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The Value of U.S. Service Employment in Manufacturing Sectors

Sarah Oliver

Abstract

Using data on service occupations in U.S. manufacturing sectors in 2016, this paper seeks to highlight the value of in-house services in U.S. manufacturing output, by assessing the relationship between the share of services occupations in a particular sector (services occupation intensity) and typical education and compensation in service occupations. Overall, this paper finds a positive and significant relationship between services intensity and the typical education level of service workers within sectors, and a positive and significant relationship between service intensity and the average compensation of service occupations across sectors. For U.S. manufacturing sectors, these in-house services represented between $8.7 and $17.5 billion in additional services value added in 2016 compared to $56.8 billion for intermediate services inputs in the same year.

Keywords: Services, global value chains, labor, manufacturing.

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Introduction

In the global value chain (GVC) framework outlined by Jones, Demirkaya, and Bethmann (2019), the contribution of services to the total value of a final good is less straightforward to measure than the contribution of intermediate goods. It is true that resources like the Trade in Value Added (TiVA) database of the OECD, or the input-output tables of the U.S. Department of Commerce Bureau of Economic Analysis (BEA) include the contribution of intermediate services added along the global supply chain. However, they do not take into account the value of in-house services embedded in a particular good.

This paper has two goals. First, it aims to illuminate some of the characteristics of services employment across individual manufacturing sectors that could indicate the relative value associated with in-house provision of services in U.S. manufacturing. For instance, manufacturing sectors with higher shares of their employees in services occupations could have a larger proportion of higher-value-added services in the goods that they export. Analyzing typical education level by service occupation helps demonstrate the value associated with in-house services: occupations that tend to employ individuals with post-secondary education are likely to contribute higher-value-added services to good exports. Finally, some manufacturing sectors may have more productive service employees than other sectors, leading to higher-value-added of in-house services provision. Average compensation within services occupations across particular manufacturing sectors can illuminate these productivity differences across manufacturing sectors.

The second goal of the paper is to compare the contribution of in-house services employment in manufacturing to intermediate services inputs across manufacturing sectors. This comparison helps to understand the relative importance of in-house versus intermediate services inputs for different types of manufacturing, and provides insight into how much services activity is not captured in standard calculations of trade in value added.

Using occupation-level data, this paper finds that in the United States in 2016, on average 31 percent of employees in manufacturing sectors are in service occupations. However, there is considerable variation in the share of service sector workers across manufacturing sectors, ranging between 10 to 80 percent of total employment. There is also a positive and significant relationship between the share of service occupations in a particular manufacturing sector and the share of service workers with at least a bachelor's degree: service-intensive manufacturing sectors tend to comprise service occupations that typically require higher levels of education than less service-intensive manufacturing sectors. This finding suggests that more service-intensive industries could also contribute higher-value-added services to the manufactured goods they produce, because of the typical skill level of their service employees. Additionally, across all types of service occupations in manufacturing, an increase in the share of service employees in a sector leads to higher average wages for employees in a particular occupation, relative to employees in the same occupation in other manufacturing sectors. This indicates that more service-intensive manufacturing sectors may also have more productive service employees than less service-intensive sectors.

In 2016, the average value of intermediate services inputs across the 15 U.S. manufacturing sectors with intermediate input data available was $56.8 billion. Using the average wage rate and number of employees by occupation to measure the total value of in house services yielded an additional total value ranging between $8.7 billion and $17.5 billion on average. This implies that in 2016, 18 to 28 percent of total value added of both in-house and intermediate services inputs was not captured in input output tables for U.S. manufacturing.

The remainder of this paper is divided into five sections. The first section describes previous literature related to the composition of service occupations in manufacturing. The second section describes the data used, and the third section describes the methodology used for this analysis. The fourth section describes results and the fifth section presents conclusions about the usefulness of employment data to measure services in-house contribution to manufactured goods.

Literature Review

Previous work on the contribution of services to manufacturing has considered several issues addressed in this paper: the characteristics of service occupations in the manufacturing sector and their overall contribution to productivity, the role of services in global value chains, and the role of in-house services in manufacturing. To understand the literature surrounding service sector contributions to manufacturing, it is first important to understand the distinction between intermediate services, which typically appear in global value chain calculations, and in-house services, which typically do not. For example, if a manufacturing firm hires an outside firm to help design a new product, the value of those research and development services are captured in calculations of intermediate service inputs. However, if a manufacturing firm has research and development teams on staff, the value of that in-house service does not appear in GVC statistics.[1]

There is likely a difference between the types of services embedded in manufacturing that are purchased from an outside provider (intermediate services) and those provided in-house. Cusumano, Kahl, and Suarez (2015) suggest three types of services that manufacturing firms may offer along with their products: “smoothing services,” which make it easier for customers to access technical support or finance purchases and are standardized across customers; “adaptive services,” which add features to a particular product in order to customize it for a specific user; and “substitute services,” where customer purchases a service instead of a product.[2] Of these three types of services, the authors note that “adaptive services” require the most technical knowledge of the products themselves and thus are more likely to be provided in-house than the other types of services. Miroudot and Cadestin (2017a) find that across OECD countries, the four service types most often bundled with manufactured goods are wholesale and retail, construction, maintenance and repair, and engineering and other technical services.[3]

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[1] Miroudot and Cadestin, “Services in Global Value Chains: From Inputs to Value-Creating Activities,” 2017, 9.

[2] One example of a substitute service is when a customer purchases cloud based software in place of a physical copy of that software. Cusumano, Kahl, and Suarez, “Services, Industry Evolution, and the Competitive Strategies of Product Firms,” 2015.

[3] Miroudot, and Cadestin, “Services In Global Value Chains: From Inputs to Value-Creating Activities,” 2017.

Previous work also suggests that more service-intensive manufacturing sectors tend to be more productive. USITC (2013) finds a positive correlation between the use of business services in manufacturing and productivity.[4] Arnold, Javorcik, and Matoo (2011), using a panel of Czech firm-level data from 1998 to 2003, find a positive relationship between service sector liberalization and the productivity of manufacturing firms that use service inputs. Greater availability of services may allow manufacturing firms to implement "productivity-enhancing" changes in their operations, such as an e-commerce platform. The authors find that increased foreign presence is a mechanism for this productivity increase, and that a one-standard-deviation increase in foreign services firms is associated with almost an 8 percent increase in the productivity of services-intensive manufacturing firms.[5] Arnold et al. (2016) find a similar relationship between service sector liberalization and manufacturing firm productivity in India.[6] Miroudot and Cadestin (2017b), using data on trade in value added, find a positive correlation between services specialization and productivity growth in global value chains.[7]

Several papers in the literature describe how intermediate services also contribute to the total value-added of final manufacturing goods. Low (2013) reports that in 2008, 45 percent of value-added in global value chains can be attributed to services, but notes that this does not capture the value of in-house services, which are likely captured in the value of goods.[8] Using the TiVA database, Miroudot and Cadestin (2017a) find that in 2011, almost half of the value-added in world gross exports is captured by the service sector intermediate inputs.[9] Francois, Manchin, and Tomberger (2013) combine data in the TiVA database with trade data from the Global Trade Analysis Project (GTAP) database to compare value added in services across countries and sectors. The authors find that in the United States in 2007, commercial services exports accounted for more than 20 percent of value-added in U.S. manufactured goods exports.[10] However, as the TiVA database is limited in that it captures only intermediate services, this estimate does not account for the contribution of in-house services to manufactured goods.

Finally, some previous work has specifically considered the role of in-house services in manufacturing. Lodefalk (2014), using seven years of Swedish firm-level data, finds a positive and significant relationship between in-house services in manufacturing firms and export intensity, measured as exports divided by sales.[11] Lodefalk notes that many of the information barriers to trade (i.e., legal requirements, language barriers) can be mitigated through services. Mirodot and Cadestin (2017a), using wage data for OECD member countries, estimate that in-

[4] USITC, "The Role of Services in Manufacturing," December 2013.
[5] Arnold, Javorcik, and Mattoo, "Does Services Liberalization Benefit Manufacturing Firms?" 2011.
[6] Arnold et al., "Services Reform and Manufacturing Performance" 2016.
[7] Miroudot and Cadestin, "Services In Global Value Chains: Trade Patterns and Gains from Specialization," November 2017.
[8] Low, "The Role of Services in Global Value Chains," June 2013.
[9] Miroudot and Cadestin, "Services in Global Value Chains: From Inputs to Value-Creating Activities," 2017.
[10] Francois, Manchin, and Tomberger. "Services Linkages and the Value Added Content of Trade," May 2013.
[11] Lodefalk, "The Role of Services for Manufacturing Firm Exports," 2014.

house services contribute 10 to 20 percent of value added in manufacturing exports in 2011.[12] Nordås (2019) finds that domestic outsourcing of services tasks replaces, rather than supports, in-house services, and that transport and other business functions are the most sensitive to this domestic outsourcing.[13]

This article is most closely related to Miroudot and Cadestin (2017a) in that it uses wage data to estimate the total value of in-house services, but focuses specifically on the U.S. manufacturing sector at a more detailed level. By focusing on in-house services in one specific country, this paper is able to highlight differences across in-house services at both the sector and occupation level. It also identifies specific characteristics of U.S. manufacturing sectors that contribute to the relative value of in-house services compared to the value of intermediate inputs.

Data

In order to understand the value that employees in service occupations contribute to manufacturing, this paper looks at a cross-section of sector-level employment by occupation from the U.S. Bureau of Labor Statistics (BLS). This cross-section provides an indication of the services-intensive manufacturing sectors in 2016 and includes 72 sectors with both export and service occupation data.

Data on occupation by manufacturing sector comes from the BLS Occupational Employment Projections for 2016.[14] This dataset provides employment information at the North American Industry Classification System (NAICS) 4-digit level by standard occupation classification (SOC) code. Since this analysis focuses on services occupations in manufacturing, data for NAICS codes 3100–3399 are used. BLS high-level aggregation groups are used to separate service occupations from other occupations in the manufacturing sector. For this paper, SOC codes 11–29 (Management, Business, Science, and Arts Occupations), and 31–39 (Service Occupations), and 41–43 (Sales and Office Occupations) are all considered services.[15] The service share of employment is calculated by dividing the sum of the total number of employees in these SOC codes (by sector) by the total number of employees in that sector in 2016.

The Occupational Employment Projection data also include a variable on "typical education" by occupation, which is used as a proxy for the relative skill level of employees in specific service occupations. Although education is not necessarily indicative of a particular individual's skill level, education and experience tend to be used together in economic literature to measure the skill of workers.[16] Since occupation-level data does not include information on job tenure, this

[12] Miroudot and Cadestin, "Services in Global Value Chains: From Inputs to Value-Creating Activities," 2017

[13] Nordås, "Offshoring of Services Functions," 2019.

[14] BLS, "Table 1.2: Employment by Detailed Occupation, 2016 and Projected 2026," and "Table 1.9: 2016-26 Industry-occupation Matrix Data, by Industry," Occupational Employment Projections, 2017.

[15] This analysis focuses on highly aggregated groups that contain only service occupations. However, this is likely underestimating the contribution of services occupations to manufacturing sectors, as codes 45–49 (Natural Resources, Construction, and Maintenance Occupations) and 51–53 (Production, Transportation, and Material Moving Occupations) also include some service occupations. BLS, "2010 SOC User Guide," February 2010, 19.

[16] See, for example, Mincer, "The Distribution of Labor Incomes," 1970.

paper cannot take experience levels of workers into account. Thus, only education is used in this analysis. Employees are divided into two educational categories: employees that typically have at least a bachelor's degree (54.5 percent of total service employment), and those that have less than a bachelor's degree (45.5 percent of total service employment), as presented in table 1. While the majority of individuals in service occupation in manufacturing sectors in the sample have either high school diplomas or bachelor's degrees, educational attainment in service occupations range from no formal education credential through doctoral or professional degrees.

Table 1: Education categories for service occupations, and total employment in the manufacturing sector, 2016.

Typical education category	**Total service occupation employment** (1,000 employees, NAICS codes 3100–3399)
No bachelor's degree	**1,697.4**
No formal education credential required	176.1
High school diploma or equivalent	1,140.0
Associate degree; postsecondary non-degree award; some college, no degree	381.3
Bachelor's degree or higher	**2,034.8**
Bachelor's degree	2,013.9
Master's degree	5
Doctoral or professional degree	15.9

Source: Author's classifications using data from BLS, "Table 1.2: Employment by Detailed Occupation, 2016 and Projected 2026," and "Table 1.9: 2016-26 Industry-occupation Matrix Data, by Industry," Occupational Employment Projections, 2017.

A second dataset from BLS, the National Industry-Specific Occupational Employment and Wage Estimates, provides average annual wage estimates for May 2016 by occupation (SOC code) and by sector (2012 NAICS 4-digit codes).[17] Unlike the education data, which cover all employees in an occupation regardless of sector, this data can be used to compare wage differentials within a particular occupation across sectors. For example, in May 2016, average wages for accountants and auditors in the manufacturing sectors ranged from $63,110 to $92,110. These data are useful as a proxy for sector productivity, as higher wages could indicate more efficient employees and potentially reflect the inherent value that manufacturing sectors place on the services embedded in their goods.

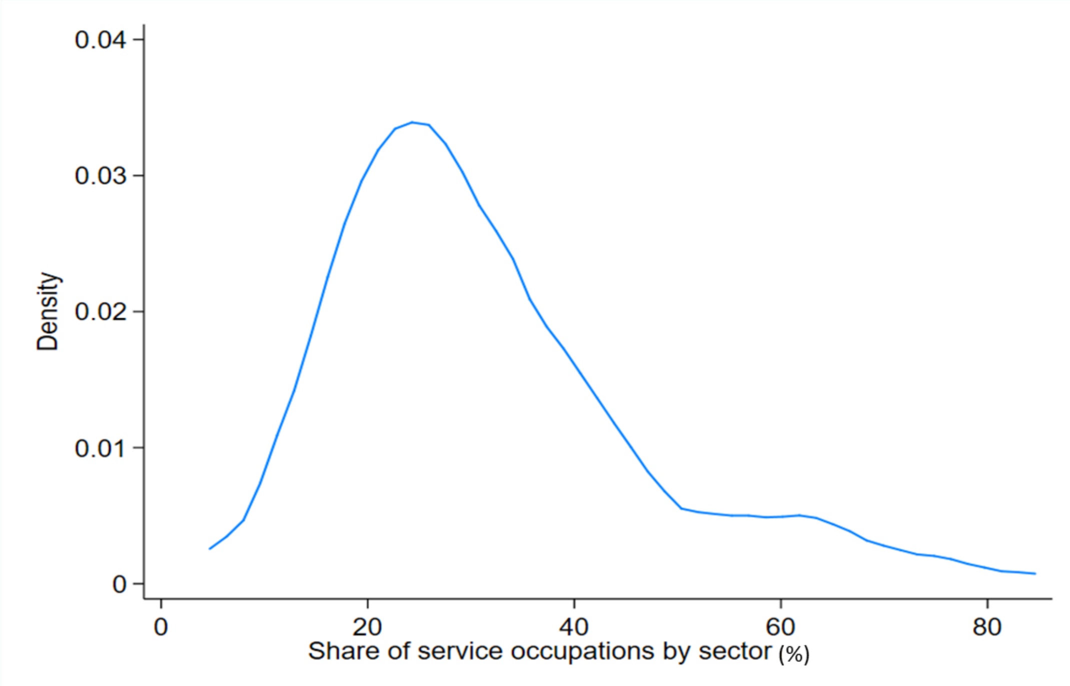
An intuitive way to understand the value of services embedded into manufactured goods is to look at the share of employees in service occupations in a particular manufacturing sector. While these data cannot definitively measure the contribution of these services to final and intermediate goods produced in a sector, sectors with higher shares of employees in service occupations (service-intensive manufacturing sectors) likely contribute more in-house value added to final and intermediate goods than sectors with lower shares of service employees.

Figure 1 shows the distribution of the share of service occupations, weighted by the number of employees per occupation, across manufacturing sectors in the U.S. economy in 2016. The

[17] BLS "May 2016 National Industry-Specific Occupational Employment and Wage Estimates," 2016.

majority of U.S. manufacturing sectors have less than 50 percent of their total workers in service occupations. However, in a few manufacturing sectors, particularly those that fall into the category of "Computer and Electronic Product Manufacturing" (NAICS code 334), the majority of workers are in services occupations.

Figure 1: Distribution of service occupation share in manufacturing sectors, United States, 2016



Source: Author's calculations using data from BLS, "Table 1.2: Employment by Detailed Occupation, 2016 and Projected 2026," and "Table 1.9: 2016-26 Industry-occupation Matrix Data, by Industry," Occupational Employment Projections, 2017.

Note: share of service occupations is the sum of all service sector employees.

Finally, this paper uses the BEA's input-output accounts use tables to measure the contribution of intermediate service inputs to different manufacturing sectors in 2016. For consistency across years, this paper uses the more aggregated annual data, rather than the detailed industry data last published for 2012.[18] For this analysis, the employment data for the 72 4-digit NAICS sectors presented above is aggregated (in most cases) to the 3-digit NAICS level. Both automobile manufacturing (NAICS 3361) and aerospace manufacturing (3364) are presented at the 4-digit NAICS level and therefore are not aggregated. This aggregation yields 15 manufacturing sectors where total services employment can be compared to total intermediate inputs of services. In the input-output data, services sector inputs are all inputs that fall under 2-digit NAICS codes 42 through 81 (excludes government services).

Table 2 summarizes the variables described above, including their source, sector coverage, and average value for 2016.

[18] BEA, "Use of Commodities by Industry," 2017.

Table 2: Summary of variables

Variable	Data Source	Sector Coverage	Average value, 2016
Service occupation share	BLS Occupational Employment Projections	72 4-digit NAICS	31.4%
Service employment bachelor's degree share	BLS Occupational Employment Projections	72 4-digit NAICS	48.7%
Services annual mean wage	BLS Occupational Employment and Wage Statistics	72 4-digit NAICS	$59,901
Intermediate services inputs	BEA Input Output Tables	15 3-digit NAICS	$56.8 billion
In-house services inputs	BLS Occupational Employment Projections and BLS Occupational Employment and Wage Statistics	15 3-digit NAICS	$8.7–$17.5 billion

Source: Author's calculations using data from BLS, "Table 1.2: Employment by Detailed Occupation, 2016 and Projected 2026," and "Table 1.9: 2016-26 Industry-occupation Matrix Data, by Industry," Occupational Employment Projections, 2017; BLS "May 2016 National Industry-Specific Occupational Employment and Wage Estimates." 2016; BEA, "Use of Commodities by Industry," 2017.

Methodology

This paper uses a series of simple linear regressions to analyze the relationship between the service occupation share in manufacturing sectors and the skill level and wages of service workers. The goal of these regressions is to assess whether the skill level of service workers and service worker wages depend on the overall share of services employment in a particular manufacturing sector.

To understand the relationship between the service intensity of a manufacturing sector and the value of the services provided in that sector, the first linear regression considers the typical education of employees in particular service occupations. Equation 1, presented below, uses the share of service sector workers with at least a bachelor's degree as the dependent variable.

$$ServiceEmployeesBachelorsDegreee2016_{i} = \beta_1 + \beta_2 ServiceOccupationShare2016_{i} + \varepsilon_i \quad (1)$$

ServiceEmployeesBachelorsDegree2016 represents the share of all service employees in a NAICS 4-digit sector that are in occupations that typically require a bachelor's degree or higher. *ServiceOccupationShare2016* represents the share of employees in service occupations by manufacturing sector, and ε_i represents the error term.

The second regression focuses on differences in wages within particular services occupation across manufacturing sectors. Manufacturing sectors that embed many high value services in their products may hope to attract the most productive workers through higher compensation relative to other sectors. Differences in compensation within service occupations could therefore indicate a relationship between service intensity and productivity, in line with the findings of USITC (2013) and Arnold, Javorcik and Matoo (2011).[19]

To test this relationship, equation 2 presents the linear regression used to assess the relationship between services intensity and wages within a sector.

$$ServicesAnnualMeanWage2016_{io} = \beta_1 + \beta_2 ServiceOccupationShare2016_{i} + \gamma_o + \varepsilon_i \tag{2}$$

ServicesAnnualMeanWage2016 represents the average wage by sector and occupation, while *ServicesOccupationShare2016* represents the share of services occupations by sector. This regression includes occupation fixed effects, γ_o, which control for unobserved characteristics that are specific to a particular occupation. Finally, ε_i represents an error term, which is clustered at the sector level to avoid misspecification of standard errors.[20]

In the results section, since equation 1 is a bivariate regression, results are presented in the main text graphically, as the slope and intercept of the linear trend line (full results are presented in the appendix). Because of the inclusion of fixed effects in equation 2, results for that regression are not presented graphically.

The second part of this analysis, comparing the value of in-house services to intermediate services in manufacturing, estimates the value of in-house services by multiplying the number of employees in an occupation and sector by their average wage in that occupation and sector. These values are then summed to get totals for all services occupations within the 3-digit NAICS manufacturing sectors available for intermediate services inputs in the BEA's input-output table for 2016. One drawback of this approach is that the BLS data used in this analysis uses number of employees, rather than full-time equivalent employees.[21] This means that total employment multiplied by average wages likely overestimates the contribution of in-house services because it does not take into account the share of less than full time employees present in the data. To mitigate this overestimation, the contribution of in-house services is presented as a range, in which the highest value assumes that all services employees are full-time workers, while the lowest value assumes all services employees are part-time workers and thus are capturing half of the average salary presented in the data.

[19] USITC, "The Role of Services in Manufacturing," December 2013; Arnold, Javorcik, and Mattoo, "Does Services Liberalization Benefit Manufacturing Firms?" 2011.

[20] See Moulton (1990) for an explanation of the issue of misspecified standard errors, and Wooldridge (2003) for an explanation of the correction used in this analysis.

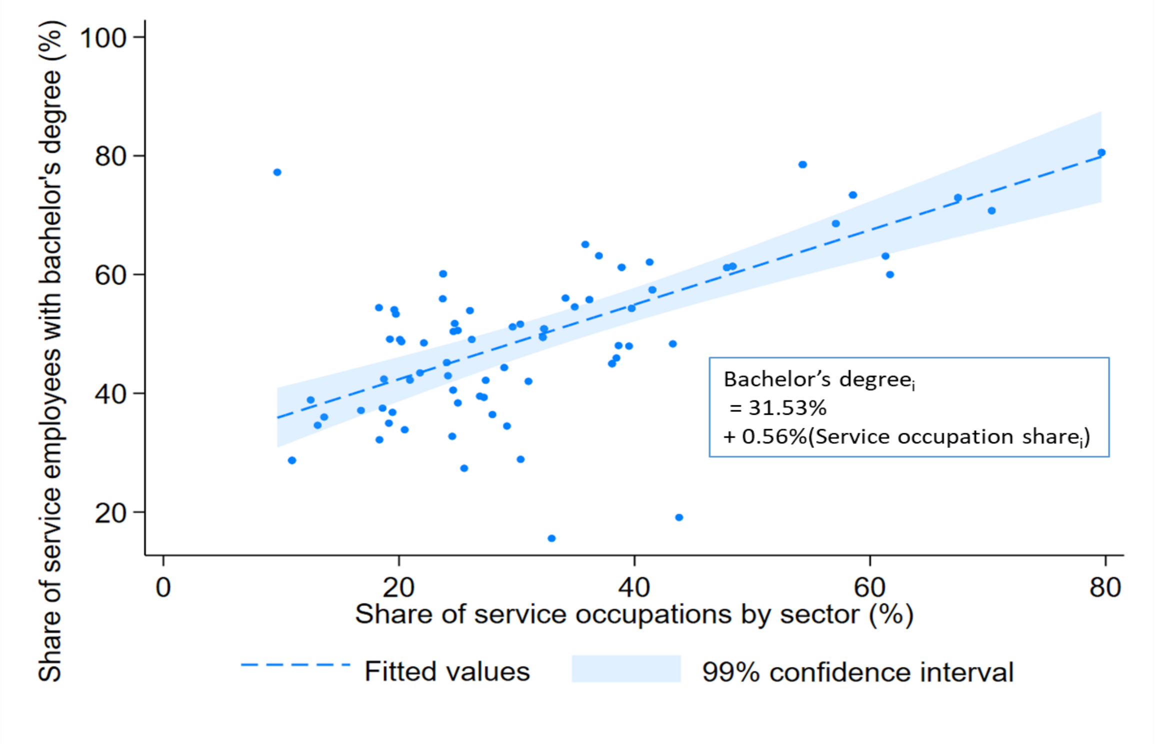
[21] The BLS Occupational Employment Statistics, used for average wage data, defines employees as "all part-time and full-time workers who are paid a wage or salary. The survey does not cover the self-employed, owners and partners in unincorporated firms, household workers, or unpaid family workers." The BLS Employment projection data, used for the number of employees per occupation, does include self-employed workers. BLS, "Occupational Employment Statistics: Frequently Asked Questions," https://www.bls.gov/oes/oes_ques.htm (Accessed August 21, 2019); BLS, "Employment Projections Methodology," https://www.bls.gov/emp/documentation/projections-methods.htm#industry_employment (Accessed August 21, 2019).

Results

Characteristics of service employees in U.S. manufacturing sectors, 2016

In U.S. manufacturing sectors in 2016, there was a positive and significant relationship between the service occupations' share in manufacturing and the share of service employees in manufacturing sectors with at least a bachelor's degree. Figure 2 compares the fitted regression line (and 99 percent confidence intervals) of this relationship as calculated in equation 1. The regression results indicate that a 1 percent increase in the share of service occupations by sector is associated with a 0.56 percent increase in the share of service employees with at least a bachelor's degree. This result is significant for $p<0.01$ with 99 percent confidence.

Figure 2: Service occupations versus service employee education, U.S. manufacturing, 2016



Source: Author's calculations using data from BLS, "Table 1.2: Employment by Detailed Occupation, 2016 and Projected 2026," and "Table 1.9: 2016-26 Industry-occupation Matrix Data, by Industry," Occupational Employment Projections, 2017.

Note: For regression results associated with the linear trend line, see appendix table A.1.

The need for highly specialized services employees in some manufacturing sectors can help explain this relationship, particularly in manufacturing sectors with a high share of services occupations. For example, in pharmaceutical manufacturing, firms require individuals with advanced degrees in chemistry and biology to develop their products. In figure 2, all of the manufacturing sectors where more than 50 percent of employment is in services occupations reflect this need for specialized services. The services occupations with the highest employment levels in these service-intensive manufacturing sectors are either computer and mathematical occupations, architecture and engineering occupations, or life, physical, and social science occupations. In contrast, manufacturing sectors below this threshold tend to have a similar services compositions: the two largest groups of service occupations below the 50 percent threshold are office and administrative support occupations and management occupations, both of which are characterized by a non-sector-specific skill set, but can require bachelor's degrees or higher to perform. This suggests that although specialized occupations may be explaining some of the trend seen in figure 2, there may also be a broader relationship between increased services employment and service employee education.

Another way to look at the relationship between service occupations and the contribution of services to manufacturing output is to consider the difference in wages across service-intensive and non-service-intensive sectors. Table 2 presents the results of equation 2. Overall, there is a positive and significant relationship between the share of service occupations in a sector and the mean annual wage across sectors: holding occupation specific variation constant, a 1 percentage point increase in the service occupation share leads to a $347.70 increase in the mean annual wage. Since the average marginal wage of service workers increases as the sector becomes more service-intensive, this result could indicate that the most service-intensive manufacturing sectors also attract the most productive services workers, regardless of occupation.

Controlling for occupation-specific determinants of wages in this analysis helps to mitigate the variation in types of service occupations across sectors. In the regression presented in figure 2, variation in the share of service employees with bachelor's degrees is at least partially explained by the types of service jobs required for different types of manufacturing output. However, by controlling for occupation specific characteristics across manufacturing sectors, the wage premium found in table 3 reflects differences in wages within the same category of occupation, and therefore indicates that employees in a particular service occupation in a services-intensive sector, such as accountants, have higher average wages than accountants in less service-intensive sectors.

Table 3: Regression results

Variables	**Mean annual wage** ($)
Service occupation share	343.7***
	[28.93]
Constant	195,844.5***
	[2327.9]
Observations	4713
R-Squared	0.948

Source: Authors calculations using data from BLS, "Table 1.2: Employment by Detailed Occupation, 2016 and Projected 2026," and "Table 1.9: 2016-26 Industry-occupation Matrix Data, by Industry," Occupational Employment Projections, 2017; BLS "May 2016 National Industry-Specific Occupational Employment and Wage Estimates." 2016.

Notes: Regression includes occupation-specific fixed effects that are not reported in this table.
Robust standard errors, in brackets, clustered at the NAICS code level.
*** p<0.01, ** p<0.05, * p<0.1.

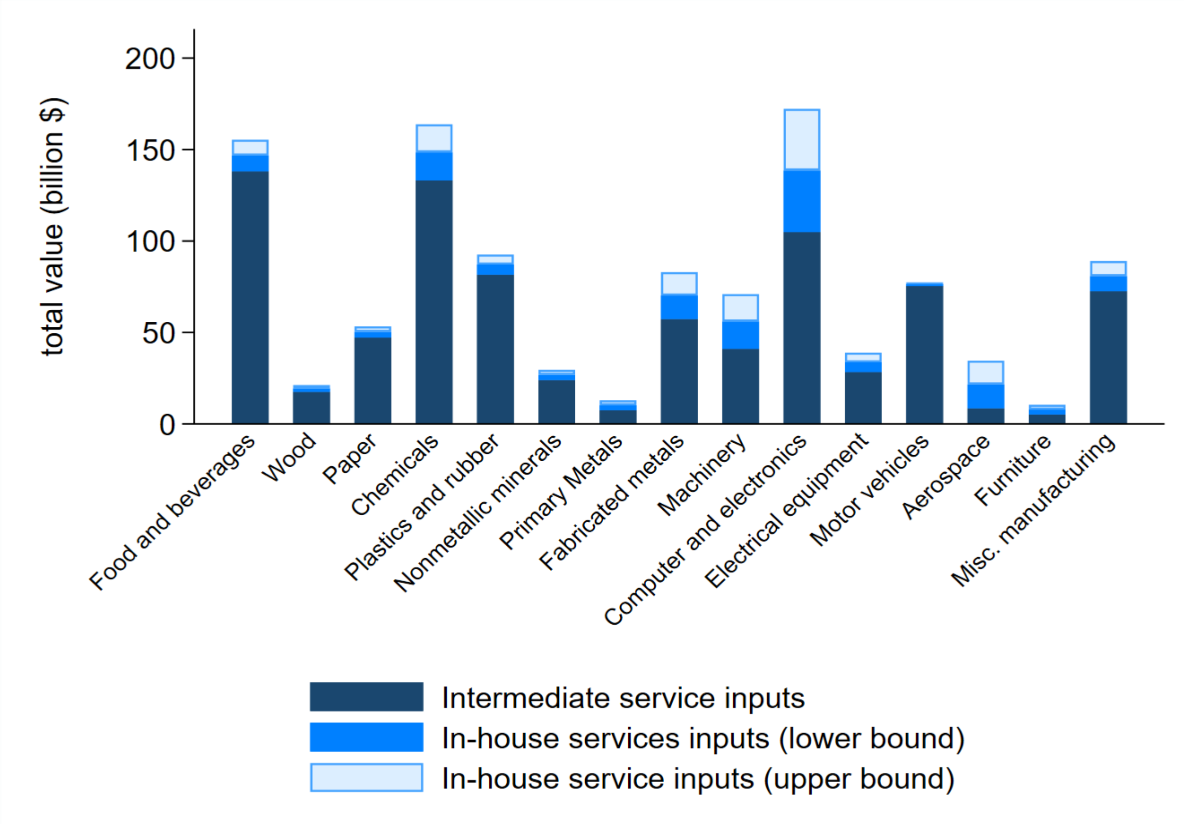
The variation in the composition of services employment in U.S. manufacturing, in terms of both education and wages, helps demonstrate that some types of manufacturing sectors rely more heavily on in-house services than others. This suggests that in manufacturing sectors where services employment is a large share of total employment, a large share of services employees have college degrees, and wages are higher within occupations, intermediate services inputs alone do not fully capture the total contribution of services to manufacturing output.

In-house services value added

To illustrate this underestimation, figure 3 compares the total value of intermediate services inputs with an estimated value of total in-house service inputs by NAICS 3-digit sector for U.S. manufacturing in 2016. The value of in-house services is based on the number of employees and typical wage rate of each of the sectors for which data are available. As stated before, since the number of employees does not distinguish between part- and full-time workers, the lower bound of in-house services inputs assumes all employees are part-time workers, while the upper bound assumes all employees are full-time workers.[22] On average, the estimated contribution of in-house services to U.S. manufacturing in 2016 was between $8.7 billion and $17.5 billion. The sectors with the highest estimated in-house services contribution were computer and electronic products (NAICS 334), with $33.7–67.3 billion in in-house services, and chemical products (NAICS 325) with $15.4–30.7 billion in in-house services. It is not surprising that these sectors have high values associated with in-house services, as both sectors tend to employ very specialized service workers (such as chemists and engineers), and make products that involve research and development, and require intellectual property protection.

[22] There may also be unobserved variation in total compensation if wages are not normally distributed within a particular occupation and sector.

Figure 3: Estimated value of in-house services versus intermediate services inputs, U.S. manufacturing sectors by NAICS codes, 2016.



Source: Author's calculation using data from BLS, "Table 1.2: Employment by Detailed Occupation, 2016 and Projected 2026," and "Table 1.9: 2016-26 Industry-occupation Matrix Data, by Industry," Occupational Employment Projections, 2017; BEA, "Use of Commodities by Industry," 2017.

The underestimation the total contributions made by services to manufacturing outputs matters more for some sectors than others. Table 4 shows the estimated "missing" share of total service value added that could be captured by in-house services production by sector. The average share of missing value added by in-house services (18 to 28 percent) is consistent with Miroudot and Cadestin (2017a), who estimate that in-house services contribute just over 20 percent of services value added in U.S. manufacturing exports in 2011.[23] In some cases, such as motor vehicle manufacturing, only 1 to 2 percent of total services value added is captured by in-house services, while the remaining share comes from intermediate services inputs. This reflects the importance of transportation services, dealerships, and maintenance services in the automotive sector are services that tend not to be part of the operations of motor vehicle and motor vehicle parts manufacturers. Makers of food and beverage products, paper products and plastics and rubber products also do not have high shares of in-house services relative to intermediate inputs. On the other hand, in aerospace manufacturing, between 60 and 75 percent of all services value added is in in-house services activity, indicating that using input-output data alone does not capture the

[23] Miroudot and Cadestin, "Services in Global Value Chains: From Inputs to Value-Creating Activities," 2017.

research and development, maintenance, and equipment-monitoring activities that U.S. aerospace manufacturers tend to perform in house.

Table 4: Estimated missing share of total services value added when in-house services are not included in value added calculations, by sector, 2016

NAICS code	Description	**Minimum estimated missing share of total services value added** (%)	**Maximum estimated missing share of total services value added** (%)
311	Food and beverage and tobacco products	5.9	11.1
321	Wood products	9.7	17.6
322	Paper products	6.1	11.5
325	Chemical products	10.3	18.8
326	Plastics and rubber products	6.3	11.8
327	Nonmetallic mineral products	10.3	18.8
331	Primary metals	26.8	42.3
332	Fabricated metal products	18.3	30.9
333	Machinery	26.7	42.2
334	Computer and electronic products	24.3	39.1
335	Electrical equipment, appliances, and components	15.7	27.1
3361	Motor vehicles, bodies and trailers, and parts	1.0	2.0
3364	Aerospace product and parts Manufacturing	60.1	75.1
337	Furniture and related products	33.8	50.5
339	Miscellaneous manufacturing	10.2	18.6
-----	Average	17.7	27.8

Source: Author's calculation using data from BLS, "Table 1.2: Employment by Detailed Occupation, 2016 and Projected 2026," and "Table 1.9: 2016-26 Industry-occupation Matrix Data, by Industry," Occupational Employment Projections, 2017; BEA, "Use of Commodities by Industry," 2017.

Conclusion

Due to data limitations, it is difficult to quantify definitively the value of in-house services embedded in manufactured goods. However, occupational data does help illuminate the range of manufacturing sectors' reliance on services in their operations. For U.S. manufacturing sectors in 2016, service-intensive manufacturing sectors tended to employ a higher share of high-skilled workers (as measured by education level) and pay higher wages. Taken together, these two relationships indicate that service-intensive manufacturers are likely to embed efficient, high-value services into their manufactured goods.

Using wage data to compare the total value of in-house services to intermediate services inputs in U.S. manufacturing in 2016 shows that, the contribution of services inputs to manufacturing outputs is likely to be underestimated, particularly in research and development intensive sectors. This shows that the input output table approach to measuring the global value chain alone is not sufficient for a full understanding of the contribution of services to manufactured goods, and should be seen as a lower bound for services value added, rather than a comprehensive measure.

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Appendix: Supplemental Regression Table

Table A-1: Average median service wage vs share of service occupations, U.S. manufacturers, 2016

Variables	**Share of employees with at least a bachelor's degree** (percent)
Service occupation share	0.56***
	[0.085]
Constant	31.53***
	[3.17]
Observations	72
R-Squared	0.355

Source: Author's calculations using data from BLS, "Table 1.2: Employment by Detailed Occupation, 2016 and Projected 2026," and "Table 1.9: 2016-26 Industry-occupation Matrix Data, by Industry," Occupational Employment Projections, 2017.

Notes: corresponds to Figure 2.
Robust standard errors, in brackets.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$