This is an author's version of the paper to be cited as
K. C. Morris and D. S. Thomas, "Measuring Manufacturing's Significance in the USA," Smart and Sustainable Manufacturing Systems 4, no. 3 (2020): 289–293.
https://doi.org/10.1520/ SSMS20200054

Measuring Manufacturing's Significance in the USA

KC. Morris[1] and Douglas S. Thomas[2]

ABSTRACT

Economic value added is a primary metric for measuring manufacturing activity; however, this metric and others exclude approximately half of the economic activity necessary for producing manufactured goods. With the recent disruption in the supply of goods and services by the COVID-19 pandemic, the criticality of these supply chains to production has become more apparent. Measuring and understanding these additional activities is foundational to reducing the effect of supply chain disruption. Additionally, manufacturing supply chains are fundamental to any response to the virus, including the production of masks, tests, and eventually a vaccine. When looked at closely, manufacturing stands out as a key driver of our economy. New manufacturing technologies can be leveraged to differentiate products in multiple ways resulting in a greater variety of products made more efficiently, with less environmental impacts, and higher quality. In addition, the digitization of manufacturing supports supply chains that are more connected, anticipatory, and agile. Metrics are needed that better reflect the role manufacturing plays in society, that better identify the social gains manufacturing produces, and that better establish the total economic activity that drives production. In this paper we propose a macro-economic metric to better measure the influence of manufacturing on our economy as an example of one such measure. We argue a need for solidifying similar radical changes to our current ways of measuring manufacturing's relevance and emphasizing the impact of new technologies that support the manufacturing economic sector.

Keywords: manufacturing metrics, input output analysis, economic impact, manufacturing impact, economics, value added

Introduction

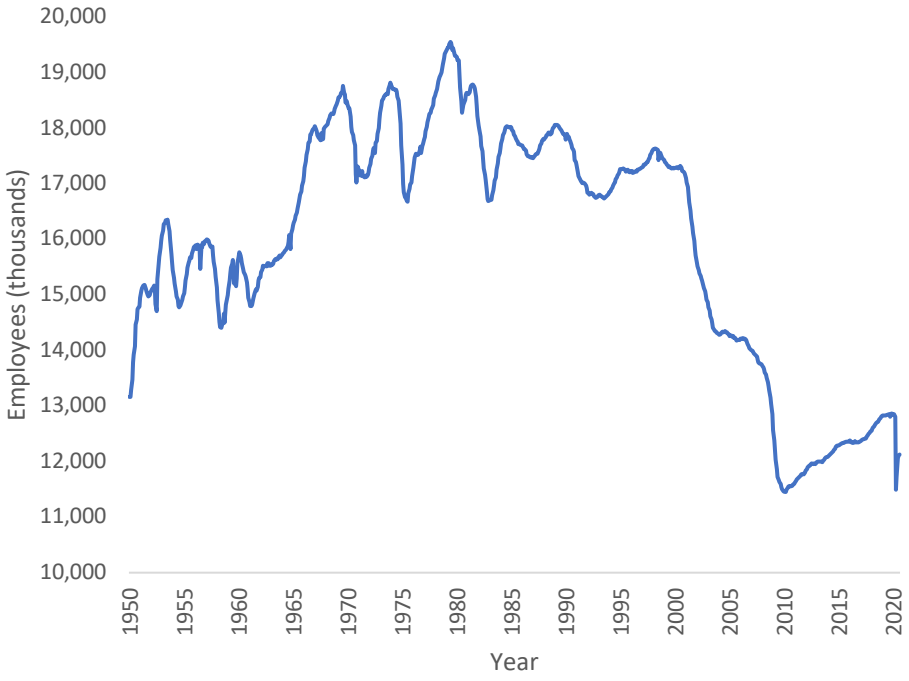
Over the last several decades American manufacturing has gone through tremendous upheaval and more is yet to come as technology and global economies evolve. In the past, value added (i.e., an industry's contribution to gross domestic product or GDP) or the number of manufacturing jobs has served as a good surrogate for manufacturing's contribution to our economy and society, but these numbers do not fully represent the industry's significance, as manufacturers purchase more and more goods and services from other industries. In recent years, some activities formerly included within manufacturing have been outsourced to non-manufacturing establishments. This transition can make manufacturing activity appear to be declining because these activities now fall under other industries.

[1] Systems Integration Division, National Institute of Standards and Technology, Gaithersburg, MD, 20899, USA
[2] Engineering Laboratory Office, National Institute of Standards and Technology, Gaithersburg, MD 20899, USA

Manufacturing's Significance

Our manufacturing workforce fell from a high of 19 million people in 1979 to a low of 11 million in 2010 with a steep decline starting in 2000, as shown in Figure 1.[1] In 2008 we saw a collapse in our automobile industry that led to a government bailout for large automobile manufacturers, the closing of plants, and a ripple throughout the supply chains. Off-shoring caused the collapse of whole communities dependent on manufacturing industries, like apparel and furniture, while severely diminishing others. In 2020 the COVID pandemic forced the shutdown of many factories across the country, and an unknown number may not reopen. Among those that will reopen, early reports indicate that more are embracing automation as a way of mitigating the risk against future disruptions. During the last decade, after years of decline, manufacturing employment was once again on the upswing pre-pandemic, but it is unclear where manufacturing employment numbers will stand post-pandemic with a trend to move more work outside of the factories.[2]

FIGURE 1: Manufacturing Industry Employment, Seasonally Adjusted [1]



On the other hand, the value that manufacturing adds to our nation's economy has continued to increase. In 2019, manufacturing contributed $2.4 trillion[3] to the American economy, the highest amount ever, and supported an estimated 12.8 million workers[1], about one out of every ten private-sector jobs. According to the Manufacturers Alliance for Productivity and Innovation (MAPI) Foundation the manufacturing sector generates about 3.4 other jobs throughout the economy for each manufacturing job[4]. In the manufacturing value chain, which includes both upstream and downstream activities, every $1.00 spent in manufacturing results in another $3.60

spent in other parts of the economy, and about one third of US jobs are part of this value chain.[4] Over the past 25 years, U.S.-manufactured goods exported have quadrupled. In 1990, for example, U.S. manufacturers exported $329.5 billion in goods. By 2000, that number had more than doubled to $708.0 billion.

Manufacturing's value cannot be measured by economics alone. In the midst of the COVID pandemic, the need for manufacturing to contribute, not only to our economic prosperity, but also to provide resources vital to our well-being has been strikingly clear. COVID has highlighted an insecurity in our manufacturing ecosystem that has been long brewing. The ability to produce goods in the US is necessary for our resiliency as a society.[5]

Similarly, the Research and Development (R&D) for developing new manufacturing ecosystems also need better metrics. Metrics for measuring the significance of manufacturing are the subject of discussion around the Manufacturing USA Program, a federal initiative to develop more robust industrial sectors.[6] The program addresses a gap in the nation's manufacturing ecosystem of moving newly developed technologies into production. The program's goal is to strengthen manufacturing capabilities in the US by creating communities of organizations, including supply chains, that will be prepared to develop and build new technologies of the future. These fledgling manufacturing ecosystems hold great hope for our future economy but are not yet realized by economic measures. Ultimately, we will look to see whether the program results in new jobs and greater prosperity but counting the number of manufacturing jobs created by technologies such as robotics and other forms of automation misses the ripple effects through the value chain.

It is increasingly clear that the traditional ways of measuring manufacturing's impact are inadequate at reflecting its significance. According to the Bureau of Labor Statistics "the Manufacturing sector comprises establishments engaged in the mechanical, physical, or chemical transformation of materials, substances, or components into new products." In earlier times that included many functions that are now procured by manufacturers as services and goods. Figure 2 illustrates some of the services and goods that manufacturers purchase from other industries. In recent years some purchases have grown faster than the industry itself. For instance, purchases of repair and maintenance along with professional and technical services has outpaced value added (see Figure 3), suggesting that these activities are increasingly outsourced from the manufacturing industry. Manufacturing has also seen increases in efficiency and productivity gains through advanced engineering and automation, a transformation that is not unlike the agricultural revolution that occurred when tractors replaced the horse and plow.

FIGURE 2: Manufacturing Value Added and Purchases [7]

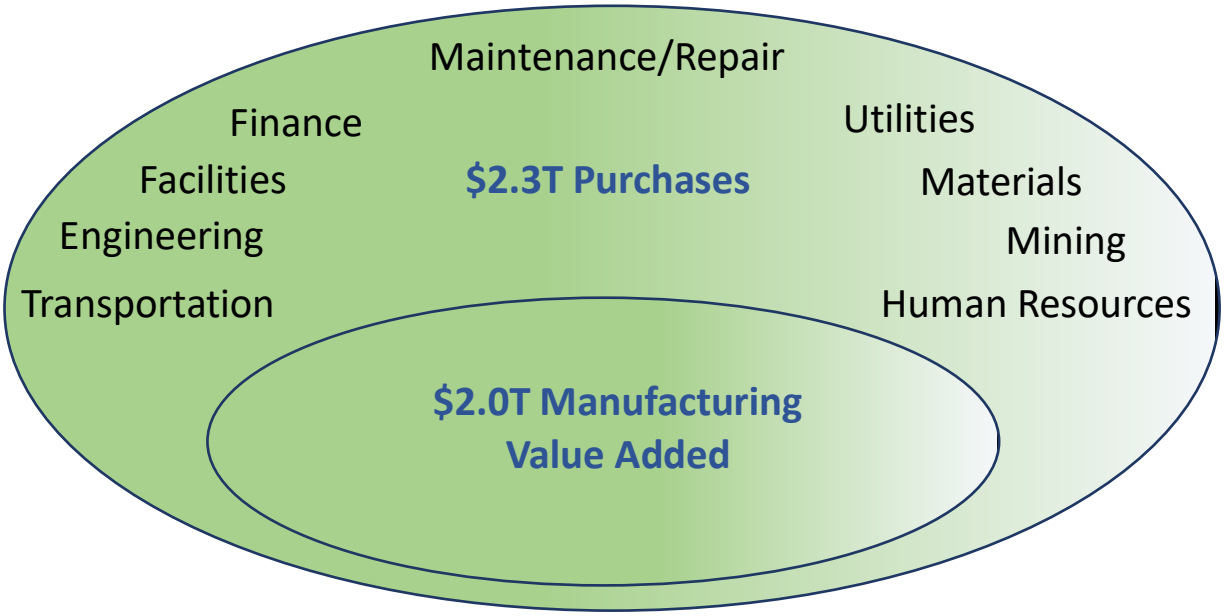
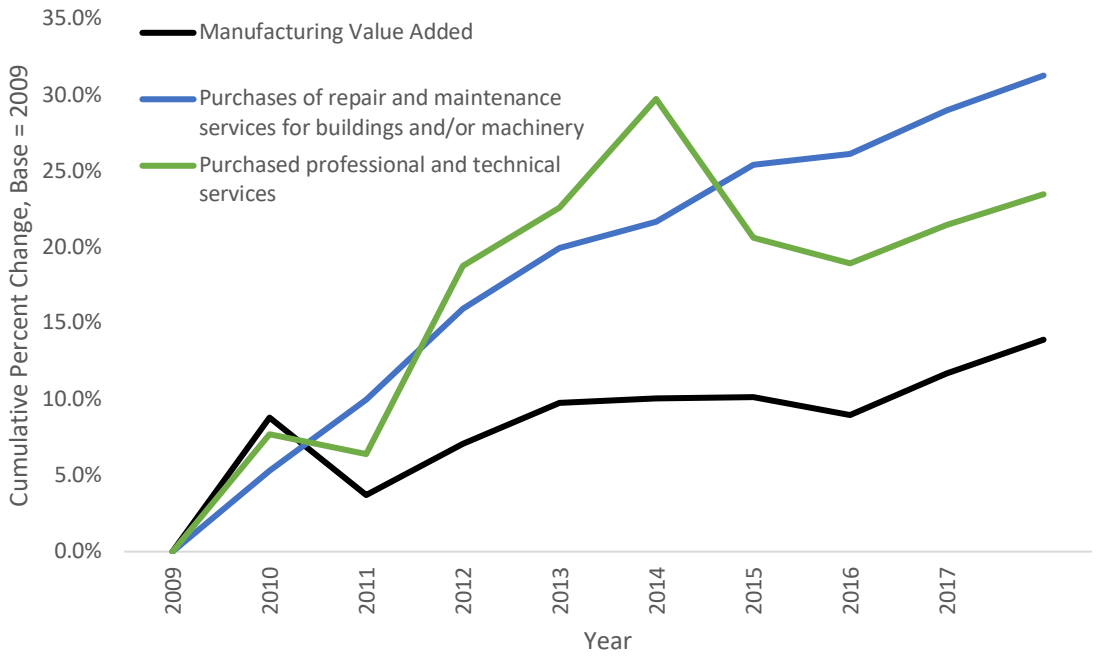


FIGURE 3: Cumulative Growth in Manufacturing Value Added and Manufacturing Industry Purchases [8]



Measuring Direct and Indirect Manufacturing Activity

As the manufacturing landscape evolves with a decrease of in-factory jobs and more reliance on other sectors, metrics more reflective of manufacturing's contributions are needed. One approach is to incorporate purchases that manufacturers make from other industries. This approach would subsume a greater extent of the manufacturing value chain than is reflected in current metrics.

Economic Input-output analysis, including its derivatives, is a prominent method for examining inter-industry relationships and economic impacts. Typically, this method is used to estimate the impact of a change in demand for a good or service. It utilizes a dataset that presents inter-industry purchases, that is the purchases that each industry makes from other industries. The method develops a total requirements matrix that when multiplied by a vector of final demands equals the output needed for production [9,10]. This method could be used to estimate all of the upstream goods and services needed for the production of final goods in the U.S. It can also be used to estimate the same for subsectors of manufacturing. Value added is calculated by assuming the proportion of output needed to produce a commodity is the same proportion of value added, which is consistent with methods proposed by Miller.[10] The proportions calculated using the input-output analysis are then multiplied by value added.

This method has been implemented in NIST's Manufacturing Cost Guide[7], a tool for estimating manufacturing industry costs. Using this tool, 2019 U.S. manufacturing value added, including purchases from other industries, was $4.3 trillion or 20% of the nation's GDP for that year (see Figure 2). For context, recall the estimate above for manufacturing value added, excluding purchases from other industries, was $2.4 trillion.[3]

Summary

The metric proposed here is one that may better represent the importance of manufacturing in our economy. It highlights the interrelation of supply chains and is a critical step in reducing the effect of supply chain disruption. The more items that are upstream in a production process, the more risk there is to supply chain disruption. The 2020 pandemic has illustrated the effect that a disruption in supplies can cause. The estimate from the Manufacturing Cost Guide suggests that the upstream value added is as large as the manufacturing industry itself. Input-output analysis identifies the industry origins of the upstream activity and can be used to identify what types of hazards pose a risk to the upstream supply chain. IO analysis reveals the importance of manufacturing to the U.S. economy and why resilience in the supply chain is important.

Certainly other metrics exist. A number of different approaches estimate the impact of manufacturing. Some include downstream industries (e.g., retailers) and others simulate an economy. Some methods are more applicable to understanding supply chains than others.

Similarly, more fine-grain metrics will be needed to track progress along the way as future factories will be very different from the past. For instance, recent reports indicate that manufacturers may adopt more automation as a result of the pandemic. We need metrics to reflect the R&D end of the manufacturing supply chain as future manufacturing systems must become more nimble to respond to disruptions. The 2019 workshop hosted by the National Academy of Sciences to review the Manufacturing USA Program[6] brought attention to metrics to evaluate

programs to develop new manufacturing capabilities. These types of metrics also will be critical for moving through the transition that manufacturing has entered into.

Ultimately, a strong US manufacturing sector will be judged by the strength of the nation's security and prosperity. Movement in well-being will be apparent at the macro-level using various types of indicators such as this one. A standard method will bring more stability to these metrics, better represent the activities in a consistent way, and, applied over time, will highlight our collective progress. The lack of new standard methods can lead to misunderstandings of the changes manufacturing is going through and misleading comparisons and conclusions within and about the industry.

References

1. Bureau of Labor Statistics, Current Employment Statistics. https://www.bls.gov/ces/data/

2. M. Levinson, Job Creation in the Manufacturing Revival. Congressional Research Service, p. 24. (2018). https://crsreports.congress.gov/product/pdf/R/R41898/25. https://web.archive.org/web/20200828223335/https://crsreports.congress.gov/product/pdf/R/R41898

3. Bureau of Economic Analysis, GDP by Industry. https://apps.bea.gov/iTable/index_industry_gdpIndy.cfm. https://web.archive.org/web/20200801221529/https://apps.bea.gov/iTable/index_industry_gdpIndy.cfm

4. D. J. Meckstroth, "The Manufacturing Value Chain Is Much Bigger Than You Think!", *Manufacturers Alliance for Productivity and Innovation (MAPI) Foundation*, (September 2016). https://static1.squarespace.com/static/58862301f7e0ab813935c244/t/58c05a2f6a4963ad69ed3734/1489001008 886/PA-165_web_0.pdf https://web.archive.org/web/20200828223631/https://static1.squarespace.com/static/58862301f7e0ab813935c244/t/58c05a2f6a4963ad69ed3734/1489001008%20886/PA-165_web_0.pdf

5. G.P. Pisano and W. Shih, *Producing Prosperity: Why America Needs a Manufacturing Renaissance*. Harvard Business Review Press. (2012). https://web.archive.org/web/20200828223935/https://www.hbs.edu/faculty/Pages/item.aspx?num=43068

6. Innovation Policy Forum, Revisiting the Manufacturing USA Institutes: Proceedings of a Workshop. National Academies Press. doi: 10.17226/25420. (2019).

7. National Institute of Standards and Technology, Manufacturing Cost Guide. (2020). https://doi.org/10.6028/NIST.AMS.200-9 https://web.archive.org/web/20200828224105/https://www.nist.gov/services-resources/software/manufacturing-cost-guide

8. U.S. Census Bureau, Annual Survey of Manufactures. (2020).

https://web.archive.org/web/20200828224221/https://www.census.gov/programs-surveys/asm/data/tables.html

9. K. J. Horowitz and M. A. Planting "Concepts and Methods of the U.S. Input-Output Accounts." (2009). https://web.archive.org/web/20200828224359/https://www.bea.gov/resources/methodologies/concepts-methods-io-accounts

10. R. E. Miller and P. D. Blair, *Input-Output Analysis: Foundations and Extensions*. (New York, NY: Cambridge University Press): 16. (2009).