturing in the United States." NIST Publication 921139. Unpublished.

Many of the direct costs are caused by losses due to waste or defects. Unfortunately, there is limited data and information on these losses. The research that does exist is often case studies within various industries and countries, which provide only limited insight to US national trends. Tabikh estimates from survey data in Sweden that the percent of planned production time that is downtime amounts to 13.3 %.[34] It is not clear what the defect rate is in manufacturing; however, the USGS estimates that 15 % of steel mill products end up as scrap in the manufacturing process.[35] Other sources cite that at least 25 % of liquid steel and 40 % of liquid aluminum does not make it into a finished product due primarily to metal quality (25 % of steel loss and 40 % of aluminum loss), the shape produced[36] (10 % to 15 % of loss), and defects in the manufacturing processes (5 % of loss).[37] Material losses mean there is the possibility of producing the same goods using less material, which could have rippling effects up and down the supply chain. There would be reductions in the burden of transportation, material handling, machinery, inventory costs, and energy use along with many other activities associated with handling and altering materials.

Manufacturing costs also accumulate in assets such as buildings, machinery, and inventory. Data on assets is collected periodically in the Economic Census. Thomas and Kandaswamy use this data to break the estimate into buildings and machinery, as seen in Table 3.4.[38] Total depreciable assets amount to $2.8 trillion with $2.3 trillion being machinery and equipment. As mentioned previously, an estimated 13.3 % of planned production time is downtime; thus, 13.3 % or $377 billion of the capital sits idle.

Table 3.4: Depreciable Assets and the Rate of Change, 2012 ($million 2012)

	Buildings	Machinery and Equipment	Total
Gross value of depreciable assets (acquisition costs), end of year	545 316	2 290 718	2 836 034
Retirements	9 224	39 466	48 690
Capital Expenditures	30 859	132 031	162 890
Capital Expenditures less Retirements	21 635	92 565	114 200
Percent of Depreciable Assets that are Replaced	1.69%	1.72%	1.72%
Percent of Depreciable Assets that are New	3.97%	4.04%	4.03%
Percent of Depreciable Assets that are New or Replaced	5.66%	5.76%	5.74%

Source: Thomas, Douglas S. and Anand Kandawsamy. (2017) “Identifying high resource consumption areas of assembly-centric manufacturing in the United States.” Journal of Technology Transfer. https://link.springer.com/article/10.1007%2Fs10961-017-9577-9

[34] Tabikh, Mohamad. “Downtime Cost and Reduction Analysis: Survey Results.” Master Thesis. KPP321. Mälardalen University. (2014). http://www.diva-portal.org/smash/get/diva2:757534/FULLTEXT01.pdf
[35] Fenton, M. D. (2001) “Iron and Steel Recycling in the United States in 1998.” Report 01-224. US Geological Survey: 3. https://pubs.usgs.gov/of/2001/of01-224/
[36] The steel and aluminum industry often produce standard shapes rather than customized shapes tailored to specific products. This results in needing to cut away some portion of material, which ends up as scrap.
[37] Allwood, J. M. & Cullen, J. M. (2012). Sustainable Materials with Both Eyes Open. Cambridge Ltd. 185. http://www.withbotheyesopen.com/
[38] Thomas, Douglas S. and Anand Kandaswamy. (2017) “Identifying high resource consumption areas of assembly-centric manufacturing in the United States.” Journal of Technology Transfer. https://link.springer.com/article/10.1007%2Fs10961-017-9577-9

A frequently invoked axiom posits that roughly 80 % of a problem is due to 20 % of the cause, a phenomenon referred to as the Pareto principle. [39] Moreover, a small portion of the cause accounts for a large portion of the problem. Identifying that small portion can facilitate making large efficiency improvements in manufacturing, Industries are categories of production activities. A larger industry suggests that there is more of a particular type of activity occurring; thus, an increase in productivity has a larger impact for a large cost area than a small cost area. Additionally, statistical evidence suggests that a dollar of research and development in a large cost supply chain entity has a higher return on investment than a small cost one.[40]

Table 3.5 presents the top 20 supply chain entities by cost for manufacturing and a selection of manufacturing subsectors. Table 3.6 presents the top 20 occupation costs for manufacturing as a whole and a selection of manufacturing subsectors. For example, the data in the row labeled "NAICS 334: Computer & Electronic Product mfg" shows the supply chain entities by NAICS code that contribute to producing computer and electronic products. These costs can be used to identify and select new research projects that have the potential for having a high impact on manufacturing efficiency. As seen in Table 3.5, wholesale trade, the management of companies and enterprises, and oil and gas extraction appear in every list. As seen in Table 3.6, general and operations managers, sales representatives (wholesale), first-line supervisors of production and operating workers, accountants and auditors, industrial production managers, and financial managers are listed in every table. Manufacturing as a whole also has team assemblers; industrial engineers; heavy and tractor-trailer truck drivers; and laborers and freight, stock, and material movers listed among the top ten.

Table 3.7 presents an accounting of costs for producing discrete high-tech finished products. The columns labeled A through O are occupation categories. The rows are industries; so, each value in column A through O is the compensation to employees by industry and occupation needed to produce high-tech products in the US. The column labeled P is the sum of the labor categories. Column S is value added for the sum of labor, taxes on production, and gross operating surplus. Column U is the sum of value added and the imports for producing these goods; thus, the total at the bottom right is the total of all costs in terms of value added and imports. This table can be used to identify high cost areas for discrete high-tech manufacturing, which can provide insight for change agents that seek to improve efficiency in production. As might be expected, production occupations represent a large proportion of the total. Management occupations also represent a large proportion. Understanding the costs of some activities requires adding costs together by industry and occupation. For instance, companies purchase transportation services, but can also conduct these activities themselves. Therefore, the total cost of transportation is the sum of the transportation industry, ($16 800 million) plus the sum of transportation and material moving occupations in

[39] Hopp, Wallace J. and Mark L. Spearman. Factory Physics. Third Edition. (Waveland Press, Long Grove, IL, 2008. 674.

[40] Thomas, Douglas. 2018. "The Effect of Flow Time on Productivity and Production." National Institute of Standards and Technology. Unpublished Article – Currently in Review.

column M, less $6153 million to avoid double counting employees in the transportation industry. The total for transportation is $36 807 million.

Figure 3.2 shows a selection of cost items as a percent of revenue using data from the Annual survey of manufactures. It is important to note that the previously discussed tables that use input-output analysis present data in terms of value added while Figure 3.2 is utilizing shipments (i.e., also known as output or revenue). Additionally, the costs are broken-up differently. The input-output analysis breaks costs into industries. For example, the value added for the coal used to produce electricity consumed by manufacturing is found in the mining industry. The data from the Annual Survey of Manufactures in Figure 3.2 lumps all the costs for electricity together. In 2016, payroll, purchased fuels, and electricity were equal to 12.0 %, 0.6 %, and 1.0 % of revenue, respectively. Materials, parts, containers, and packaging were 49.7 %, attesting to the fact that a large portion of costs are in the supply chain. Note that these items also use labor, energy, and other resources; thus, this data does not strictly separate the costs of producing a product. Machinery and buildings were equivalent to 2.8 % and 1.0 % of revenue.

Table 3.5: Top 20 Supply Chain Entities for Selected Manufacturing Subsectors

NAICS 31-33: Total manufacturing			NAICS 311-312 (except tobacco): Food and Beverage mfg		
NAICS	Description	Value Added ($millions)	NAICS	Description	Value Added ($millions)
211000	Oil and gas extraction	185 507	420000	Wholesale trade	45 965
420000	Wholesale trade	143 674	1121A0	Beef cattle ranching and farming, including feedlots and dual-purpose ranching and farming	21 895
550000	Management of companies and enterprises	92 690	211000	Oil and gas extraction	21 022
324110	Petroleum refineries	68 771	550000	Management of companies and enterprises	20 590
325412	Pharmaceutical preparation manufacturing	54 408	31161A	Animal (except poultry) slaughtering, rendering, and processing	18 754
336411	Aircraft manufacturing	49 270	312120	Breweries	13 156
312200	Tobacco product manufacturing	46 357	112A00	Animal production, except cattle and poultry and eggs	13 065
336112	Light truck and utility vehicle manufacturing	33 443	112120	Dairy cattle and milk production	11 526
336111	Automobile manufacturing	24 375	311910	Snack food manufacturing	11 283
334413	Semiconductor and related device manufacturing	23 223	311810	Bread and bakery product manufacturing	11 039
1121A0	Beef cattle ranching and farming, including feedlots and dual-purpose ranching and farming	22 407	484000	Truck transportation	9 833
484000	Truck transportation	21 162	311615	Poultry processing	9 478
31161A	Animal (except poultry) slaughtering, rendering, and processing	19 144	312110	Soft drink and ice manufacturing	9 242
334511	Search, detection, and navigation instruments manufacturing	18 876	1111A0	Oilseed farming	8 985
52A000	Monetary authorities and depository credit intermediation	16 661	311300	Sugar and confectionery product manufacturing	8 953
541100	Legal services	16 419	3118A0	Cookie, cracker, pasta, and tortilla manufacturing	8 304
334510	Electromedical and electrotherapeutic apparatus manufacturing	16 370	111300	Fruit and tree nut farming	7 965
336412	Aircraft engine and engine parts manufacturing	16 335	112300	Poultry and egg production	7 920
325610	Soap and cleaning compound manufacturing	16 207	311111	Dog and cat food manufacturing	6 544
325620	Toilet preparation manufacturing	16 017	324110	Petroleum refineries	6 529

NAICS 333: Machinery mfg			**NAICS 334: Computer &electronic product mfg**		
NAICS	Description	Value Added ($millions)	NAICS	Description	Value Added ($millions)
420000	Wholesale trade	17 444	334511	Search, detection, and navigation instruments manufacturing	17 015
333111	Farm machinery and equipment manufacturing	9 562	334510	Electromedical and electrotherapeutic apparatus manufacturing	16 073
333130	Mining and oil and gas field machinery manufacturing	8 744	334413	Semiconductor and related device manufacturing	15 354
333120	Construction machinery manufacturing	8 641	420000	Wholesale trade	9 885
550000	Management of companies and enterprises	8 411	334220	Broadcast and wireless communications equipment	8 527
333920	Material handling equipment manufacturing	7 288	550000	Management of companies and enterprises	6 347
33391A	Pump and pumping equipment manufacturing	6 383	334516	Analytical laboratory instrument manufacturing	6 103
33399A	Other general purpose machinery manufacturing	6 331	334515	Electricity and signal testing instruments manufacturing	5 560
33329A	Other industrial machinery manufacturing	5 843	334111	Electronic computer manufacturing	5 069
211000	Oil and gas extraction	5 473	33451A	Watch, clock, and other measuring and controlling device manufacturing	4 402
331110	Iron and steel mills and ferroalloy manufacturing	4 902	334513	Industrial process variable instruments manufacturing	4 253
333912	Air and gas compressor manufacturing	4 155	334517	Irradiation apparatus manufacturing	3 175
33331A	Vending, commercial laundry, and other commercial and service industry machinery manufacturing	3 942	334418	Printed circuit assembly (electronic assembly) manufacturing	2 803
333611	Turbine and turbine generator set units manufacturing	3 585	211000	Oil and gas extraction	2 386
333514	Special tool, die, jig, and fixture manufacturing	3 341	541100	Legal services	2 177
333295	Semiconductor machinery manufacturing	3 184	334112	Computer storage device manufacturing	2 074
333511	Industrial mold manufacturing	2 920	533000	Lessors of nonfinancial intangible assets	1 810
33351A	Metal cutting and forming machine tool manufacturing	2 676	541610	Management consulting services	1 559
33291A	Valve and fittings other than plumbing	2 537	561300	Employment services	1 534
333415	Air conditioning, refrigeration, and warm air heating equipment manufacturing	2 427	334210	Telephone apparatus manufacturing	1 386

NAICS 335: Electrical equipment, appliance, & component mfg

NAICS	Description	Value Added ($millions)
335999	All other miscellaneous electrical equipment and component manufacturing	2 967
420000	Wholesale trade	2 309
335313	Switchgear and switchboard apparatus manufacturing	1 647
335221	Household cooking appliance manufacturing	1 442
335311	Power, distribution, and specialty transformer manufacturing	1 432
335912	Primary battery manufacturing	1 414
335222	Household refrigerator and home freezer manufacturing	1 338
335224	Household laundry equipment manufacturing	1 068
550000	Management of companies and enterprises	1 049
211000	Oil and gas extraction	924
331110	Iron and steel mills and ferroalloy manufacturing	759
335228	Other major household appliance manufacturing	724
335210	Small electrical appliance manufacturing	631
33441A	Other electronic component manufacturing	465
33211B	Crown and closure manufacturing and metal stamping	387
331490	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying	375
335911	Storage battery manufacturing	328
332720	Turned product and screw, nut, and bolt manufacturing	301
334413	Semiconductor and related device manufacturing	300
484000	Truck transportation	287

NAICS 336: Transportation equipment mfg

NAICS	Description	Value Added ($millions)
336411	Aircraft manufacturing	48 828
420000	Wholesale trade	43 810
336112	Light truck and utility vehicle manufacturing	33 415
550000	Management of companies and enterprises	25 436
336111	Automobile manufacturing	24 278
336412	Aircraft engine and engine parts manufacturing	14 764
336413	Other aircraft parts and auxiliary equipment manufacturing	13 995
211000	Oil and gas extraction	10 926
336370	Motor vehicle metal stamping	9 382
336611	Ship building and repairing	9 135
336390	Other motor vehicle parts manufacturing	7 649
331110	Iron and steel mills and ferroalloy manufacturing	7 513
336350	Motor vehicle transmission and power train parts manufacturing	6 911
336414	Guided missile and space vehicle manufacturing	5 900
336360	Motor vehicle seating and interior trim manufacturing	5 636
336120	Heavy duty truck manufacturing	5 627
484000	Truck transportation	5 138
336310	Motor vehicle gasoline engine and engine parts manufacturing	4 833
334413	Semiconductor and related device manufacturing	4 180
541100	Legal services	4 112

Table 3.6: Top 20 Occupation Categories for Selected Manufacturing Subsectors

NAICS 31-33: Total manufacturing			NAICS 311-312 (except tobacco): Food and Beverage mfg (excluding agricultural occupations)		
SOC	Description	Value Added ($millions)	SOC	Description	Value Added ($millions)
111021	General and Operations Managers	45 658	111021	General and Operations Managers	10 661
512092	Team Assemblers	33 726	414012	Sales Representatives, Wholesale and Manufacturing, Except Technical and Scientific Products	7 790
414012	Sales Representatives, Wholesale and Manufacturing, Except Technical and Scientific Products	26 645	519111	Packaging and Filling Machine Operators and Tenders	6 692
511011	First-Line Supervisors of Production and Operating Workers	24 485	533032	Heavy and Tractor-Trailer Truck Drivers	6 561
132011	Accountants and Auditors	16 939	511011	First-Line Supervisors of Production and Operating Workers	5 867
172112	Industrial Engineers	15 207	537062	Laborers and Freight, Stock, and Material Movers, Hand	5 034
533032	Heavy and Tractor-Trailer Truck Drivers	14 383	513022	Meat, Poultry, and Fish Cutters and Trimmers	4 146
537062	Laborers and Freight, Stock, and Material Movers, Hand	14 010	513092	Food Batchmakers	4 042
113051	Industrial Production Managers	13 604	132011	Accountants and Auditors	3 814
113031	Financial Managers	13 509	499041	Industrial Machinery Mechanics	3 565
514041	Machinists	12 984	499071	Maintenance and Repair Workers, General	3 392
519061	Inspectors, Testers, Sorters, Samplers, and Weighers	12 952	537064	Packers and Packagers, Hand	3 367
172141	Mechanical Engineers	12 711	537051	Industrial Truck and Tractor Operators	2 968
119041	Architectural and Engineering Managers	11 632	113031	Financial Managers	2 928
434051	Customer Service Representatives	11 516	513023	Slaughterers and Meat Packers	2 859
112022	Sales Managers	11 428	434051	Customer Service Representatives	2 841
499071	Maintenance and Repair Workers, General	10 804	113051	Industrial Production Managers	2 745
499041	Industrial Machinery Mechanics	10 779	112022	Sales Managers	2 716
131199	Business Operations Specialists, All Other	10 300	519198	Helpers--Production Workers	2 494
111011	Chief Executives	10 084	452092	Farmworkers and Laborers, Crop, Nursery, and Greenhouse	2 485

NAICS 333: Machinery mfg

SOC	Description	Value Added ($millions)
111021	General and Operations Managers	6 892
512092	Team Assemblers	5 142
514041	Machinists	4 615
414012	Sales Representatives, Wholesale and Manufacturing, Except Technical and Scientific Products	4 181
511011	First-Line Supervisors of Production and Operating Workers	3 864
172141	Mechanical Engineers	3 625
514121	Welders, Cutters, Solderers, and Brazers	3 299
172112	Industrial Engineers	2 312
132011	Accountants and Auditors	2 267
113051	Industrial Production Managers	2 119
519061	Inspectors, Testers, Sorters, Samplers, and Weighers	2 002
113031	Financial Managers	1 773
119041	Architectural and Engineering Managers	1 740
112022	Sales Managers	1 687
537062	Laborers and Freight, Stock, and Material Movers, Hand	1 681
514011	Computer-Controlled Machine Tool Operators, Metal and Plastic	1 676
499041	Industrial Machinery Mechanics	1 650
434051	Customer Service Representatives	1 571
111011	Chief Executives	1 525
499071	Maintenance and Repair Workers, General	1 475

NAICS 334: Computer &electronic product mfg

SOC	Description	Value Added ($millions)
111021	General and Operations Managers	4 421
151133	Software Developers, Systems Software	3 578
119041	Architectural and Engineering Managers	2 709
512022	Electrical and Electronic Equipment Assemblers	2 331
151132	Software Developers, Applications	2 331
172071	Electrical Engineers	2 321
172112	Industrial Engineers	2 208
172072	Electronics Engineers, Except Computer	2 016
414012	Sales Representatives, Wholesale and Manufacturing, Except Technical and Scientific Products	1 779
132011	Accountants and Auditors	1 629
172141	Mechanical Engineers	1 620
113021	Computer and Information Systems Managers	1 590
172061	Computer Hardware Engineers	1 510
414011	Sales Representatives, Wholesale and Manufacturing, Technical and Scientific Products	1 482
113031	Financial Managers	1 458
512092	Team Assemblers	1 445
511011	First-Line Supervisors of Production and Operating Workers	1 444
173023	Electrical and Electronics Engineering Technicians	1 279
112022	Sales Managers	1 241
113051	Industrial Production Managers	1 217

NAICS 335: Electrical equipment, appliance, & component mfg

SOC	Description	Value Added ($millions)
512092	Team Assemblers	898
111021	General and Operations Managers	749
511011	First-Line Supervisors of Production and Operating Workers	458
414012	Sales Representatives, Wholesale and Manufacturing, Except Technical and Scientific Products	454
512022	Electrical and Electronic Equipment Assemblers	363
172112	Industrial Engineers	330
172141	Mechanical Engineers	328
519061	Inspectors, Testers, Sorters, Samplers, and Weighers	294
132011	Accountants and Auditors	274
113051	Industrial Production Managers	269
172071	Electrical Engineers	256
537062	Laborers and Freight, Stock, and Material Movers, Hand	244
119041	Architectural and Engineering Managers	238
113031	Financial Managers	228
514041	Machinists	221
499071	Maintenance and Repair Workers, General	220
112022	Sales Managers	213
434051	Customer Service Representatives	208
533032	Heavy and Tractor-Trailer Truck Drivers	191
537051	Industrial Truck and Tractor Operators	186

NAICS 336: Transportation equipment mfg

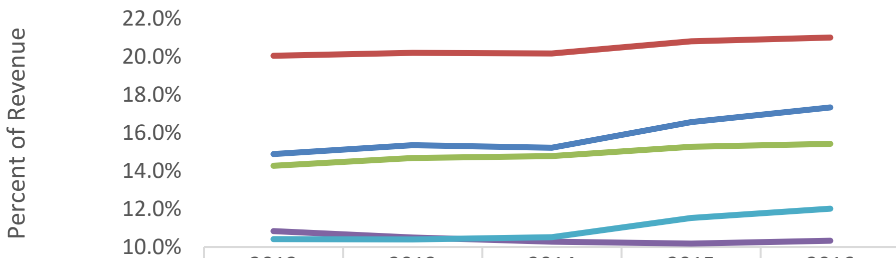
SOC	Description	Value Added ($millions)
512092	Team Assemblers	19 754
111021	General and Operations Managers	11 162
511011	First-Line Supervisors of Production and Operating Workers	7 247
414012	Sales Representatives, Wholesale and Manufacturing, Except Technical and Scientific Products	6 844
172112	Industrial Engineers	6 217
514041	Machinists	5 106
172141	Mechanical Engineers	5 043
519061	Inspectors, Testers, Sorters, Samplers, and Weighers	4 635
132011	Accountants and Auditors	4 233
172011	Aerospace Engineers	4 008
113051	Industrial Production Managers	3 981
537062	Laborers and Freight, Stock, and Material Movers, Hand	3 801
514121	Welders, Cutters, Solderers, and Brazers	3 761
119041	Architectural and Engineering Managers	3 705
533032	Heavy and Tractor-Trailer Truck Drivers	3 483
113031	Financial Managers	3 456
151133	Software Developers, Systems Software	3 125
151132	Software Developers, Applications	3 094
499041	Industrial Machinery Mechanics	3 044
499071	Maintenance and Repair Workers, General	2 934

Table 3.7: Value Added and Supply Chain for Discrete High-Tech Manufacturing (i.e., Machinery, Electronics, Computers, and Transportation Equipment), $millions 2014

	A	B	C	D	E	F	G	H	I	J	K	L	M	O	P = Sum of A thru O	Q	R	S = P + Q + R	T	U = S + T
NAICS and Industry	Management Occupations	Business and Financial Operations Occupations	Computer and Mathematical Occupations	Architecture and Engineering Occupations	Life, Physical, and Social Science Occupations	Legal Occupations	Building and Grounds Cleaning and Maintenance Occupations	Sales and Related Occupations	Office and Administrative Support Occupations	Construction and Extraction Occupations	Installation, Maintenance, and Repair Occupations	Production Occupations	Transportation and Material Moving Occupations	Other	Compensation of employees	Taxes on production and imports, less subsidies	Gross operating surplus	Value Added	imports	Total
11: Agriculture	33	10	0	0	7	0	4	4	42	7	28	16	123	760	1034	8	1504	2546	743	3289
21A: Energy - Processes	149	118	44	130	20	5	3	23	149	136	319	167	46	16	1324	1046	2477	4848	50	4898
21B: Energy - Facilities	33	26	10	31	5	1	1	5	33	15	72	39	4	4	279	238	522	1038	5	1044
21C: Energy - Other/Undesignated Onsite	92	64	26	92	17	3	2	12	82	37	219	117	12	12	789	722	1480	2990	22	3013
21D: Oil and Gas Extraction	446	241	89	513	223	44	1	31	110	217	45	101	92	14	2167	2595	14948	19709	17537	37246
21E: Mining	198	70	10	164	58	1	3	14	85	1114	473	240	424	25	2878	995	6848	10721	1073	11794
2213: Other Utilities	9	2	0	2	0	0	0	1	11	5	7	20	1	0	59	19	88	166	-	166
331-332: Metal Refining and Forming	5414	1544	427	2337	100	4	107	1209	2841	968	3112	21129	1886	186	41262	2009	31249	74520	63420	137940
333: Machinery	10525	3978	1933	9020	65	75	144	3212	4664	724	2993	26718	1434	376	65859	2649	35834	104339	43455	147794
334: Computer and Electronics	13088	5626	8499	15777	378	213	61	2578	3204	51	1183	9398	405	473	60934	2721	45154	108809	35236	144045
335: Electrical Equipment	1891	833	362	1826	12	8	19	464	732	102	495	4750	484	58	12035	293	6583	18910	11114	30024
336: Transportation Equipment	13042	9397	6341	20097	38	132	142	1367	4996	3317	7900	52844	3553	935	124101	3592	92508	220198	73220	293418
324-326: Chemicals, Rubber, and Plastic	1919	590	202	986	413	12	30	461	915	133	1027	6466	761	70	13984	1202	19749	34935	18995	53930
23-327: Construction and Other Materials	1695	505	151	457	45	5	39	585	1117	257	856	6179	1110	2495	15496	622	7917	24035	11578	35612
42: Wholesale Trade	6288	2385	1677	541	108	53	76	11476	5256	104	2114	1218	4664	659	36618	14959	21871	73448	-	73448
44-45: Retail Trade	250	68	15	1	0	1	9	1009	248	5	396	31	144	131	2308	877	848	4033	-	4033
48-49: Transportation	771	259	102	71	3	14	9	125	911	226	808	186	6153	48	9685	733	5872	16290	510	16800
493: Warehousing and Storage	176	79	18	10	-	-	16	41	366	2	78	68	1048	18	1921	37	579	2537	-	2537
492, 517: Communications	535	391	1008	127	2	15	2	419	579	2	547	8	869	30	4534	834	5260	10627	16	10643
52: Finance, Insurance, and Real estate	2494	4036	1004	6	6	132	90	2706	3197	20	262	4	12	142	14111	1122	12137	27370	642	28013
53: Equipment Rental	226	101	26	4	0	9	3	284	137	16	141	10	141	33	1133	769	8161	10063	-	10063
54: Legal and Professional Services	2147	2985	3154	171	37	3061	15	779	2148	25	53	64	42	976	15656	1044	10684	27384	853	28237
541: Engineering, Consulting, and Research	1897	2279	929	2368	483	33	17	391	860	125	72	157	66	557	10236	241	3324	13801	1683	15484
55: Management of Companies	12498	7944	3855	1043	300	576	52	1418	4520	148	507	248	416	1343	34869	1499	4875	41242	-	41242
56: Admin and Support	1717	1226	727	240	72	91	1948	1069	3287	442	583	1066	1350	2027	15845	444	5566	21855	73	21928
485, 511-515, 61-92: Other	1485	665	600	77	18	30	241	683	1165	69	1337	412	919	3562	11265	1234	7557	25681	105	25786
TOTAL	79019	45422	31208	56090	2409	4518	3034	30366	41655	8269	25628	131656	26159	14949	500382	42504	353595	902098	280329	1182427

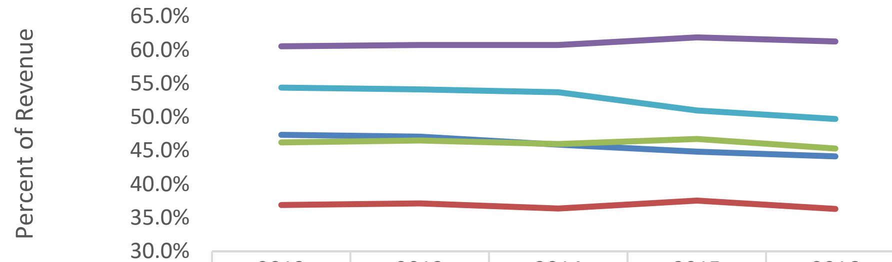
Figure 3.2: Breakdown of Expenditures as a Percent of Revenue, Annual Survey of Manufactures

Payroll



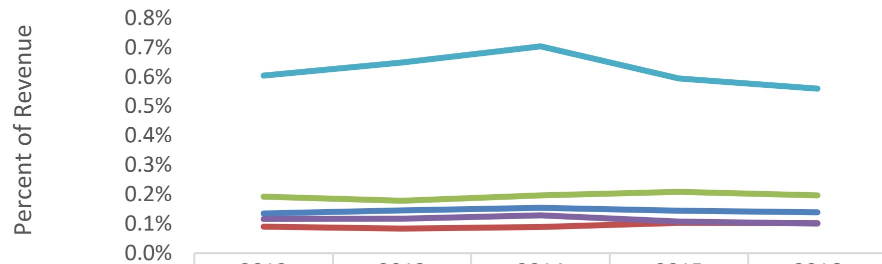
	2012	2013	2014	2015	2016
NAICS 333	14.9%	15.4%	15.2%	16.6%	17.3%
NAICS 334	20.1%	20.2%	20.2%	20.8%	21.0%
NAICS 335	14.3%	14.7%	14.8%	15.3%	15.4%
NAICS 336	10.8%	10.5%	10.3%	10.2%	10.3%
NAICS 31-33	10.4%	10.4%	10.5%	11.5%	12.0%

Materials, Parts, Containers, and Packaging Used



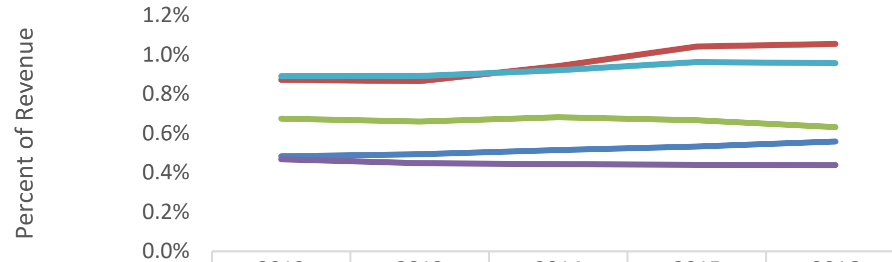
	2012	2013	2014	2015	2016
NAICS 333	47.4%	47.1%	45.9%	44.9%	44.1%
NAICS 334	36.9%	37.1%	36.4%	37.6%	36.3%
NAICS 335	46.2%	46.5%	46.0%	46.7%	45.3%
NAICS 336	60.5%	60.7%	60.7%	61.9%	61.2%
NAICS 31-33	54.4%	54.1%	53.7%	51.0%	49.7%

Purchased Fuels Consumed



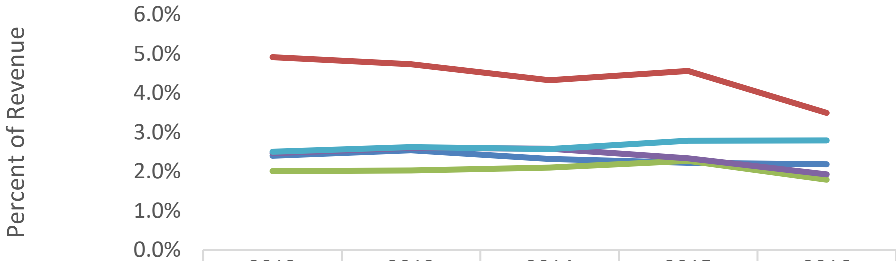
	2012	2013	2014	2015	2016
NAICS 333	0.1%	0.1%	0.2%	0.1%	0.1%
NAICS 334	0.1%	0.1%	0.1%	0.1%	0.1%
NAICS 335	0.2%	0.2%	0.2%	0.2%	0.2%
NAICS 336	0.1%	0.1%	0.1%	0.1%	0.1%
NAICS 31-33	0.6%	0.6%	0.7%	0.6%	0.6%

Purchased Electricity



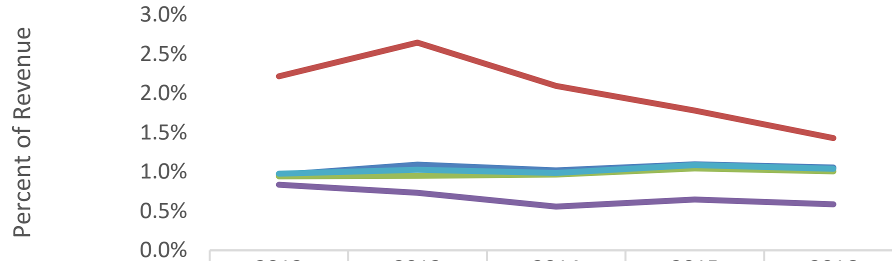
	2012	2013	2014	2015	2016
NAICS 333	0.5%	0.5%	0.5%	0.5%	0.6%
NAICS 334	0.9%	0.9%	0.9%	1.0%	1.1%
NAICS 335	0.7%	0.7%	0.7%	0.7%	0.6%
NAICS 336	0.5%	0.4%	0.4%	0.4%	0.4%
NAICS 31-33	0.9%	0.9%	0.9%	1.0%	1.0%

Machinery - Rentals and Purchases



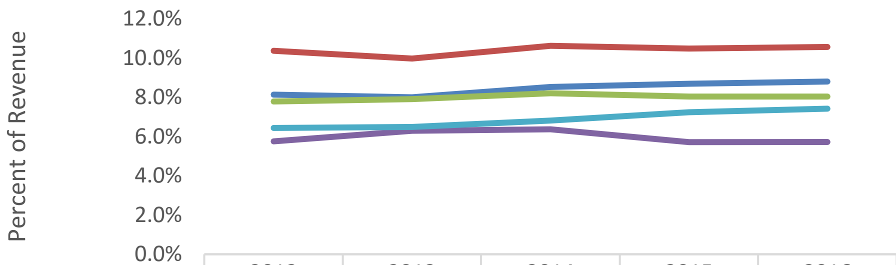
	2012	2013	2014	2015	2016
NAICS 333	2.4%	2.5%	2.3%	2.2%	2.2%
NAICS 334	4.9%	4.7%	4.3%	4.6%	3.5%
NAICS 335	2.0%	2.0%	2.1%	2.3%	1.8%
NAICS 336	2.5%	2.6%	2.6%	2.3%	1.9%
NAICS 31-33	2.5%	2.6%	2.6%	2.8%	2.8%

Buildings - Rentals and Purchases



	2012	2013	2014	2015	2016
NAICS 333	1.0%	1.1%	1.0%	1.1%	1.1%
NAICS 334	2.2%	2.6%	2.1%	1.8%	1.4%
NAICS 335	0.9%	0.9%	1.0%	1.0%	1.0%
NAICS 336	0.8%	0.7%	0.6%	0.6%	0.6%
NAICS 31-33	1.0%	1.0%	1.0%	1.1%	1.0%

Other Purchases



	2012	2013	2014	2015	2016
NAICS 333	8.1%	8.0%	8.5%	8.7%	8.8%
NAICS 334	10.4%	10.0%	10.6%	10.5%	10.6%
NAICS 335	7.8%	7.9%	8.2%	8.0%	8.0%
NAICS 336	5.7%	6.3%	6.4%	5.7%	5.7%
NAICS 31-33	6.4%	6.5%	6.8%	7.2%	7.4%

4 Employment, Compensation, and Productivity

The Annual Survey of Manufactures estimates that there were 11.1 million employees in the manufacturing industry in 2016, which is the most recent data available (see Table 4.1). The Current Population Survey and Current Employment Statistics have more recent data that estimate that there were 15.4 million and 12.4 million employees in 2016, respectively (see Table 4.2 and Table 4.3). Each of these estimates has its own method for how the data was acquired and its own definition of employment. The Current Population Survey considers an employed person to be any individual who did any work for pay or profit during the survey reference week or were absent from their job because they were ill, on vacation, or taking leave for some other reason. It also includes individuals who completed at least 15 hours of unpaid work in a family-owned enterprise operated by someone in their household. In contrast, the Current Employment Statistics specifically exclude proprietors, self-employed, and unpaid family or volunteer workers. Therefore, the estimates from the Current Employment Statistics are lower than the Current Population Survey estimates. Additionally, the Current Employment Statistics include temporary and intermittent employees. The Annual Survey of Manufactures considers an employee to include all full-time and part-time employees on the payrolls of operating establishments during any part of the pay period being surveyed excluding temporary staffing obtained through a staffing service. It also excludes proprietors along with partners of unincorporated businesses.

Between 2016 and 2017, manufacturing employment remained the same according to the Current Population Survey (see Table 4.2) and increased 0.7 % according to the Current Employment Statistics (see Table 4.3). Meanwhile, total employment increased 1.3 % according to the Current Population Survey (see Table 4.2). Moreover, manufacturing employment is growing slower than total employment.

Table 4.1: Employment, Annual Survey of Manufactures

	2015 (employees)	**2016 (employees)**	**Percent Change**
Employees			
a. NAICS 324: Petroleum & coal products mfg	102,740	104,280	1.5%
b. NAICS 325: Chemical mfg	742,192	744,590	0.3%
c. NAICS 326: Plastics & rubber products mfg	730,005	741,224	1.5%
d. NAICS 327: Nonmetallic mineral product mfg	368,081	371,852	1.0%
e. NAICS 331: Primary metal mfg	379,426	364,199	-4.0%
f. NAICS 332: Fabricated metal product mfg	1,372,326	1,327,632	-3.3%
g. NAICS 333: Machinery mfg	1,042,664	988,688	-5.2%
h. NAICS 334: Computer & electronic product mfg	777,261	768,650	-1.1%
i. NAICS 335: Electrical equipment & component mfg	337,146	330,944	-1.8%
j. NAICS 336: Transportation equipment mfg	1,470,862	1,478,941	0.5%
k. NAICS 339: Miscellaneous mfg	512,988	513,593	0.1%
l. NAICS 311: Food mfg	1,390,907	1,417,046	1.9%
M. Other: apparel, wood product, and printing mfg	1,941,666	1,961,124	1.0%
N. TOTAL MANUFACTURING	**11,168,264**	**11,112,764**	**-0.5%**

Table 4.2: Employment by Industry for 2015 and 2016 (Thousands): Current Population Survey

Industry	Total Employed 2016	Total Employed 2017	Employment Change	Percent Change
Mining	792	748	-44	-5.6%
Construction	10 328	10 692	364	3.5%
Manufacturing	15 408	15 408	0	0.0%
Wholesale and Retail Trade	20 218	20 314	96	0.5%
Transportation and Utilities	8 012	8 159	147	1.8%
Information	2 855	2 903	48	1.7%
Financial Activities	10 404	10 482	78	0.7%
Professional and Business Services	18 325	18 835	510	2.8%
Education and Health Services	34 263	34 483	220	0.6%
Leisure and Hospitality	14 193	14 291	98	0.7%
Other Services	7 320	7 485	165	2.3%
Public Administration	6 857	7 083	226	3.3%
Agriculture	2 460	2 454	-6	-0.2%
TOTAL*	151 435	153 337	1 902	1.3%

* The sum may not match the total due to rounding of annual averages

Source: Current Population Survey, Bureau of Labor Statistics. "Table 17: Employed Persons by Industry, Sex, Race, and Occupation." <http://www.bls.gov/cps>

Table 4.3: Manufacturing Employment (Thousands): Current Employment Statistics

	2016	2017	Percent Change
Manufacturing	12 354	12 444	0.7%
Durable Goods	7 714	7 740	0.3%
Nondurable Goods	4 640	4 704	1.4%

Source: Bureau of Labor Statistics. Current Employment Statistics. http://www.bls.gov/ces/home.htm

Table 4.4: Manufacturing Employment by Occupation

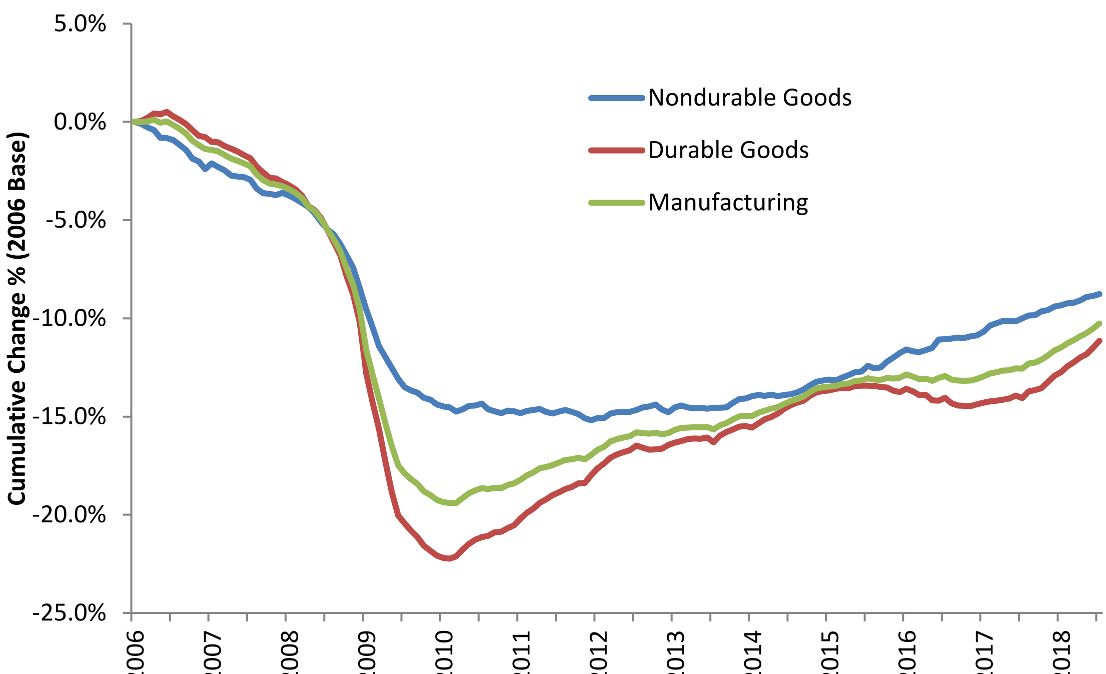
Occupation	Employed (Thousands)	Percent of Total
Protective service occupations	14.5	0.1%
Social, educational, personal care, and legal	35.6	0.3%
Building and grounds cleaning and maintenance occupations	66.3	0.5%
Arts, design, entertainment, sports, and media occupations	82.9	0.7%
Food preparation and serving related occupations	90.3	0.7%
Life, physical, and social science occupations	119.1	1.0%
Construction and extraction occupations	189.1	1.5%
Computer and mathematical occupations	288.8	2.3%
Sales and related occupations	393.7	3.2%
Installation, maintenance, and repair occupations	621.4	5.0%
Architecture and engineering occupations	795.4	6.4%
Transportation and material moving occupations	973.2	7.9%
Office and administrative support occupations	1123.7	9.1%
Management and financial occupations	1177.3	9.5%
Production occupations	6377.1	51.6%
TOTAL	12348.4	100.0%

Between January 2006 and January 2010, manufacturing employment declined by 19.4 %, as seen in Figure 4.1. As of August 2018, employment is still 10.3 % below its 2006 level. In times of financial difficulty, large purchases are often delayed or determined to be unnecessary. Thus, it would be expected that during the recent recession durable goods would decline more than nondurable goods. As can be seen in Figure 4.1, durable goods declined more than manufacturing as a whole while nondurable goods did not decline as much. By January 2010, durable goods had declined 22.2 % while nondurables declined 14.5 %. As of August 2018, employment in durables was 11.1 % below its 2006 levels while that for nondurables was at 8.8 % below 2006 levels.

The employees that work in manufacturing offer their time and, in some cases, risk their personal safety in return for compensation. In terms of safety, the number of fatal injuries decreased 9.9 % between 2015 and 2016 (see Table 4.5). Nonfatal injuries decreased along with the injury rate (see Table 4.6). However, the incident rate for nonfatal injuries in manufacturing remains higher than that for all private industry. As seen in Figure 4.2, fatalities, injuries, and the injury rate have had an overall downward trend since 2000.

During the late 2000s recession, the number of hours worked per week declined, as seen in Figure 4.3. Unlike employment, however, the number of hours worked per week returned to its pre-recession levels or slightly higher. Average wages increased significantly during the recession and decreased during the following recovery, as can be seen in Figure 4.4. This is likely because low wage earners are disproportionately

Figure 4.1: Cumulative Change in Percent in Manufacturing Employment (Seasonally Adjusted), 2006-2016



Source: Bureau of Labor Statistics. Current Employment Statistics. http://www.bls.gov/ces/

Table 4.5: Fatal Occupational Injuries by Event or Exposure

		Total	Violence and other injuries by persons or animals	Transportation Incidents	fires and explosions	Falls, slips, trips	exposure to harmful sub-stances or environments	Contact with objects and equipment
2015	Total	4836	703	2054	121	800	424	722
	Manufacturing	353	37	94	19	63	38	102
2016	Total	5190	866	2083	88	849	518	761
	Manufacturing	318	48	73	12	49	28	107
Percent Change	Total Private Industry	7.3%	23.2%	1.4%	-27.3%	6.1%	22.2%	5.4%
	Manufacturing	-9.9%	29.7%	-22.3%	-36.8%	-22.2%	-26.3%	4.9%

Source: Bureau of Labor Statistics. Census of Fatal Occupational Injuries. "Industry by Event or Exposure." <http://stats.bls.gov/iif/oshcfoi1.htm>
Source: Bureau of Labor Statistics. Census of Fatal Occupational Injuries. "Industry by Event or Exposure." http://stats.bls.gov/iif/oshcfoi1.htm

Table 4.6: Total Recordable Cases of Nonfatal Injuries and Illnesses, Private Industry

		2015	2016	Percent Change
Manu-facturing	Incident Rate per 100 full time workers*	3.4	3.3	-2.9%
	Total Recordable Cases (thousands)	425.7	410.5	-3.6%
Private Industry	Incident Rate per 100 full time workers	2.9	2.8	-3.4%
	Total Recordable Cases (thousands)	2765.3	2719.8	-1.6%

Source: Bureau of Labor Statistics. Injuries, Illness, and Fatalities Program. 2010-2011. http://www.bls.gov/iif/

* The incidence rates represent the number of injuries and illnesses per 100 full-time workers and were calculated as: (N/EH) x 200,000, where

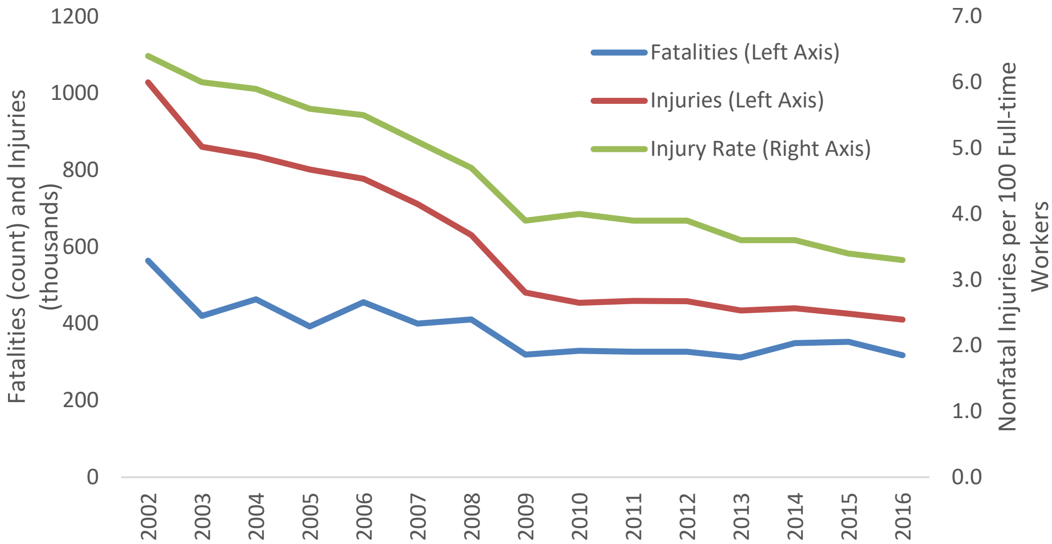
N = number of injuries and illnesses

EH = total hours worked by all employees during the calendar year
200,000 = base for 100 equivalent full-time workers (working 40 hours per week, 50 weeks per year)

impacted by employment reductions, which suggests that high wage earners not only receive more pay, they also have more job security. The compound annual growth rate in real for private sector wages was 0.8 % between 2013 and 2018 while it was 0.5 % for manufacturing. As seen in Figure 4.5, employee compensation, which includes benefits, has had a five-year compound annual growth of 3 %.

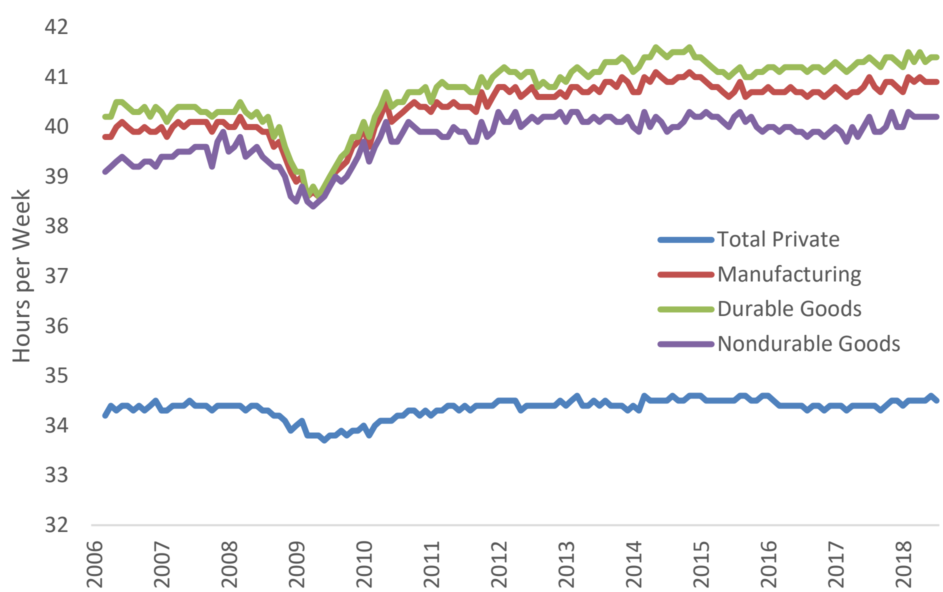
The Bureau of Labor Statistics provides an index of labor productivity and multifactor productivity. Labor productivity for manufacturing increased 0.2 % from 2015 to 2016 and has had a slight upward trend, as seen in Figure 4.6. The Bureau of Labor Statistics multifactor productivity is “a measure of economic performance that compares the amount of goods and services produced (output) to the amount of combined inputs used to produce those goods and services. Inputs can include labor, capital, energy, materials, and purchased services." For US manufacturing, multifactor productivity declined 3 % from 2015 to 2016 and has had a downward trend in recent years, as seen in Figure 4.7. US productivity is relatively high compared to other countries. As illustrated in Figure 4.8, the US is ranked fifth in output per hour among 67 countries using data from the Conference Board.

Figure 4.2: Manufacturing Fatalities and Injuries



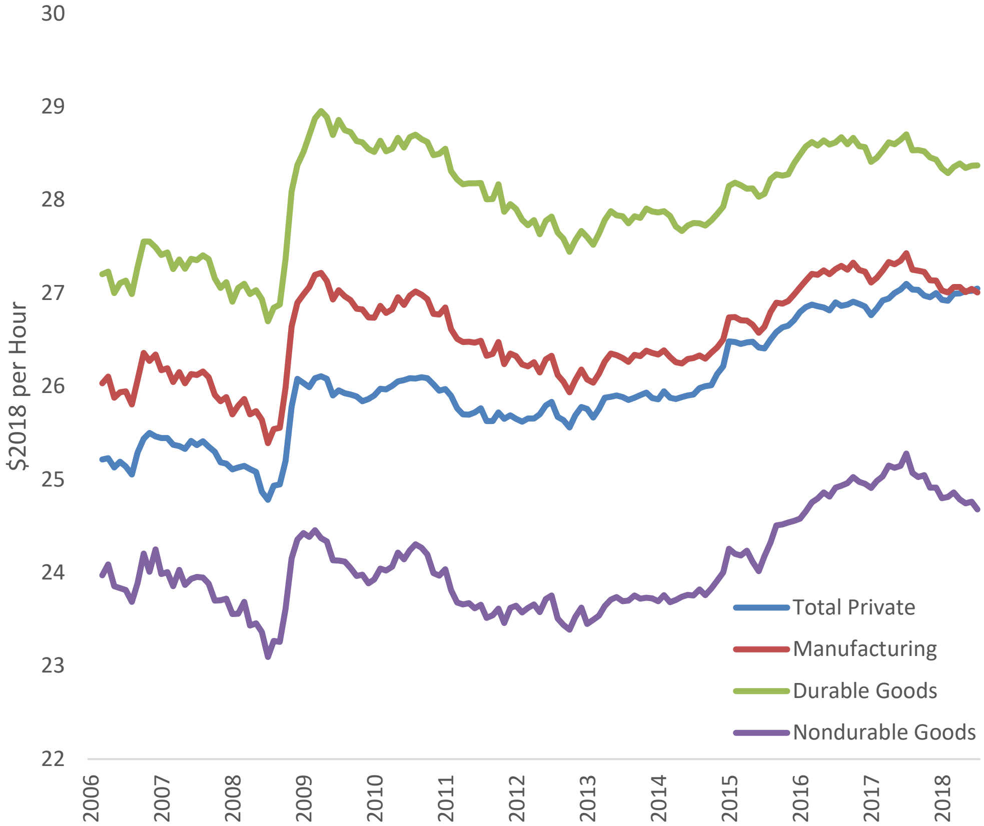
Source: Bureau of Labor Statistics. Injuries, Illness, and Fatalities Program. 2013-2014. http://www.bls.gov/iif/

Figure 4.3: Average Weekly Hours for All Employees (Seasonally Adjusted)



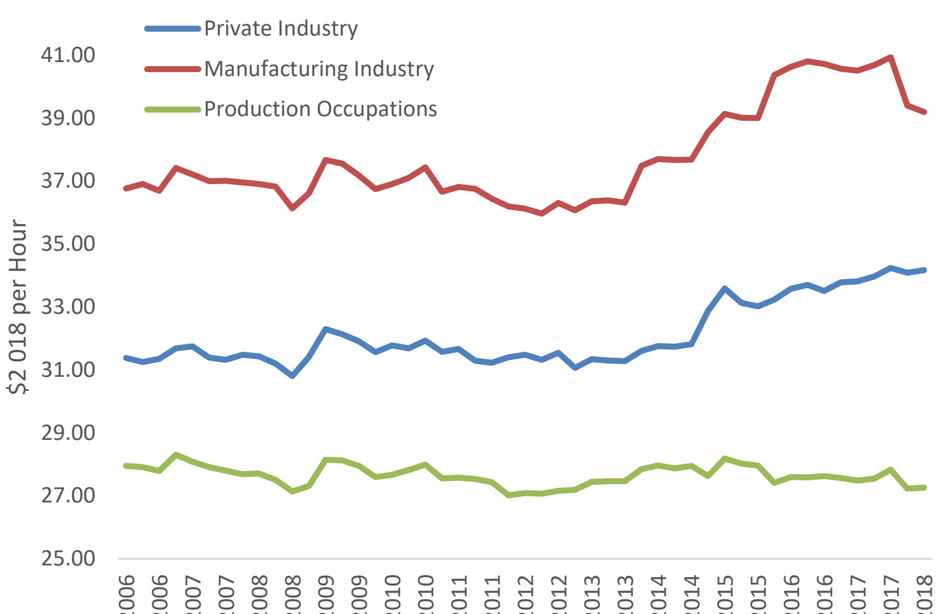
Source: Bureau of Labor Statistics. Current Employment Statistics. http://www.bls.gov/ces/home.htm

Figure 4.4: Average Hourly Wages for Manufacturing and Private Industry (Seasonally Adjusted)



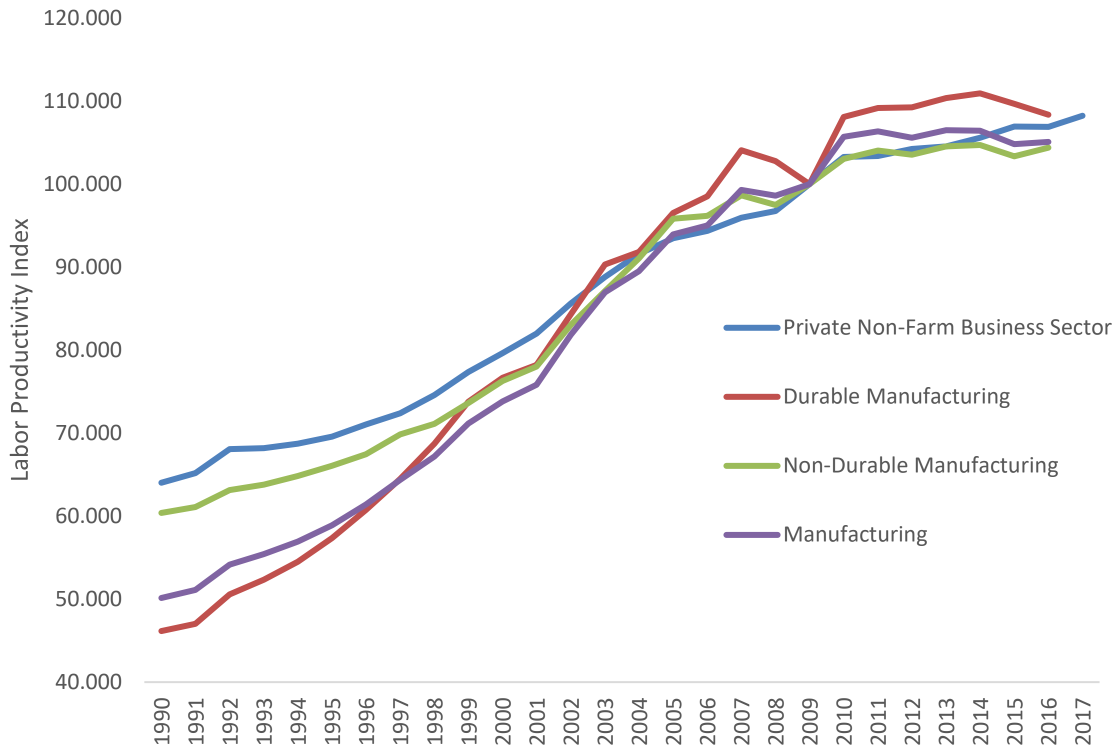
Source: Bureau of Labor Statistics. Current Employment Statistics. http://www.bls.gov/ces/home.htm

Figure 4.5: Employee Compensation (Hourly)



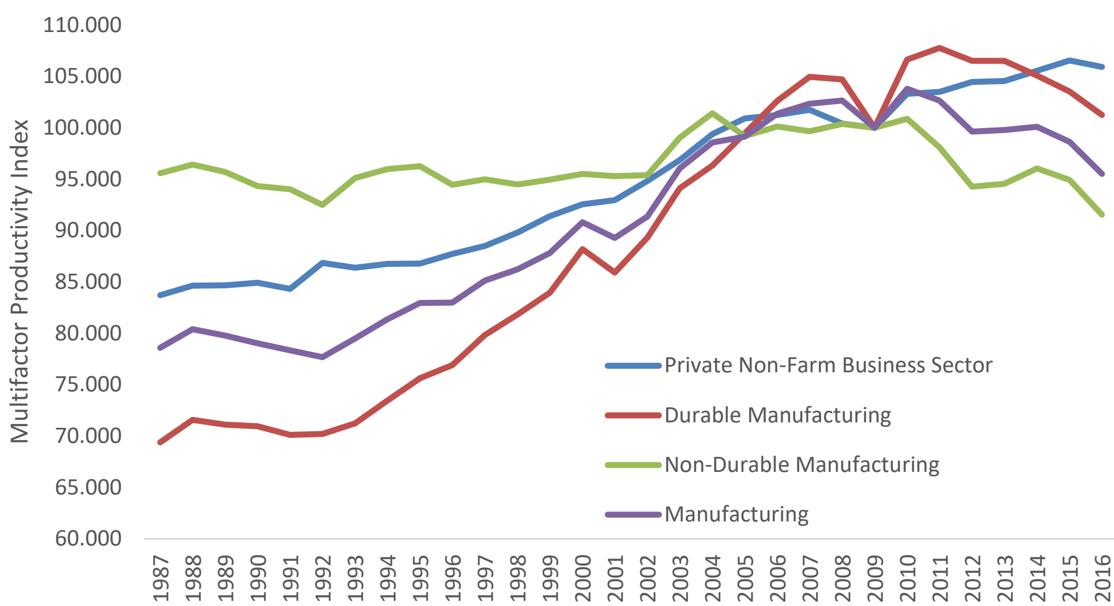
Source: Bureau of Labor Statistics. National Compensation Survey. http://www.bls.gov/ncs/

Figure 4.6: Manufacturing Labor Productivity



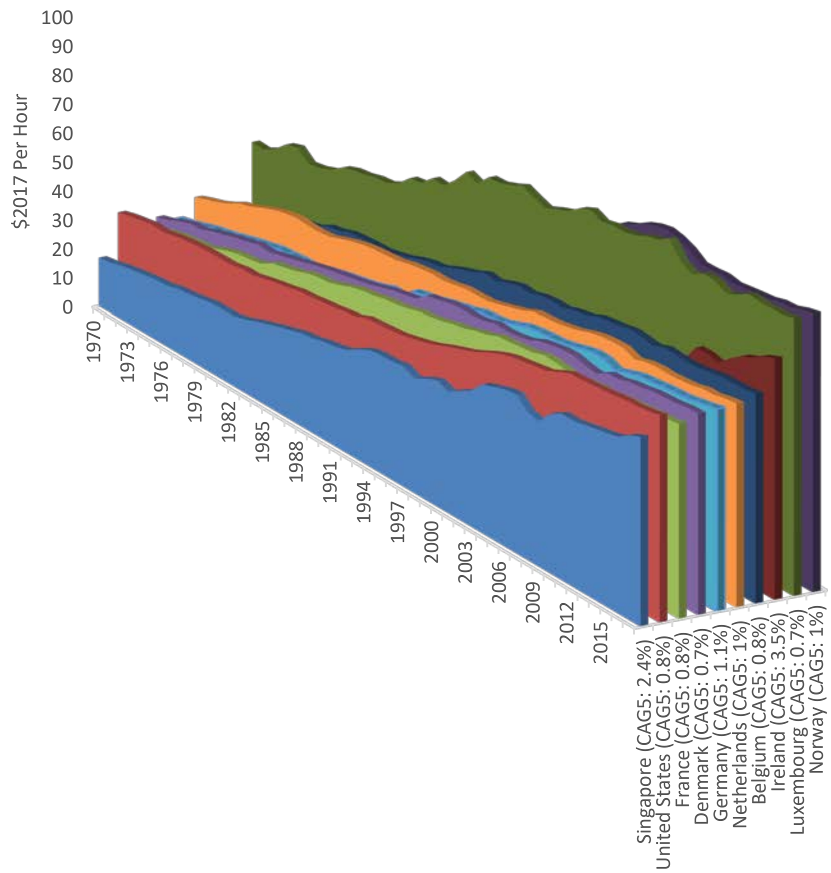
Source: Bureau of Labor Statistics. Productivity. 2017. https://www.bls.gov/mfp/

Figure 4.7: Manufacturing Multifactor Productivity



Source: Bureau of Labor Statistics. Productivity. 2017. https://www.bls.gov/mfp/

Figure 4.8: Output per Labor Hour (Top Ten Countries Out of 62), $2016

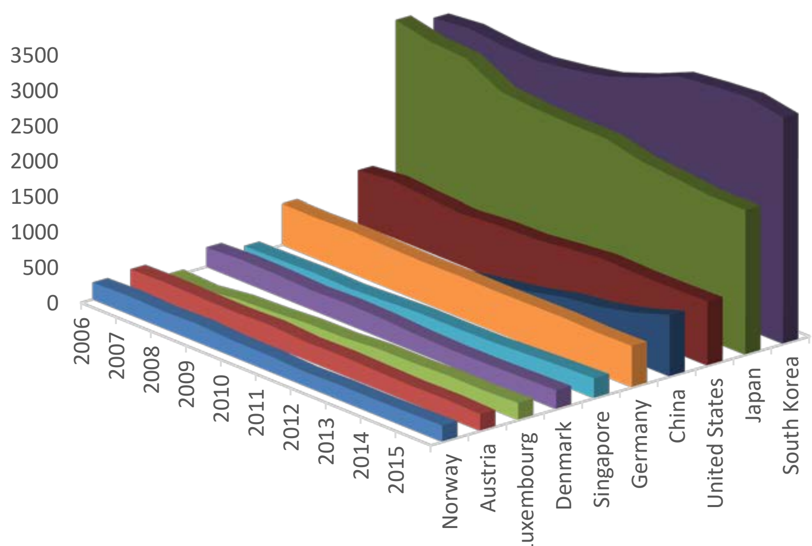


Source: Conference Board. Total Economy Database: Output, Labor and Labor Productivity. May 2017. https://www.conference-board.org/data/economydatabase/index.cfm?id=27762
Note: CAG5 = 5-year compound annual growth rate (Calculated using Conference Board data)

5 Research, Innovation, and Factors for Doing Business

Manufacturing goods involves not only physical production, but also design and innovation. Measuring and comparing innovation between countries is problematic, however, as there is not a standard metric for measuring this activity. Four measures are often discussed in regards to innovation: number of patent applications, research and development expenditures, number of researchers, and number of published journal articles. As seen in Figure 5.1, the US ranked 3rd in 2016 in resident patent applications per million people, which puts it above the 95th percentile among 125 countries. Using patent application as a metric can be problematic though, as not all innovations are patented and some patents might not be considered innovation. The US ranked 9th in research and development expenditures as a percent of GDP in 2015, which puts it at the 88th percentile (see Table 5.1). As seen in Figure 5.2, real fixed investment in research and development increased between 2017 and 2018 and has a compound annual growth rate of 4.3 % (not shown). Note, however, that this is for all industries and not just manufacturing. As seen in Table 5.2, China outspends the US in research and development for all of manufacturing and 10 of the 12 subcategories. In terms of researchers per million people, the US ranked 14th, putting it at the 78th percentile (see Table 5.3). In journal articles per million people it ranked 21st in 2013, putting it at the 91st percentile (see Table 5.4).[41]

Figure 5.1: Patent Applications (Residents) per Million People, Top Ten



World Bank. 2018. World Development Indicators. https://data.worldbank.org/products/wdi

[41] World Bank. World Development Indicators. http://data.worldbank.org/data-catalog/world-development-indicators

Table 5.1: Research and Development Expenditures as a Percent of GDP

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Israel	4.13	4.41	4.33	4.12	3.94	4.02	4.16	4.14	4.29	4.27
Korea, Rep.	2.83	3.01	3.14	3.30	3.45	3.75	4.02	4.15	4.28	4.23
Japan	3.28	3.34	3.34	3.23	3.14	3.25	3.21	3.32	3.40	3.28
Sweden	3.50	3.25	3.49	3.45	3.22	3.25	3.29	3.31	3.14	3.26
Austria	2.38	2.44	2.58	2.62	2.73	2.68	2.93	2.96	3.06	3.07
Denmark	2.41	2.51	2.78	3.08	2.93	2.97	3.01	3.02	2.98	3.01
Finland	3.33	3.34	3.54	3.75	3.73	3.64	3.42	3.29	3.18	2.90
Germany	2.46	2.45	2.60	2.73	2.71	2.80	2.87	2.82	2.89	2.88
United States	2.54	2.62	2.77	2.82	2.73	2.77	2.70	2.74	2.75	2.79
Belgium	1.81	1.84	1.92	1.98	2.05	2.16	2.36	2.44	2.46	2.46
United States - Rank	7	6	7	7	8	8	10	9	9	9
United States - Percentile	91	94	93	93	91	91	88	90	89	88

Source: World Bank. 2018. World Development Indicators. https://data.worldbank.org/products/wdi

Figure 5.2: Real Private Fixed Investment in Research and Development, BEA

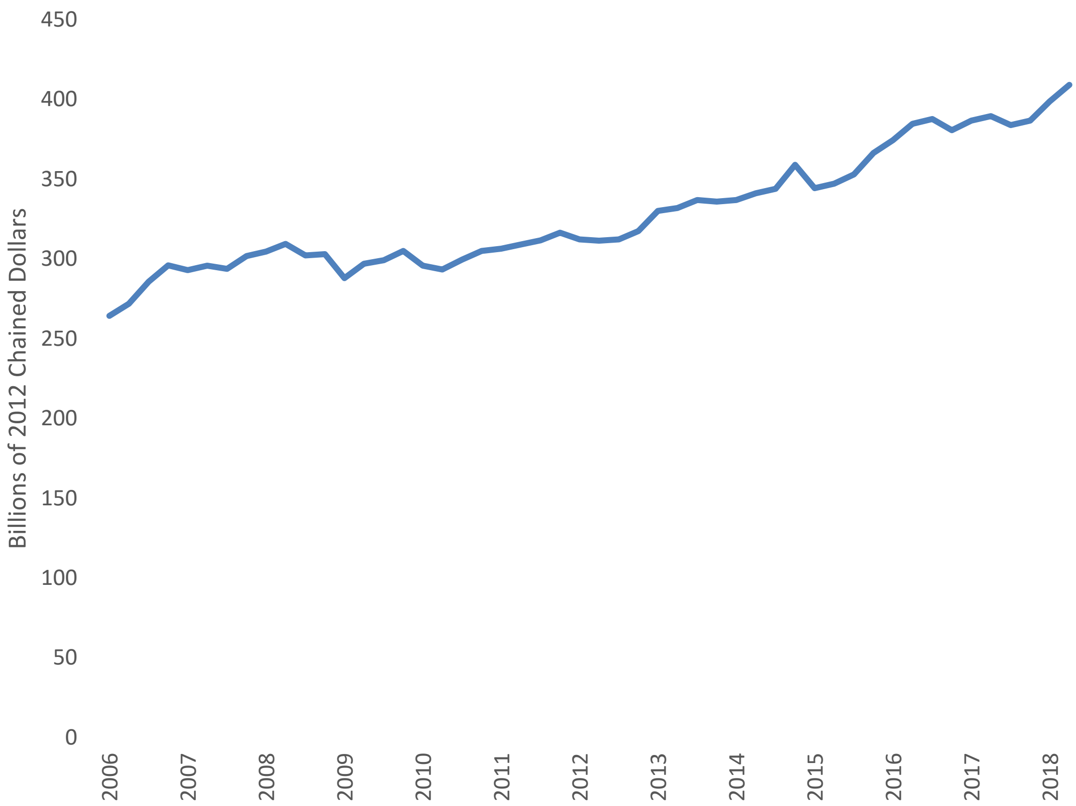


Table 5.2: Research and Development Expenditures by Industry, $Billion 2015

	China	United States	Japan	Germany	Korea	Italy	United Kingdom	Switzerland	Sweden	Austria
Total	288	327	121	70	57	16	28	11	10	8
MANUFACTURING	255	217	105	59	51	11	11	7	7	5
Food products; beverages and tobacco products	12	5	2	0	1	0	0	0	-	0
Textiles, wearing apparel, leather and related products	9	1	1	0	0	1	0	-	-	-
Wood, paper, printing and reproduction	5	1	1	0	0	0	0	-	-	0
Coke and refined petroleum products	3	0	0	0	0	0	0	-	-	-
Chemicals and chemical products	23	9	7	4	3	1	0	0	-	0
Basic pharmaceutical products and pharmaceutical preparations	12	54	13	5	2	1	1	4	-	0
Rubber and plastic products	6	2	3	1	1	0	0	-	0	0
Other non-metallic mineral products	7	1	1	0	0	0	0	-	-	0
Basic metals	25	1	2	1	1	0	0	0	0	0
Fabricated metal products, computer, electronic and optical products, electrical equipment, machinery, motor vehicles and other transport equipment	149	130	73	45	42	8	9	-	5	4
Furniture	1	0	0	0	0	0	0	-	-	0
Other manufacturing	3	13	2	1	0	0	0	-	-	0

Source: OECD. Business Enterprise R-D Expenditure by Industry (ISIC 4). http://stats.oecd.org/#

In addition to some of the previously mentioned metrics, a number of indices have been developed to assess national competitiveness. The IMD World Competitiveness Index provides additional insight into the US innovation landscape. Figure 5.3 provides the US ranking for 20 measures of competitiveness. This provides some indicators to identify opportunities for improvement in US economic activity. In 2018, the US ranked low in public finance, prices, societal framework, and attitudes and values. Overall, the US had the highest ranking in competitiveness for conducting business.[42] The Competitive Industrial Performance Index, published by the United Nations Industrial Development Organization, ranks the US 3rd in its economic performance. This index assesses an economy's ability to competitively produce and export manufactured goods.[43]

The 2016 Deloitte Global Manufacturing Competitiveness Index uses a survey of CEOs to rank countries based on their perception. The US was ranked 2nd out 40 nations with China being ranked 1st. High-cost labor, high corporate tax rates, and increasing investments outside of the US were identified as challenges to the US industry. Manufacturers indicated that companies were building high-tech factories in the US due to rising labor costs in China, shipping costs, and low-cost shale gas.[44] According to

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42 IMD. IMD World Competitiveness Country Profile: US. https://worldcompetitiveness.imd.org/countryprofile/US

43 United Nations Industrial Development Organization. Competitive Industrial Performance Report 2014. Working Paper 12/2014. http://www.unido.org/fileadmin/user_media/Services/PSD/WP2014_12_CIPReport2014.pdf

44 Deloitte. 2016 Global Manufacturing Competitiveness Index. http://www2.deloitte.com/content/dam/Deloitte/us/Documents/manufacturing/us-gmci.pdf

Table 5.3: Researchers per Million People

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Denmark	5201	5302	5519	6497	6660	6744	7026	7156	7089	7333
Finland	7545	7673	7373	7692	7649	7717	7414	7460	7188	6986
Korea, Rep.	3777	4175	4604	4868	5001	5380	5853	6362	6457	6899
Sweden	6091	6133	5005	5443	5085	5256	5147	5164	6670	6868
Singapore	5292	5425	5769	5741	6149	6307	6496	6442	6665	6658
Norway	4584	4838	5163	5360	5439	5408	5496	5548	5569	5679
Japan	5360	5387	5378	5158	5148	5153	5160	5084	5201	5386
Austria	3457	3531	3816	4142	4146	4359	4406	4695	4763	4884
Luxembourg	4864	4412	4636	4716	4829	5145	5444	4339	4595	4724
Netherlands	2930	3241	3101	3071	2833	3229	3675	4372	4561	4519
Ireland	2756	2835	2893	3237	3113	3070	3282	3482	3606	4433
Germany	3350	3452	3597	3752	3941	4078	4211	4379	4400	4364
United Kingdom	4129	4188	4132	4084	4116	4091	3979	4029	4186	4299
United States	3718	3782	3758	3912	4073	3869	4011	4016	4118	4232
United States - Rank	12	13	13	14	13	15	16	20	18	14
United States - Percentile	83	80	83	82	83	81	79	72	75	78

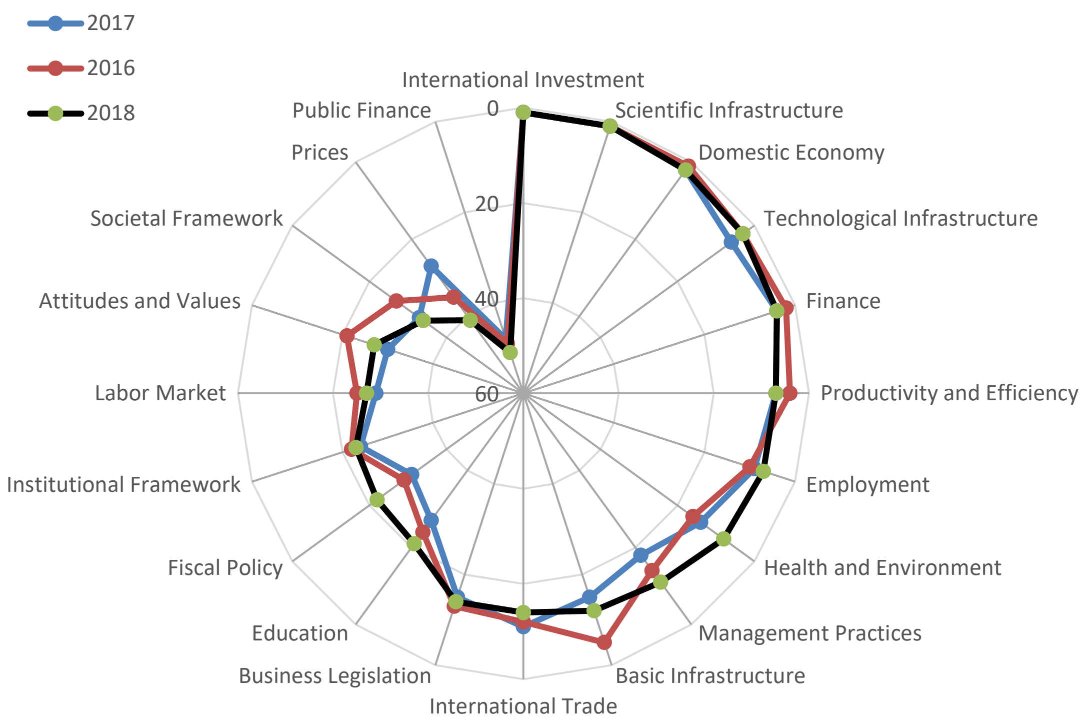
World Bank. 2018. World Development Indicators. https://data.worldbank.org/products/wdi

Table 5.4: Journal Articles per Million People

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Switzerland	2189	2241	2280	2337	2421	2519	2651	2705	2748	2642	2523
Denmark	1570	1652	1690	1782	1874	2081	2267	2325	2485	2473	2352
Australia	1599	1719	1733	1798	1887	1986	2040	2157	2240	2186	2109
Norway	1522	1630	1667	1812	1852	1970	2064	2038	2084	2017	2049
Sweden	1832	1832	1804	1864	1891	1951	2040	2093	2179	2109	2009
Singapore	1864	1798	1795	1788	1941	1948	2035	2034	2038	2027	2007
Iceland	1190	1170	1359	1561	1784	1734	1984	1837	1801	1849	1943
Finland	1748	1780	1803	1858	1860	1920	1937	1990	2054	1962	1919
Netherlands	1496	1564	1613	1735	1759	1811	1880	1905	1918	1834	1759
Slovenia	1192	1365	1488	1579	1585	1842	1802	1809	1837	1760	1650
New Zealand	1340	1421	1474	1529	1573	1692	1741	1710	1737	1628	1591
Canada	1512	1591	1607	1652	1668	1687	1730	1724	1732	1688	1582
Czech Republic	863	970	1025	1072	1210	1290	1327	1370	1489	1600	1511
United Kingdom	1447	1490	1489	1522	1521	1557	1591	1607	1594	1557	1487
Belgium	1236	1299	1352	1394	1414	1456	1525	1540	1561	1495	1447
Ireland	1137	1255	1289	1419	1543	1623	1562	1571	1583	1457	1437
Austria	1107	1191	1242	1311	1341	1409	1466	1481	1509	1497	1415
Luxembourg	420	440	634	781	910	1132	1122	1421	1556	1401	1405
Israel	1565	1565	1555	1506	1445	1470	1506	1458	1493	1458	1392
Portugal	678	723	820	906	1005	1136	1246	1350	1410	1408	1334
United States	1284	1293	1289	1300	1325	1364	1377	1376	1382	1337	1265
Germany	1025	1075	1110	1160	1188	1257	1310	1307	1349	1295	1252
Korea, Rep.	759	853	903	933	1028	1096	1143	1174	1235	1265	1231
United States Rank	13	15	17	18	18	18	18	19	21	21	21
United States Percentile	94	93	92	92	92	92	92	91	90	90	90

World Bank. 2018. World Development Indicators. https://data.worldbank.org/products/wdi

Figure 5.3: IMD World Competitiveness Rankings for the US: Lower is Better (i.e., a Rank of 1 is Better than a Rank of 60)

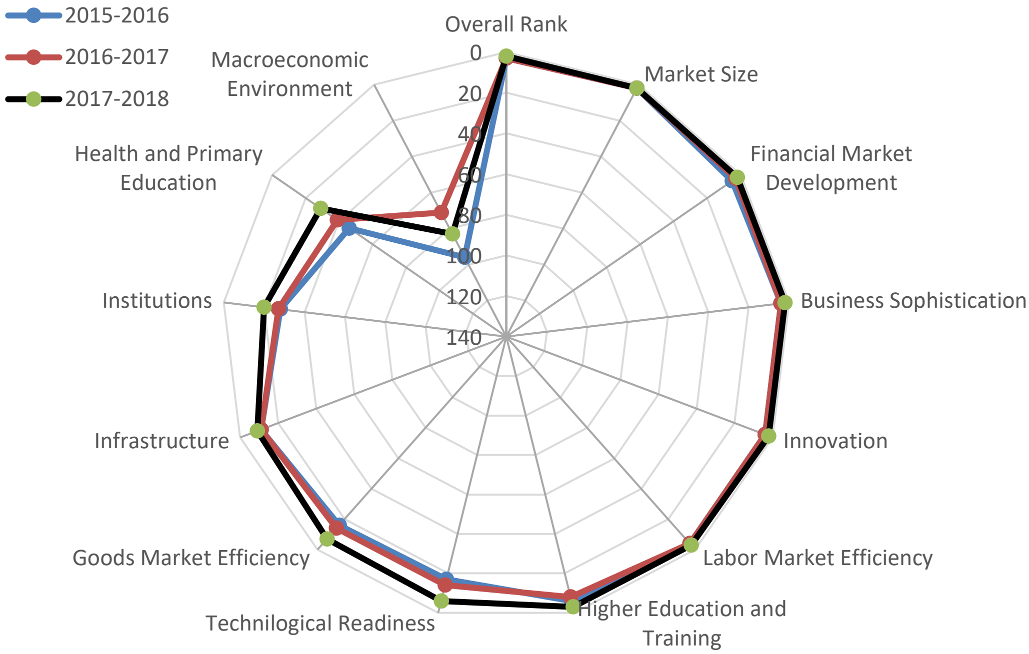


the Deloitte Global Manufacturing Competitiveness Index, advantages to US manufacturers included its technological prowess and size, productivity, and research support. China was ranked 1st with advantages in raw material supply, advanced electronics, and increased research and development spending. China has challenges in innovation, slowing economic growth, productivity, and regulatory inefficiency.

The World Economic Forum's 2017-2018 Global Competitiveness Report uses 12 items to assess the competitiveness of 138 economies, which includes the set of "institutions, policies and factors that determine the level of productivity of an economy, which in turn sets the level of prosperity that the country can achieve." As illustrated in Figure 5.4, the US was ranked 2nd overall with low rankings in macroeconomic environment, health and primary education, and institutions.[45] The index uses a set of 115 factors to produce the 12 items in Figure 5.4 (see Table 5.5). Business executives were asked to identify

[45] World Economic Forum. The Global Competitiveness Report 2015-2016. http://www3.weforum.org/docs/gcr/2015-2016/Global_Competitiveness_Report_2015-2016.pdf

Figure 5.4: World Economic Forum 2016-2017 Global Competitiveness Index: US Pillar Rankings: Lower is Better



and rank the top 5 most problematic factors for doing business from a list of 16 factors. As seen in Figure 5.5, "insufficient capacity to innovate" was ranked low as a problematic factor in the US compared to China.

The Annual Survey of Entrepreneurs makes inquiries concerning the negative impacts of eight items:

- Access to financial capital
- Cost of financial capital
- Finding qualified labor
- Taxes
- Slow business or lost sales
- Late or nonpayment from customers
- Unpredictability of business conditions
- Changes or updates in technology
- Other

As seen in Figure 5.6, there are five items where more than a third of the firms indicated negative impacts. Among them were taxes, slow business or lost sales, unpredictability of business conditions, finding qualified labor, and government regulations. [46]

[46] US Census Bureau. Annual Survey of Entrepreneurs. https://www.census.gov/programs-surveys/ase.html

Table 5.5: US Rank for Indicators used in the World Economic Forum Competitiveness Index: Lower is Better

Pillar	Description	Rank
6.14	Imports % GDP	132
10.04	Exports % GDP	129
3.04	Government debt % GDP	125
3.01	Government budget balance % GDP -	95
6.05	Total tax rate % profits	95
1.13	Business costs of terrorism	86
4.05	HIV prevalence % adult pop	85
4.06	Business impact of HIV/AIDS	85
4.10	Primary education enrollment rate net %	84
3.02	Gross national savings % GDP	83
4.04	Business impact of tuberculosis	80
1.14	Business costs of crime and violence	61
1.15	Organized crime	57
5.01	Secondary education enrollment rate gross %	57
7.10	Female participation in the labor force ratio to men	56
6.06	No of procedures to start a business	53
2.08	Mobile-cellular telephone subscriptions / pop	47
4.07	Infant mortality deaths/, live births	40
9.04	Internet users % pop	39
4.08	Life expectancy years	37
9.06	Internet bandwidth kb/s/user	37
1.05	Irregular payments and bribes	34
6.10	Trade tariffs % duty	34
6.12	Business impact of rules on FDI	32
1.21	Strength of investor protection - (best)	31
6.07	Time to start a business days	28
2.07	Quality of electricity supply	26
1.06	Judicial independence	25
2.09	Fixed-telephone lines / pop	24
8.06	Soundness of banks	24
1.03	Diversion of public funds	23
1.16	Reliability of police services	22
6.11	Prevalence of foreign ownership	22
1.01	Property rights	20
1.17	Ethical behavior of firms	19
9.05	Fixed-broadband Internet subscriptions / pop	19
6.04	Effect of taxation on incentives to invest	18
7.02	Flexibility of wage determination	18
8.07	Regulation of securities exchanges	18
1.07	Favoritism in decisions of government officials	17
1.04	Public trust in politicians	16
1.18	Strength of auditing and reporting standards	16
1.19	Efficacy of corporate boards	15
7.05	Effect of taxation on incentives to work	15
11.04	Nature of competitive advantage	15
1.02	Intellectual property protection	14
7.01	Cooperation in labor-employer relations	14
6.09	Prevalence of non-tariff barriers	13

Key to Pillars

Pillar	Description
1	Institutions
2	Infrastructure
3	Macroeconomic Environment
4	Health and Primary Education
5	Higher Education and Training
6	Goods Market Efficiency
7	Labor Market Efficiency
8	Financial Market Development
9	Technological Readiness
10	Market Size
11	Business Sophistication
12	Innovation

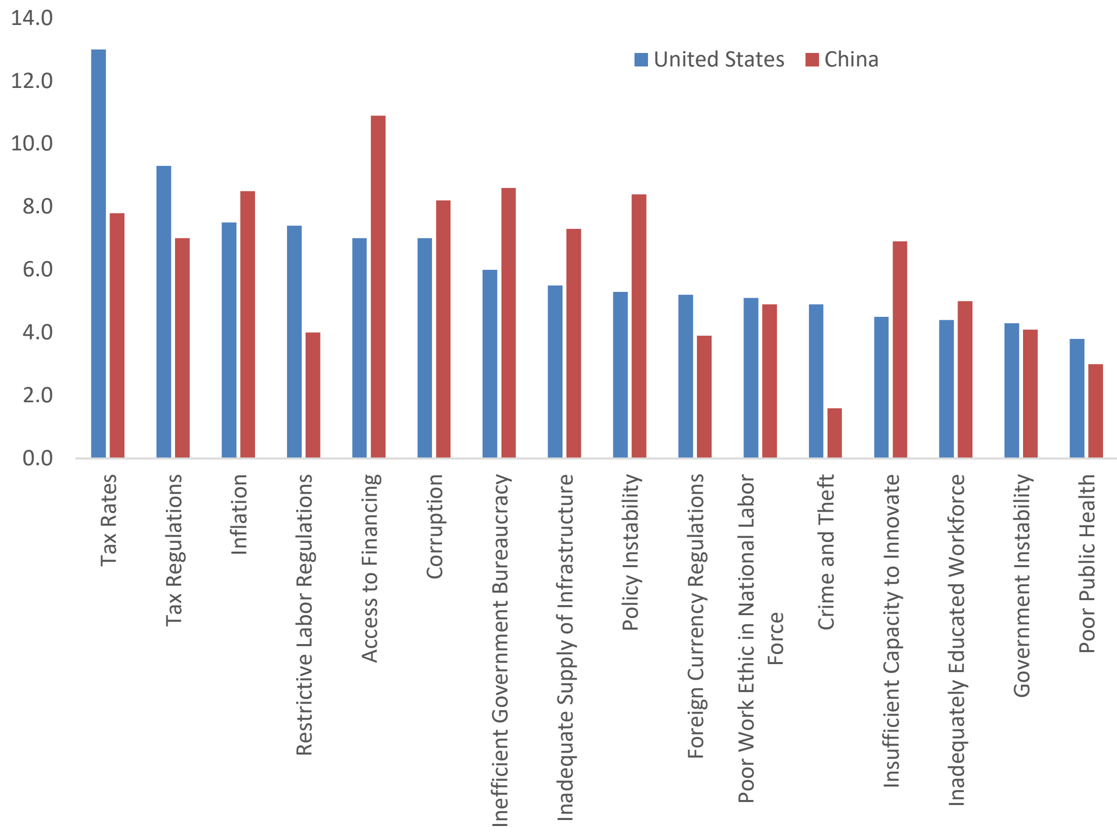
Table 5.5 (continued)

Pillar	Description	Rank
7.07	Reliance on professional management	13
1.09	Burden of government regulation	12
1.12	Transparency of government policymaking	12
4.09	Quality of primary education	11
9.07	Mobile-broadband subscriptions / pop	11
2.01	Quality of overall infrastructure	10
2.02	Quality of roads	10
2.03	Quality of railroad infrastructure	10
5.04	Quality of math and science education	10
5.06	Internet access in schools	10
5.07	Local availability of specialized training services	10
8.02	Affordability of financial services	10
12.07	PCT patents applications/million pop	10
2.04	Quality of port infrastructure	9
2.05	Quality of air transport infrastructure	9
5.02	Tertiary education enrollment rate gross %	9
11.07	Production process sophistication	9
1.10	Efficiency of legal framework in settling disputes	8
1.20	Protection of minority shareholders' interests	8
6.13	Burden of customs procedures	8
11.09	Willingness to delegate authority	8
6.15	Degree of customer orientation	7
1.11	Efficiency of legal framework in challenging regulations	6
5.05	Quality of management schools	6
6.01	Intensity of local competition	6
6.08	Agricultural policy costs	6
9.01	Availability of latest technologies	6
11.02	Local supplier quality	6
7.03	Hiring and firing practices	5
7.09	Country capacity to attract talent	5
9.03	FDI and technology transfer	5
12.02	Quality of scientific research institutions	5
3.05	Country credit rating - (best)	4
5.03	Quality of the education system	4
8.08	Legal rights index - (best)	4
11.05	Value chain breadth	4
1.08	Efficiency of government spending	3
4.03	Tuberculosis incidence cases/, pop	3
6.02	Extent of market dominance	3
6.03	Effectiveness of anti-monopoly policy	3
7.06	Pay and productivity	3
7.08	Country capacity to retain talent	3
11.01	Local supplier quantity	3
5.08	Extent of staff training	2
8.01	Availability of financial services	2
8.04	Ease of access to loans	2
9.02	Firm-level technology absorption	2
10.01	Domestic market size index	2

Table 5-5 (continued)

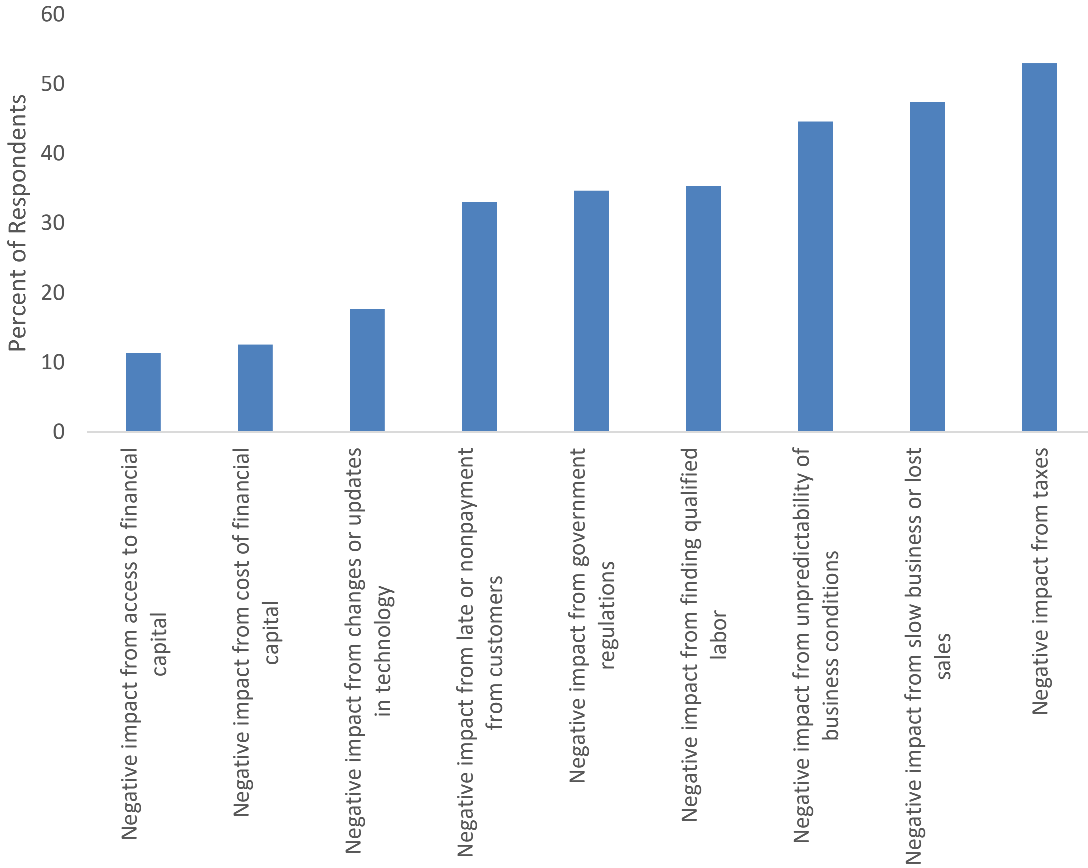
Pillar	Description	Rank
10.02	Foreign market size index	2
10.03	GDP (PPP) PPP $ billions	2
12.01	Capacity for innovation	2
12.03	Company spending on R&D	2
12.04	University-industry collaboration in R&D	2
12.05	Gov't procurement of advanced technology products	2
12.06	Availability of scientists and engineers	2
2.06	Available airline seat kilometers millions/week ,	1
3.03	Inflation annual % change	1
6.16	Buyer sophistication	1
7.04	Redundancy costs weeks of salary	1
8.03	Financing through local equity market	1
8.05	Venture capital availability	1
11.03	State of cluster development	1
11.06	Control of international distribution	1
11.08	Extent of marketing	1

Figure 5.5: Problematic Factors for Doing Business (16 total possible factors ranked): Higher Indicates a More Problematic Factor, 2017-2018



Note: From a list of 16 factors, respondents were asked to select the five most problematic factors and rank them from 1 to 5. The results are tabulated and weighted according to the ranking assigned by respondents.

Figure 5.6: Factors Impacting Business (Annual Survey of Entrepreneurs), 2016



6 Discussion

This report provides an overview of the US manufacturing industry. There are three aspects of US manufacturing that are considered: (1) how the US industry compares to other countries, (2) the trends in the domestic industry, and (3) the industry trends compared to those in other countries. The US remains a major manufacturing nation; however, other countries are rising rapidly. US manufacturing was significantly impacted by the previous recession and has only recently returned to pre-recession levels of production and still remains below pre-recession employment levels.

US compound real annual growth between 1991 and 2016 (i.e., 25-year growth) was 2.4 %, which places the US in the 51st percentile of all countries and is slower than the global average (3.3 %). The compound annual growth for the US between 2011 and 2016 (i.e., 5-year growth) was 1.0 %. This puts the US at the 34th percentile. US manufacturing value added, as measured in constant 2010 dollars, is the second largest behind that of China. In current dollars, the US produced $1.9 trillion in manufacturing valued added while China produced $3.0 trillion. Among the ten largest manufacturing countries, the US is the 4th largest manufacturing value added per capita. Out of all countries the US ranks 18th.

The US ranks high in categories of innovation, productivity, and in competitiveness indices. Although the US ranks high in productivity, multifactor productivity has declined in recent years.

The Annual Survey of Entrepreneurs identified that more than a third of firms indicated negative impacts in finding qualified labor, taxes, slow business or lost sales, nonpayment from customers, and unpredictability of business conditions. Approximately 17 % indicated negative impacts from changes or updates in technology.

High cost areas have a disproportional impact on productivity; thus, research in these areas have been shown to have a higher return on investment. Using BEA Input Output data on value added, wholesale trade, the management of companies and enterprises, and oil and gas extraction are a major supply chain cost for discrete high-tech manufacturing as a whole and among selected subsectors.

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