CHAPTER 3
Services' Contribution to Manufacturing

Overview

Services are used throughout the manufacturing process and the manufacturing value chain.[1] Some services are needed early in the chain (e.g., research and development); some are needed at the end (retailing, maintenance and repair); and some are needed at every stage (telecommunications and financial services).[2] Individual manufacturers often require a full spectrum of services.[3] In the United States, on average, 25.3 percent of intermediate inputs purchased by manufacturers in 2011 were from the services sector. For certain manufacturing sectors, such as computer and electronic products, this percentage—a measure of "services intensity"—is as high as 47.6 percent.

Services can include a wide variety of activities, such as trade, transportation, information, education, health, and financial and professional services.[4] The emphasis in this chapter, however, is on business services. Business services are defined as those that are predominantly purchased by other businesses rather than final consumers; examples include legal, data processing, and accounting services, among many others (box 3.1).

These services play an important role in manufacturing. In 2008, business services accounted for nearly half of all services purchased by manufacturing sectors. Moreover, business services are dynamic, having grown more rapidly than the services sector as a whole: since 1980, the share of business services in the U.S. economy has increased by 59 percent, more than double the 24 percent share increase of overall services.[5] These sectors have benefited strongly from recent technological innovations, particularly those related to information and communications technologies (ICT), and in turn provide the benefits of improved productivity to the buyers of their products, many of whom are manufacturers.

In describing the contribution of services in manufacturing, the chapter considers services inputs broadly, including services purchased by manufacturers from other firms, as well as services tasks performed within the firm. Not every employee in a manufacturing firm is directly involved in the physical production of goods. Rather, many employees provide services that support the manufacturing process. Examples include in-house lawyers,

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[1] Value chains encompass all activities necessary to bring a product from conception to consumption. To the extent that they involve suppliers in different countries, they are referred to as global value chains or global supply chains. See USITC, *Import Restraints*, 2011, chapter 3.

[2] Nordås, "Trade in Goods and Services," 2010; Miroudot and Rouzet, "Trade Policy Implications of Global Value Chains," 2013.

[3] Kommerskollegium, *At Your Service*, 2010.

[4] While there is no universal definition of services, a basic definition would correspond to the services activities described in industry classification systems. Most of the data presented later in this chapter are based on the North American Industry Classification System (NAICS) and similar categorizations. The statistical classification of economic activities in the European Community (Nomenclature Générale des Activités Économiques dans les Communautés Européennes, or NACE) forms the basis for the World Input-Output Database (WIOD).

[5] USDOC, BEA, GDP-by-Industry Data (accessed July 11, 2013).The trends in business services are discussed in more detail below.

BOX 3.1 Business services

Services sectors vary in how much they sell to final users versus how much they sell to producers. Some sectors sell primarily to final users; examples include restaurants, hotels, and public transportation. Business services, the sectors of interest to this study, sell the majority of their output, such as data processing, legal, and accounting services, to other firms.

In this chapter, **business services** are defined as those that primarily supply producers and use high-skilled workers. For a sector to be considered a business services sector, more than 50 percent of its output must be used as intermediate inputs, and more than 60 percent of its labor force must work in certain high-skilled occupations (described below).

Business services include the following activities, as classified by the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce:[a] (1) publishing (includes software), (2) motion picture and sound recording, (3) broadcasting and telecommunications, (4) information and data processing services, (5) services involving Federal Reserve banks, credit intermediation, and related activities, (6) services involving securities, commodity contracts, and investments, (7) insurance carriers and related, (8) rental and leasing services and services involving lessors of intangible assets, (9) legal services, (10) computer systems design and related services, (11) miscellaneous professional, scientific, and technical services, and (12) management of companies and enterprises.[b]

Employees in **business services-providing occupations** are defined as workers in several major occupation groups in the Occupational Employment Statistics (OES) database kept by the Bureau of Labor Statistics of the U.S. Department of Labor: (1) management, (2) business and financial operations, (3) sales and related, (4) office and administrative support, (5) computer and mathematical, (6) architecture and engineering, (7) life, physical, and social science, (8) legal, and (9) art, design, and media.

An extensive literature focuses on services sectors that supply producers. These are sometimes referred to as producer services. Depending on the author and the dataset examined, the sectors may also include wholesale trade and transport services, and may exclude communications.[c]

[a] These correspond to sectors in the U.S. annual input-output tables published by USDOC, BEA.

[b] The World Input-Output Database (WIOD) data source used in this chapter uses a slight variation on the BEA-based definition of the sector used in other parts of this chapter. In particular, WIOD includes national postal services and administrative and support services in addition to the business services used in this chapter's analysis. WIOD excludes publishing, software, motion picture and sound recording, and broadcasting.

[c] See Francois and Woerz, "Producer Services," 2008; Liu et al., "Embodied Services," 2013. Other research that examines business services includes Lesher and Nordås, "Business Services, Trade and Costs," 2006; Kox, "Unleashing Competition in EU Business Services," 2012; Antipa and de la Serve, "International Comparisons," 2010.

accountants, and researchers developing and applying technologies, as well as maintenance workers and administrative assistants. In 2012, about a third of all workers in U.S. manufacturing firms were in business services occupations, a share that has been rising in recent years.

The chapter first describes how U.S. manufacturers in the 21st century are taking advantage of services in new and innovative ways to manage global supply chains, cut costs, improve efficiency, and strengthen customer relationships. This description draws from the literature and industry accounts. The chapter then considers the linkages between the increased use of business services and manufacturing productivity using U.S. input-output (I-O) data. Also using I-O data and occupational data, the chapter describes recent trends and sectoral patterns in the use of services by manufacturers. A global I-O database permits the comparison of the services intensity of U.S. manufacturing with that of other economies, as well as an assessment of the importance of foreign services to U.S. manufacturers. Finally, three case studies—on semiconductors, medical devices, and performance textiles—illustrate the types of services that have upgraded efficiency, increased competiveness, and enhanced customer relationships.

Rationales for the Increased Use of Services in the Manufacturing Sector

Services have always been embedded throughout the manufacturing value chain. In recent years, developments in the services economy have transformed the way traditional services activities are conducted and have even introduced new services related to the use of new technology. Manufacturing firms now have more employees conducting research and development (R&D), business information management, and accounting, given the huge increase in computational capacity brought about by advances in information technology (IT). They also have more employees in marketing and advertising, reflecting the expansion of customer channels of communication fostered by the Internet and social media.[6] At the same time, new communications technologies have enabled many activities previously maintained in-house to be outsourced to specialist services providers.[7] As a result of these trends, the U.S. manufacturing sector appears to be growing more business service-intensive over time.[8] This increased importance of services is especially marked in such manufacturing subsectors as computer and electronic products, where services represent a high and growing proportion of inputs purchased outside the company as well as activities undertaken in-house.

While changes in the pattern of manufacturers' use of services are likely to reflect how firms have responded to a variety of business and economic factors, three key drivers of manufacturing firms' use of services are identified and further discussed in this section:

1. **The increasing geographic dispersion of supply chains with specialization**. Firms are seeking opportunities to move low-skill production work to low-wage locations and to concentrate their intellectual property development efforts in high-skill locations with favorable regulatory environments.
2. **The need to cut costs and improve efficiency**. Firms are using a variety of new technologies, particularly technologies related to ICT, to improve production efficiency and lower costs.
3. **The desire to deepen customer relationships by providing services related to their products**. Firms are using new types of services to better differentiate and customize their products, increasing their opportunities for premium pricing or improved market position.

These prospective competitive gains encourage manufacturers to incorporate more services at all stages in the product value chain. In early stages, ICT and transportation services increase manufacturing productivity by allowing firms to take advantage of

[6] As discussed later in the chapter, the share of U.S. manufacturing employees engaged in business services activities rose from 29.7 percent in 2002 to 32.5 percent in 2012.

[7] For example, many manufacturing companies are increasingly purchasing "cloud" data processing services instead of maintaining their own data processing facilities. It is currently estimated that about 5 percent of all enterprise IT spending is on cloud services, but this is expected to rise exponentially in the next few years. USITC, *Digital Trade*, 2013, 3-4; Venkatraman, "The Battle for the Cloud," 2013, 19.

[8] The share of business services in U.S. manufacturing value added has held roughly steady at close to 16 percent from 1995 to 2008. Combining this with an observed increase in business services occupations may suggest an increase in services intensity overall. This and other trends are discussed later in this chapter.

global economies of scale and use new process-improving technologies. At later stages in the chain, integrating services with manufactured goods into a more tailored product offering allows firms to increase their product differentiation, creating new business opportunities. Additionally, advances in ICT, particularly Internet-enabled services, have enabled firms to establish dynamic feedback loops, allowing them to collaborate with their customers and to deliver more customized products.[9]

Services Enable the Geographic Dispersion of Global Value Chains

Better services provision, particularly in ICT, logistics, and financial services, has reduced the trade and coordination costs associated with greater geographic dispersion of global value chains (GVCs). Including more services components is likely to strengthen the competitiveness of an entire value chain, including both production and services activities, because more people are able to specialize in certain tasks along the chain and coordination is more effective.[10] High-quality ICT infrastructure—fast, reliable telecommunications networks and broadband access—has become more universally widespread, reducing the costs of coordination for GVCs.[11] At the same time, multinational manufacturing firms are seeing great benefits from integrating supply chain management services into their business. For example, Intel has been able to significantly shorten lead times, reduce inventory holdings, and respond much faster to customers using a networked GVC management system.[12]

Improvements in logistics services have also fueled the globalization of supply chains. Containerization transformed the logistics and warehousing industries in the 1970s and 1980s, while more recently the advent of location tracking and temperature sensors made possible by new digital communications (the so-called Internet of Things) has enabled more efficient shipment of parts and goods all around the world with reduced handling losses.[13] Shippers like UPS and FedEx increasingly provide maintenance and care services for the products they move, in addition to mere shipment.[14]

The quality of professional and financial services available locally or on a global-account basis may have also played a role in enabling GVCs. Global manufacturing firms are likely to find it easier to set up significant production or sales operations in countries with established legal and insurance services and strong financial sectors; local access to credit and efficient payment systems help improve efficiency and lower supply costs.[15] In addition, services providers have also expanded their range of products and geographic coverage in recent years in order to assist multinational corporations. For example, global supply chain management insurance is a relatively recent innovation designed to help

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[9] Kommerskollegium, *Everybody Is in Services*, 2012; USITC, *Digital Trade*, 2013, F-6.

[10] Nordås and Kim, "Interaction between Goods and Services," 2013, 19.

[11] USITC, *Digital Trade*, 2013, 1-9.

[12] Intel, "Accelerating Business Growth through IT," 2013, 10.

[13] Copeland, "Identifying the Potential of Logistics Technology," 2013, describes DHL's use of digital technologies and radio frequency identification devices to improve logistics efficiency and tracking capabilities. See also Bernhofen et al., "Estimating the Effects of the Container Revolution," 2012; Notteboom and Rodrigue, "The Future of Containerization," 2009.

[14] Shactman, "UPS, FedEx Growing by Tapping 'Adjacent Business,'" 2012; Bughin et al., "Ten IT-Enabled Business Trends," 2013, 5.

[15] Arkell, "The Essential Role of Insurance Services," 2011, 2; OECD, "Global Value Chains (GVCs): United States," 2013, 3.

protect large multinationals setting up operations abroad against business continuity risks from supply disruption.[16]

Services Supported by New Technologies Help Firms Lower Costs and Improve Efficiency

Technology changes have led to improvements in existing services—as in the logistics industry, as described above—and have enabled the introduction of some entirely new services, such as software development for 3-D printing of prototypes.[17] Table 3.1 describes how technology enables services to provide direct benefits to producers in terms of improved processes, greater efficiency, and increased customization and customer interaction. The table also illustrates how these services advances percolate throughout the product value chain.

ICT services are seen to be central in helping companies develop better products and get these products to market more quickly. Along with widely adopted new organizational paradigms, such as "lean manufacturing," manufacturing companies now use enterprise resource planning and business information systems to manage suppliers, track parts and inventory, reduce energy costs and other production costs, track orders, and coordinate sales and after-sales services. Increasing reliance on these services has enabled companies to improve efficiency, cut costs, and diversify their products.[18]

Firms now need more scientific, engineering, and technical services for R&D, as well as maintenance and training services, as a result of major scientific advances in recent decades, including research into new materials in machinery and electronics, and progress in genetic engineering in the life sciences.[19] For example, the aircraft "composites revolution" has saved plane producers money by adding strength, reducing weight and fatigue, and decreasing production costs. However, designing and learning how to maintain new composite parts requires new performance measurement processes, both while new parts are in the design stage and after they have been produced and installed.[20]

Opportunities for new types of R&D and prototyping services have arisen with the advent of 3-D printing, robotics, and other forms of automation—and the IT and Internet technologies that they rely upon. Producers are now often able to customize products to specific customer requirements or to run smaller batch runs with little additional cost. Flexible machine tools and automated business processes allow cost-efficient batch production to take place at several sites, including locations in high-wage economies, if customer requirements dictate. Engineering and designing processes that automate customers' requests create more services opportunities.[21]

Innovations such as "Big Data" analytical services and cloud computing services are expected to have profound effects on manufacturers' business models. Big Data analytics

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[16] Zurich Insurance, "Supply Chain Risk," 2012, 5.
[17] Brynjolfsson, "The 4 Ways IT Is Revolutionizing Innovation," 2010.
[18] Infor, "Supporting the Lean Value Stream," n.d. (accessed August 30, 2013); SAP, "Riding the Growth Wave," 2008; IBM, "IBS and IBM Optimize ERP," 2010.
[19] Lind and Freedman, "Value Added: America's Manufacturing Future," 2012.
[20] Careless, "The Aircraft Composites Revolution," 2012.
[21] Nordås and Kim, "Interaction between Goods and Services," 2012, 8.

TABLE 3.1 Services advances throughout the product value chain

Driver	Stage in the value chain	Service	Benefit to producer	Enabling technology
More efficiency and lower costs of product development, production, and overhead	Design	Design services	Makes process more efficient	Computer-aided design (CAD) software
				Information technologies
	R&D	R&D services; prototyping services	Improves products; reduces development costs and shortens product development cycle; increases product efficiency (in decreased cost of failure)	Advanced manufacturing
				–3-D printing
				–New composite materials and chemistry
				–Nanotechnology
	Sourcing of intermediate inputs	Logistics and transportation services; supply chain management services	Allows geographic dispersion of GVC with the aim of lowering costs	Containerization; digital communications; radio frequency ID tracking
	Manufacture and assembly	IT services/production process management services; testing services; parts inventory tracking	Makes process more efficient	Robotics and automation
		Network and communications services; data analytics and processing services	Makes process more efficient	Cloud computing
			Increases production process quality and cuts production times	Algorithms for processing Big Data
				“The Internet of Things”: smart systems and sensor networks
		Utilities, including telecommunications and electricity	Makes manufacturing more efficient owing to high-quality provision of services (no interruptions)	Fiber optic telecommunications and broadband networks; smart grid
	Management of the firm	Human capital management services	Lowers overhead costs and improves coordination of the enterprise	Digital communications and cloud computing; enterprise management software
		IT services		
		Financial and treasury services	Lowers financing costs	
		Legal, accounting, and other professional services	Lowers overhead costs	
	Warehousing and distribution	Inventory management services; logistics and transportation services	Allows geographic dispersion of GVC with the aim of lowering costs	Containerization; digital communications
More product differentiation and customer satisfaction, enabling higher sales margins and more competitive product positioning	Marketing, branding, and sales	Online sales	Facilitates outreach to customers and offers ways to access new markets	Cloud computing; e-commerce platforms
		Sales force management services	Enables faster and more efficient customer targeting	Enterprise management software and networks; cloud computing
		Financial services (such as customer finance or equipment leasing services)	Enables sales of large-ticket items such as aircraft via customer financing solutions; allows customers to buy functionality that can be easily scaled up and down via equipment leasing	Innovative asset securitization structures; digital communications
	Aftermarket service	Digital services including cloud computing, social media, customer relationship management; IT services	Attracts more customer insights and collaboration	Cloud computing; digital communications technologies
		Maintenance and repair services	Shortens response times to repair products and upgrades ability to do preventative maintenance, improving customer service	“Internet of Things” communications; cloud computing; machine sensors

Sources: USITC, *Import Restraints,* 2011, 3-2; WEF, *The Shifting Geography of Global Value Chains*, 2012, 21; Kommerskollegium, *Everybody Is in Services*, 2012, 14; Ebner and Bechtold, “Are Manufacturing Companies Ready?” 2012**,** 4.

encompass a range of ICT services focused on gathering and interpreting large information datasets—such ICT services include wireless communications, software programming, data processing, mathematical modeling, and data storage and retrieval. On the factory floor, companies collect real-time metadata on their manufacturing processes through digitally connected testing and monitoring equipment, and use these data for ongoing process improvement.[22] Some use data approaches developed in-house, while others purchase the services of data scientists or data miners. In response to constant analysis of testing results, production process recipes can be quickly adjusted to meet technical and quality standards, with a minimum of downtime cost. Companies like GlobalFoundries, a semiconductor foundry, use Big Data analytics to monitor and refine manufacturing procedures, including forecasting quality and yields in new production batches. Big Data analytics are also helpful in the development phase of semiconductor manufacturing, enabling producers to model multiple client designs at one time or estimate the performance characteristics of a range of product variations.[23]

Cloud computing services have also become important in the manufacturing sphere. Amazon, Google, Microsoft, Rackspace, and many other companies provide cloud hosting, data communications, and infrastructure services for manufacturers of all sizes, often in coordination with software services offered by IBM, Oracle, or SAP. Clients pay according to amount of space they use, and besides hosting, securing, and maintaining data, services providers offer infrastructure services and applications. Because cloud services remove the need for a large IT infrastructure investment, businesses—especially small to medium-sized firms—often find them a cost-saving alternative. Small firms can also benefit from the economies of scale of large data centers, as cloud services providers can use their security systems to protect and store data from many different customers at once, passing on the unit cost savings to customers. [24]

Services Are Increasingly Part of Manufacturers' Product Offerings, Helping to Differentiate and Customize Goods

In addition to using services in the production process, manufacturing firms are combining goods with services to differentiate their products from those of other suppliers and to provide a more customized product offering. In so doing, they make themselves more appealing to shoppers and build a stronger relationship with their customers. Examples include the monitoring and evaluation capabilities that come with Emerson Electric devices[25] or the OnStar customer support system in new GM vehicles. Customizing goods through services components helps manufacturers stand out in a market that relies increasingly on non-price competition.[26] As a result, many firms that once saw services as merely part of operating costs now highlight them as essential for providing a premium product and building brand loyalty and product dependence.[27]

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[22] McGuire et al., "Why Big Data Is the New Competitive Advantage," 2012.

[23] Industry representatives, interviews by USITC staff, May 2013.

[24] Brodkin, "Ten Cloud Computing Companies to Watch," 2009. Amazon Web Services website, http://aws.amazon.com/what-is-cloud-computing (accessed August 30, 2013); Oracle, "Managing the Product Value Chain," 2011; USITC, *Digital Trade*, 2013, 2-31.

[25] Emerson Process Management website, http://www2.emersonprocess.com (accessed September 17, 2013).

[26] Nordås and Kim, "Interaction between Goods and Services," 2012, 8; Lind and Freedman, "Value Added: America's Manufacturing Future," 2012.

[27] Aberdeen Group, "Service Excellence and the Path," 2012.

Advances in ICT Give Firms Enhanced Customer Information and Feedback

Manufacturers are also using services to create a system of dynamic feedback that uses an array of customer information to align production with customer needs and wants. An example of this is the use of analytics and metrics to analyze trends and develop customer insights. Like other services that support the customizing of goods, metadata analysis helps firms to segment the customer base and then tailor products for each market they serve, as well as to provide them with customer information that is valuable in shaping future product offerings.[28]

Hewlett-Packard, an IT company, uses software-as-a-service (SaaS)[29] to analyze customers' Web metrics and uses the results in a dynamic model of production. In addition to allowing Hewlett-Packard to use clickthrough information to improve product pages, Web metrics such as time spent viewing a page and click counts help the company to learn which products are most popular on their site and adjust production accordingly.[30]

Many firms are also using online interactions with their target market, including social media, to bolster sales, identify demand, and build brand loyalty. Customers can provide product feedback using firms' online presence and, in many cases, can expect a response. As described below, companies have also developed entire social media departments—often separate from customer service departments—to use Twitter and Facebook to interact with customers and improve customer service and brand recognition.[31]

Digital interaction services offer customers a direct line of feedback into a product that they care about, and they in turn provide firms with an inexpensive pool of testers, designers, and consumers. Frito-Lay used Facebook to host its "Do Us a Flavor" campaign, accessing customers from across the world and engaging them to suggest and vote on new potato chip flavors.[32] The contest created a buzz and caused many customers both to pay more attention to Frito-Lay's products and to buy more of them. This contest brought in more than eight million customers to vote from all over the world.[33]

Lego uses its CUUSOO platform to solicit suggestions for new toy sets and allow potential consumers to vote on the most popular sets. On CUUSOO, a set suggestion that receives 10,000 votes of support is reviewed for possible production, though Lego also provides feedback and encouragement on suggestions that have yet to receive that many votes.[34] Similarly, digital communications are enabling video game developers like Microsoft to access a global pool of beta testers.[35]

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[28] McGuire et al., "Why Big Data Is the New Competitive Advantage," 2012.

[29] Software-as-a-service (SaaS) refers to the provision of computer software applications from a remote "cloud" installation on an on-demand basis. USITC, *Digital Trade*, 2013, 2-29.

[30] Boulton, "H-P Using Its Analytics Software to Grow Sales," 2013.

[31] Oliver Wyman, "Social Media Management," 2013, 5.

[32] PepsiCo, "Lay's Potato Chips Teams Up," July 2012; Frito-Lay's Facebook website, https://www.facebook.com/FritoLay (accessed August 14, 2013).

[33] Champagne, "How Lay's Got Its Chips to Taste," 2013.

[34] Lego's CUUSOO website, http://lego.cuusoo.com (accessed August 9, 2013).

[35] Microsoft Game Studios Beta Program website, http://connect.microsoft.com/MGSBetas (accessed August 9, 2013).

Services Help Customers Purchase and Use Products

More and more, companies are integrating services into the latter stages of the manufacturing value chain, facilitating the purchase and consumption of the good. Manufacturers combine the sale of their goods with complementary services that enable purchasing firms to source and integrate the goods into their business, or help final consumers make their purchase. Examples include financial, transportation, and shipping services.

Leasing services also promote product sales. Many large machinery and equipment manufacturers, for example, are able to capture more of their potential market by offering both purchasing and leasing opportunities to their customers. Markets that involve large equipment or heavy machinery can have both large cost barriers to entry and high equipment maintenance fees. Leasing gives manufacturers a way to enable their customers to use a larger variety of their products over time rather than simply waiting for the old ones to break down before procuring new ones. Leasing also helps the manufacturers ensure that the newest of their product offerings can be the most prominent and best maintained of their offerings.[36]

Performance-based contract services are similarly gaining importance. Such arrangements allow buyers to outsource performance risk to suppliers, who differentiate themselves by being willing to take it on as part of a maintenance and service contract.[37] Rolls-Royce's "Power by the Hour" program provides an example. The program uses a complex combination of problem-detecting sensors and regular downtime maintenance to ensure that when an airline purchases a Rolls-Royce engine, buying high level of engine performance is guaranteed.[38]

Finally, many large machinery and transportation manufacturers provide basic training services to make their products useful for even the most inexperienced or small-scale customers. Companies like GE find these services offerings to be so beneficial that they are expanding them beyond their previously established customer base as a sales tool.[39] Another example is StartupBoeing, a services program that helps potential new airline owners with everything from maintenance and flight crew training to fuel conservation services. Boeing works with potential customers very early in the process, offering advice on when and how to start a new airline. It then builds and maintains its customer relationships by offering a range of products, product upgrades, and related services, such as training for maintenance workers and navigation services, to its new and existing airline customers.[40]

Services Enhance Manufacturing Productivity

The previous discussion has highlighted a number of the business strategies in which manufacturers use services to reduce costs, increase efficiency, and expand sales. This

[36] Cusumano et al., "A Theory of Services in Products Industries," October 2008, 27.
[37] Baiman et al., "Procurement in Supply Chains," 2004.
[38] Rolls-Royce, "Rolls-Royce Celebrates 50th Anniversary of Power-by-the-Hour," October 2012; Knowledge@Wharton, "'Power by the Hour,'" 2007.
[39] PWC, "Customer Collaboration Designs Excellence," 2011, 5.
[40] StartupBoeing website, http://www.boeing.com/boeing/commercial/startup/ (accessed August 30, 2013).

section turns to the available quantitative evidence linking the use of services with improved productivity in manufacturing. Productivity measurement seeks to find evidence that firms are producing a higher value of output with the same or fewer inputs. Productivity improvement can take the form of either cost savings (e.g., reduced materials or energy use) or improvements in product quality that raise the real value of output.

There is some evidence that productivity gains are, on average, larger for manufacturing industries that make greater use of business services, as well as for manufacturing industries with larger increases in the use of business services.[41] In addition, productivity gains within the services sectors themselves have enabled manufacturers to benefit from services inputs that are both lower-priced and more efficiently provided than before. While these findings are subject to the caveats associated with productivity measurement—particularly the challenges involved in constructing price indices for services—the evidence is nonetheless suggestive.[42]

Productivity Gains in Manufacturing Are Associated with Business Services

Many of the most widely used strategies and tactics for achieving productivity gains make intensive use of business services.[43] In the United States, there is a correlation across manufacturing sectors between the use of business services and productivity gains in manufacturing. That is, the manufacturing sectors in which the use of business services has grown the most rapidly have, on average, enjoyed the highest productivity growth (figure 3.1). This is true whether growth in the use of business services is measured by manufacturers' purchases of business services from other firms or by their employment of their own workers in business services occupations.[44]

Of the various U.S. manufacturing sectors, the one producing computers and electronics products uses business services the most intensively—both purchased and in-house—and has shown the greatest productivity gains. This sector is especially important as a driver of productivity gains for knowledge-based workers in other sectors and as a means of accessing information and communication services in general. However, even when computers and electronic products are excluded from the analysis, a positive correlation

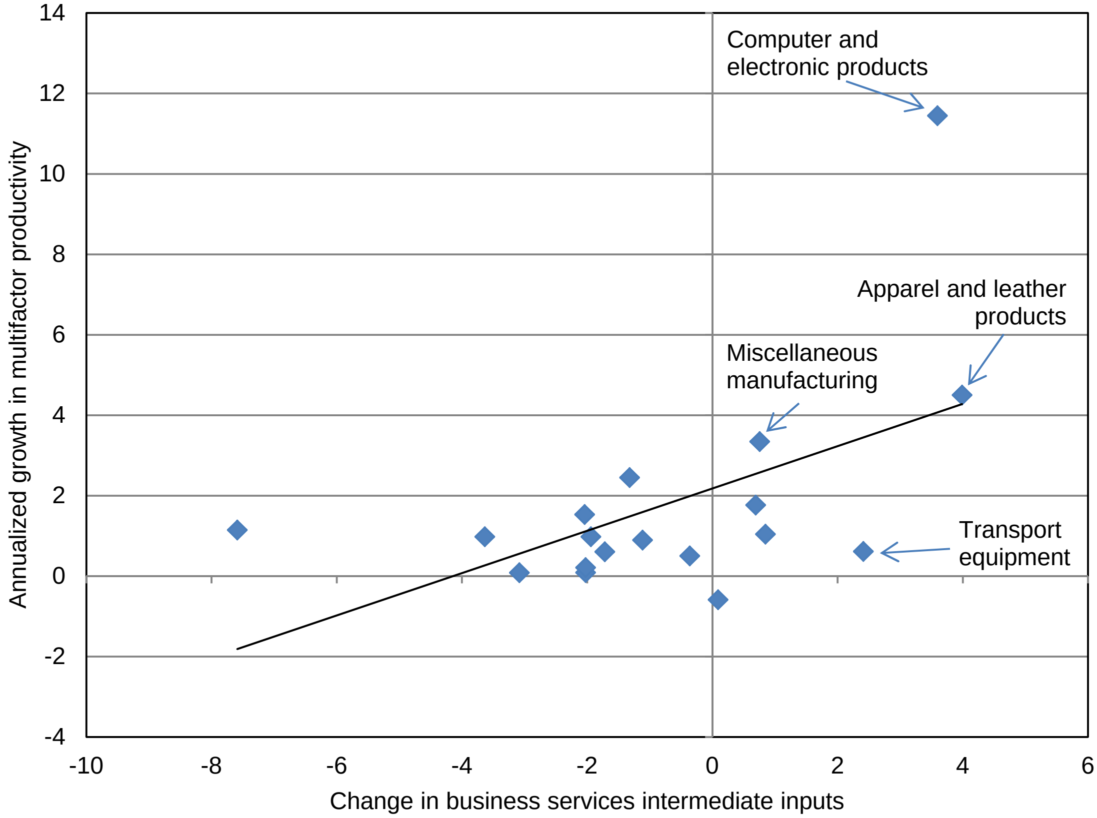
[41] Multifactor productivity or MFP (also called total factor productivity or TFP) measures how rapidly the real value of output is growing relative to a bundle of inputs. Measures of MFP used in this discussion are from the Bureau of Labor Statistics (BLS) of the U.S. Department of Labor. In the BLS's KLEMS framework, there are five inputs—capital, labor, energy, materials, and purchased services. For details of the techniques used by BLS in measuring multifactor productivity, see USDOL, BLS, "Technical Information," 2007.

[42] Challenges in the measurement of productivity include issues in measuring capital and difficulties with constructing appropriate price indexes for goods of variable quality. The price index problem is more challenging for services than for goods. For a discussion of productivity measurement issues in services industries see Triplett and Bosworth, "Productivity Measurement Issues in Service Industries," 2003.

[43] Although productivity gains can also be associated with other services—for example, transportation services linked to logistics—the focus on this section is on business services.

[44] It is also true that the level of business services used is correlated with growth in multifactor productivity, and that this is so whether or not business services use is measured by purchased services or business services employment. This correlation implies that increasing use of business services enhances productivity regardless of sector. At the same time, the relationship noted above between the level of business services use and productivity growth implies that sectors which use more business services may enjoy more opportunities for innovation.

FIGURE 3.1 Manufacturing sectors that buy more business services have had more rapid productivity growth, percent, 2002–11



Sources: USDOL, BLS, Multifactor Productivity tables (accessed May 22, 2013); USDOC, BEA, Annual Input-Output tables (accessed June 25, 2013); Commission calculations.

remains between use of business services and productivity gains for the rest of U.S. manufacturing.

In recent years, U.S. manufacturing output has grown more rapidly than purchased inputs in manufacturing (i.e., the productivity of purchased inputs has increased), implying increasing value added. Over the period 1997–2011, real output in manufacturing rose 5.9 percent while purchased inputs (energy, materials, and services) fell by 8.2 percent, enabling a 34.3 percent increase in real value added.[45] Thus, productivity gains in manufacturing led to increased payments to the factors of production.

Productivity Gains in Services Create Downstream Benefits for Manufacturers

Many of the services industries have themselves experienced significant productivity gains in recent years. Often, these gains have been made possible by ICT. Productivity gains in services have an effect on manufacturers purchasing those services analogous to a drop in the price of oil, or an improvement in the quality of materials. By either reducing costs or improving the quality of productive inputs, productivity gains in

[45] USITC calculation based on USDOL, BLS, Multifactor Productivity tables.

services have been passed on to manufacturers, leading to further benefits for manufacturing.

Because services are labor intensive, it is often thought that productivity gains in services are harder to achieve than in goods production. This observation may have been valid in the period before widespread computer use, and it is still valid for personal services such as education, healthcare, and entertainment.[46] However, productivity growth in services as a whole accelerated markedly beginning in the 1990s and is now on a par with productivity growth in goods.[47]

As table 3.2 shows, the types of services most purchased by manufacturers have shown significant productivity gains in recent years. In the period from 1987 to 2002, cumulative productivity gains exceeding 10 percent were observed in wholesale trade; securities, commodities, and investments; rail and truck transportation; and computer systems and related activities. In the most recent period for which data are available (2002–10), comparable productivity gains have been achieved in the utilities and computer systems design and related services sectors. Over a longer period, these productivity gains have been substantial. For the whole period 1987–2010, cumulative productivity gains have amounted to 53 percent for wholesale trade, 34 percent for truck transportation, 35 percent for rail transportation, 166 percent for the securities industry, and 56 percent for computer systems design and related activities. These gains are concentrated in sectors which are particularly relevant to the ability of manufacturers to upgrade the performance of supply chains and manage innovation.

Advances in ICT Generate Productivity Benefits

There is a sizable literature on the link between ICT and productivity growth. While earlier studies had difficulty identifying ICT's impact on productivity, it is now generally recognized that ICT has led to productivity improvements in services as well as manufacturing.[48] As noted above, productivity improvements in most of the services types most widely used by manufacturers have provided spillover benefits to manufacturing. Available estimates[49] broadly cluster around gains of 0.5–0.6 percent productivity growth associated with a 10 percent increase in ICT use. These gains appear to have accelerated over the last 20 years, to be stronger for firms that invest in organizational change and organizational capital, and to have been larger in the United States than the European Union (EU).

[46] The difficulty in achieving cost reductions in personal services has been recognized since the 1960s. See Baumol, "Health Care, Education, and the Cost Disease," 1993.

[47] See Triplett and Bosworth, "Productivity Measurement Issues in Service Industries," 2003; Triplett and Bosworth, "Productivity in the U.S. Services Sector," 2004.

[48] In the late 1980s, Nobel Prize-winning economist Robert Solow famously noted that "You can see the computer age everywhere but in the productivity statistics." See Solow, "We'd Better Watch Out," 1987. Brynjolfsson, "The Productivity Paradox of Information Technology," 1993, reviewed a number of studies which investigated the disconnect between the U.S. productivity slowdown that started around 1973 and the simultaneous rapid growth in computing power. Later analysis, focusing on the acceleration of U.S. productivity from about 1995 onward, provides a more optimistic view of the impact of computers and information technology on productivity. See Jorgenson et al., "A Retrospective Look," 2008.

[49] This discussion relies on the review in Kretschmer, "Information and Communication Technologies and Productivity Growth," 2009, wherein the range of available estimates is cited.

TABLE 3.2 Productivity gains for services most purchased by manufacturers

Sector	2011: Purchases by manu-facturers, million dollars	2011: Share of total intermediate use in manu-facturing, percent	Changes in multifactor productivity, cumulative percentage change: 1987–2002	2002–2010	1987–2010
Wholesale trade	240,828	6.6	46.7	4.1	52.7
Management of companies and enterprises	128,242	3.5	3.9	–19.0	–15.8
Miscellaneous professional, scientific, and technical services	126,748	3.5	7.5	5.9	13.9
Utilities	75,192	2.1	–1.1	21.0	19.6
Truck transportation	65,265	1.8	23.0	8.6	33.6
Administrative and support services	42,160	1.1	2.0	9.8	12.0
Rail transportation	33,481	0.9	31.8	2.4	35.0
Rental and leasing services and lessors of intangible assets	32,819	0.9	–32.9	2.6	–31.1
Securities, commodity contracts, and investment	30,472	0.8	155.5	4.0	165.9
Real estate	20,328	0.6	–2.8	-5.7	-8.3
Federal Reserve banks, credit intermediation, and related activities	17,244	0.5	–14.2	0.6	–13.7
Computer systems design and related activities	16,362	0.4	15.8	34.3	55.5

Sources: USDOL, BLS, Multifactor Productivity tables (accessed May 22, 2013); USDOC, BEA, Annual Input-Output tables (accessed June 25, 2013); Commission calculations.

Services Are Associated with Intangible Capital, a Source of Gains in Labor Productivity

It is widely recognized that investments in capital, or "capital deepening," can increase labor productivity and boost wages. Capital is often thought of as consisting primarily of physical capital, such as equipment and structures. However, more broadly, capital consists of any asset that enhances productivity over an extended period of time—for example, a year or more—rather than being used up in the production process. Thus, there is also nonphysical or intangible capital,[50] primarily associated with the generation of knowledge-based assets. Most forms of intangible capital are produced by services activities.

Business intangibles can be grouped into three broad categories: computerized information, which includes software and computerized databases; innovative property, which is acquired both through R&D and through nonscientific inventive and creative activity; and economic competencies, which include knowledge embedded in human resources and firm-specific business and organizational practices, including brand names. Software and computer systems design, R&D, creative and artistic design (as in apparel and furniture, and certain features of motor vehicles and electronics), and certain management activities are examples of services which can give rise to intangible capital.

[50]Corrado et al. estimated that by the late 1990s, investment in business intangibles amounted to 10 to 12 percent of U.S. GDP, was at least as large as tangible capital spending in equipment and structures, and was growing more rapidly than tangible capital spending. Corrado et al., "Measuring Capital and Technology," 2005.

As of yet there is no readily available measure of intangible capital specific to the U.S. manufacturing sector.[51] Table 3.3, below, presents several measures related to intangible capital in manufacturing, as well as some other measures for comparison. These include investment in software, R&D expenses,[52] and wages spent by manufacturers in occupations associated with the creation of intangible capital.[53] These measures do not represent all intangible capital—for example, they do not include the value of brand names, nor all of the payments made to services firms that may provide intangible capital to manufacturing—nor should they be summed to provide an overall measure. Some of the measures are overlapping; both the software measure and the wages measure include certain items counted in R&D spending. Nonetheless, they provide a broad indication of the formation and growth of intangible capital in manufacturing.

Even if the measures are highly overlapping, it appears likely that investment in overall intangible capital in manufacturing is larger than tangible investment in equipment and structures, and growing more rapidly. Investment in software accelerated rapidly in the 1990s, though it decelerated thereafter, while R&D spending accelerated in the 2000s. Wages spent to create intangible capital, particularly wages of top-level scientific, technical, and creative personnel, have grown over the last decade significantly more rapidly than either software investment or wages in occupations not associated with intangible capital. Thus, the contribution of intangible capital to gains in manufacturing productivity has likely also been significant.

Services Liberalization Benefits Manufacturing

There is now substantial evidence that access to a wide variety of high-quality services promotes manufacturing competitiveness.[54] For example, countries and products that make greater use of services inputs exhibit higher product quality and higher export prices. As noted above, services inputs boost manufacturing competitiveness in several ways. They increase productivity in activities that manufacturers currently perform, give manufacturers the flexibility to specialize in new high-skill activities, and facilitate the outsourcing of less productive tasks.

Liberalization of services trade can reduce costs and increase the variety of services available to manufacturers. Hence, services liberalization can be an important component

[51] The role of intangible capital in U.S. official data is expanding significantly in the 2013 comprehensive revision of the national income and product accounts (NIPA). Historically, only one type of intangible capital—software—has been recognized and accounted for in U.S. official data on investment and fixed assets. The revisions recognize private and government expenditures on R&D as fixed investment, as well as private expenditures on entertainment, literary, and other artistic originals. Tables and reports reflecting the new concepts were phased in during July–August 2013. At the time of writing, the new measures of fixed investment were available on an economy-wide basis but not for manufacturing specifically. See McCulla et al., "Improved Estimates," 2013, for details.

[52] These include R&D expenses paid by manufacturers, by government, and by other organizations.

[53] The definition of "scientific, technical, and creative personnel" in table 3.3 includes most occupations in business and financial operations, computer, engineering, and science occupations, and certain arts and design occupations, as well as librarians and library technicians. This definition is somewhat narrower than the definition of "business services" occupations used elsewhere in the chapter. Following Corrado et al., the calculation in table 3.3 assumes that 20 percent of managerial time is spent on organizational innovation. Corrado et al., "Measuring Capital and Technology," 2005.

[54] This section summarizes empirical evidence presented in Francois and Woerz, "Producer Services, Manufacturing Linkages, and Trade," 2008; Francois and Hoekman, "Services Trade and Policy," 2010; Gonzales et al., "Globalisation of Services and Jobs," 2012; Nordås, "Business Services," 2010; Nordås and Kim, "The Role of Services," 2013.

TABLE 3.3 Indicators of intangible capital in manufacturing, 1992–2011

Indicator	2011[a]	Cumulative increase, percent 1992–2002	2002–11	1992–2011
Intangible capital				
Investment in software	30.5	111.8	19.9	154.1
Research and development expenditures[b]	195.1	20.9	79.0	116.3
Wages spent to create intangible capital	137.4	n.a.	28.2	n.a.
Top-level scientific, technical, and creative personnel	75.5	n.a.	52.7	n.a.
20 percent of wages of top-level managers[c]	61.8	n.a.	7.2	n.a.
Memo items				
Investment in equipment and structures	161.7	25.5	16.2	45.9
Wages in other occupations	334.4	n.a.	2.8	n.a.

Sources: USDOC, BEA, National Economic Accounts (accessed July 16, 2013); USDOL, BLS, Occupational Employment Statistics (accessed June 20, 2013); NSF, Business Research and Development and Innovation Survey, various issues (accessed July 15, 2013); Commission calculations.

Note: The indicators of intangible capital should not be summed in an attempt to create an overall measure, since they are partly overlapping.

[a]Billion current dollars.
[b]Data end in 2010. Expenditures include expenditures paid for by companies, by government, and by other organizations.
[c]Assuming that 20 percent of managerial time is spent on organizational innovation. See text and notes.

of efforts to boost manufacturing competitiveness. Increased business services openness has a strong positive effect on the competitiveness of downstream industries. As with any trade liberalization, however, the effects will differ by sector, and not every industry will benefit. Estimates in the literature suggest that reducing services trade costs would have strong positive effects on motor vehicles, plastics, and rubber, but no effect in apparel.[55] Increased use of imported business services raised exports of skill- and technology-intensive industries in a panel of Organisation for Economic Co-operation and Development (OECD) countries, but reduced exports of labor-intensive manufactures.[56]

The benefits of services liberalization are particularly marked in manufacturing industries that are tightly integrated into production networks. Parts and components that cross multiple borders are subject to regulations and potential restrictions in multiple countries. Restrictions on the services needed to produce these parts, or restrictions on the services that facilitate their movement, can occur in widely distributed places, and effects can compound as goods move through the supply chain. As supply chains spread through an increasing number of countries and industries, manufacturers are increasingly exposed to the effects of services restraints occurring in locations with which they may have no direct contact.

Manufacturers are also affected by regulations and restrictions affecting the movement of goods in these same locations. Hence, some studies conclude that broad regional or global trade liberalization, including both goods and services and affecting barriers both

[55] See Nordås, "Business Services," 2010; Francois and Woerz, "Producer Services, Manufacturing Linkages, and Trade," 2008.
[56] Francois and Woerz, "Producer Services, Manufacturing Linkages, and Trade," 2008.

at and behind the border, can most effectively address the potential inefficiencies along the entire supply chain.[57]

Services Inputs into U.S. Manufacturing: Patterns and Trends

Over the last several decades, services have become an increasingly large share of the U.S. economy. In 1950, business services contributed 8.7 percent of U.S. gross domestic product (GDP); in 2012, they contributed 21.5 percent (figure 3.2).[58] This growth became particularly pronounced in the 1980s and 1990s, but has plateaued in the last decade.

A few patterns and trends emerge from an analysis of aggregate-level databases. As U.S. business services sectors have increased relative to the size of the economy, some manufacturing sectors have increased their use of business services. In addition, there has been a recent increase in business services-providing occupations within manufacturing. At the sector level, there is a positive correlation between the use of business services inputs and the share of business service-providing occupations.

Most of the data described in the rest of this chapter are restricted to the last decade, due to the lack of longer time series. Again, the focus is on business services, which, as discussed at the beginning of the chapter in box 3.1, are the services that are primarily used as intermediate inputs by other businesses and that use high-skilled services workers intensively.[59]

The Share of Business Services-Providing Occupations in Manufacturing Has Risen Slightly Since 2006

The share of workers in business services occupations within manufacturing has grown in recent years.[60] Manufacturing sector employment includes significant numbers of services-providing staff, conducting activities such as R&D, accounting, or marketing and advertisement. This increasing share of services-providing staff in manufacturing suggests the importance of these activities for manufacturing.

From 2002 to 2012, the share of business services occupations in manufacturing employment increased by 2.8 percentage points, rising from 29.8 to 32.6 percent (figure 3.3). Much of this increase occurred beginning in 2008. While production occupations—occupations directly related to the production process—retained by far the largest share of total manufacturing employment, their share declined slightly from 54.5 percent in 2002 to 52.9 percent in 2012; there was an increase in the downward trend following the

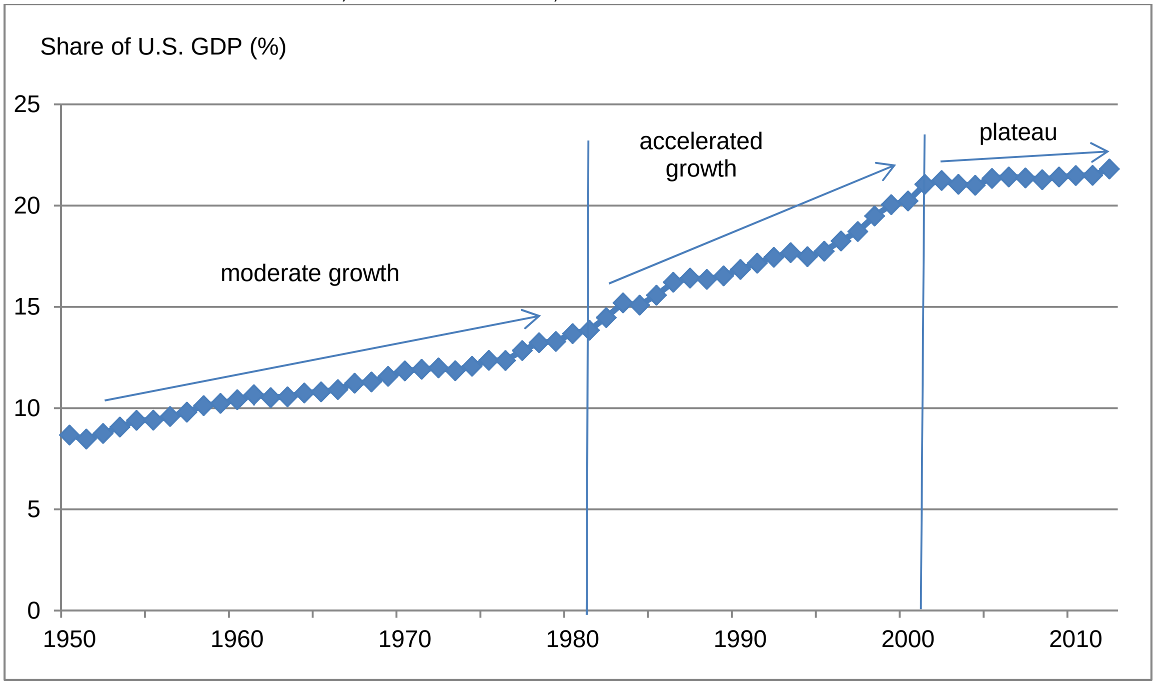
[57] Kommerskollegium, *Everybody Is in Services*, 2012, 22–23.

[58] USDOC, BEA, GDP-by-Industry Data (accessed July 11, 2013). This historical time series constructed using data from the Bureau of Economic Analysis (BEA) includes the sectors defined in box 3.1, with one addition and one omission: (1) funds, trusts, and other financial vehicles are included in the definition used in the historical time series; (2) rental and leasing services and lessors of intangible assets are excluded.

[59] The short time series availability is due to changes in sector and occupation classifications, as well as the lack of historical data for newly constructed databases.

[60] Similar analysis has been undertaken in Falk and Jarocinska, "Linkages between Services and Manufacturing," 2010, which uses EU data.

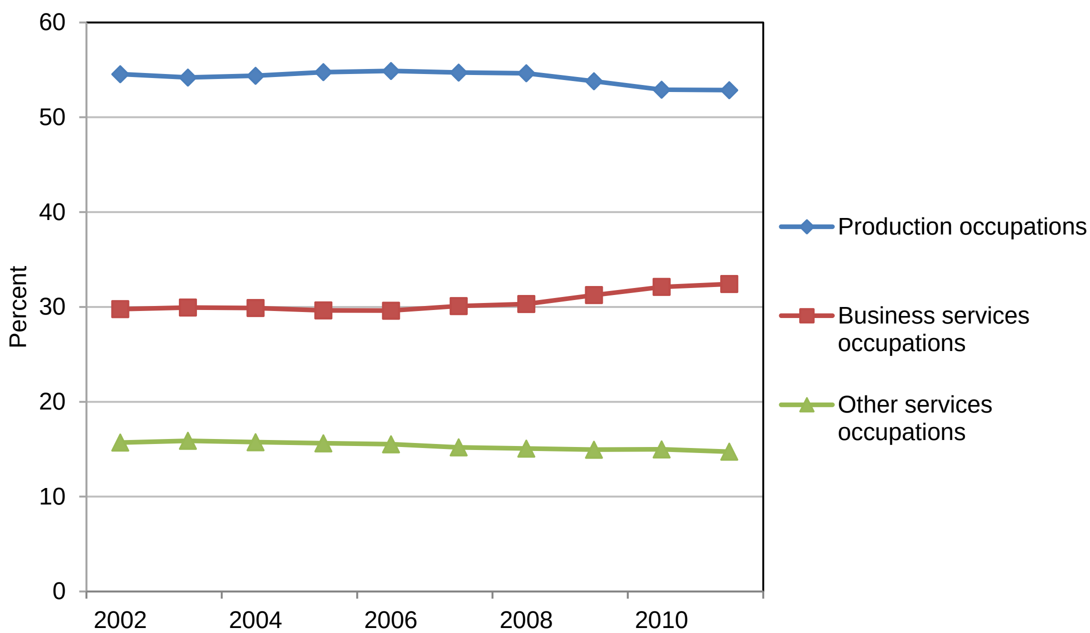
FIGURE 3.2 Business services, share of U.S. GDP, 1950–2011



Source: USDOC, BEA, GDP-by-Industry Data (accessed July 11, 2013); Commission calculations.

Note: The definition of business services used in this figure is slightly modified relative to the definition laid out in box 3.1: funds, trusts, and other financial vehicles are included in the definition, while rental and leasing services and lessors of intangible assets are excluded. This modification was necessary due to the lack of detailed sector-level data in earlier years.

FIGURE 3.3 The share of business services-providing occupations in U.S. manufacturing has increased over time, 2002–12



Sources: USDOL, BLS, Occupational Employment Statistics (accessed June 20, 2013); Commission calculations.

financial crisis in 2008. The share of other services-providing occupations dipped by 1.1 percentage point from 2002 to 2012.[61]

This structural shift of manufacturing employment toward business services occupations reflects the rising use of business services within manufacturing operations. It may also signal increased insourcing of business services products, with manufacturers hiring more business services workers even as they expanded purchases from other services sectors.

Nearly all sectors saw gains in the share of business services occupations employed; growth was most pronounced in computer and electronic products, apparel and leather, electrical equipment, and motor vehicles and parts (table 3.4), each of which has increased its share of business services-providing occupations by more than 5 percentage points. Only two sectors saw declines in their use of business services occupations: chemicals, and food, beverages, and tobacco.

The Share of Services as Direct Intermediate Inputs in Manufacturing Has Remained Stable since 1997

"Direct services" measures the direct contribution of each sector to manufacturing inputs.[62] On a constant-dollar basis, purchased services have remained stable at just under 20 percent throughout this time period.[63] Materials remain the largest intermediate input into manufacturing, and their share of total intermediate inputs increased slightly from 76.2 percent in 1997 to 78.8 percent in 2011 (figure 3.4). Energy is a fairly small portion of intermediate inputs into manufacturing at around 3 percent.

However, about half of all sectors increased their purchases of business services used as intermediate inputs (table 3.5) from 2002 to 2011. The fastest increases were seen in the computer and electronics and the apparel and leather products sectors—notably, the same sectors that experienced the fastest growth in business services occupation shares (table 3.4).[64]

Examining the levels of business services used, it appears that manufacturing sectors that use purchased business services intensively also have a high share of business services employment (figure 3.5). This relationship is most notable for computer and electronics products, which rank first both in purchased business services and in business services

[61] Other services-providing occupations include education, health care, social and personal services, transportation, and installation, maintenance and repair occupations.

[62] This section uses the data in Fleck et al., "A Prototype," 2012, as well as data from the BEA's input-output tables. Fleck et al. produce a constant-price time series (in 2005 prices) of the intermediate inputs in three cost categories—energy, materials, and purchased services. "Materials" includes the cost of raw materials and intermediate goods. This permits a discussion based on constant prices, although only for the aggregated cost categories. Fleck et al. apply a KLEMS production framework to BEA's estimates of industry production. See Strassner et al., "Annual Industry Accounts," 2005, for details.

[63] The last two years of data show a slight decline, but more data would be needed to establish a downward trend.

[64] Although both figure 3.5 and table 3.5 display direct services inputs into manufacturing, they are not directly comparable. Table 3.5 uses nominal values (not adjusted for inflation) as the basis for share calculations, while the Fleck et al. data displayed in figure 3.5 uses real (constant price) values as the basis for share calculations. Table 3.5 also uses only business services inputs, while Fleck et al. use all purchased services. Although constant-price adjustments are preferred, they are not available at a disaggregated sector level.

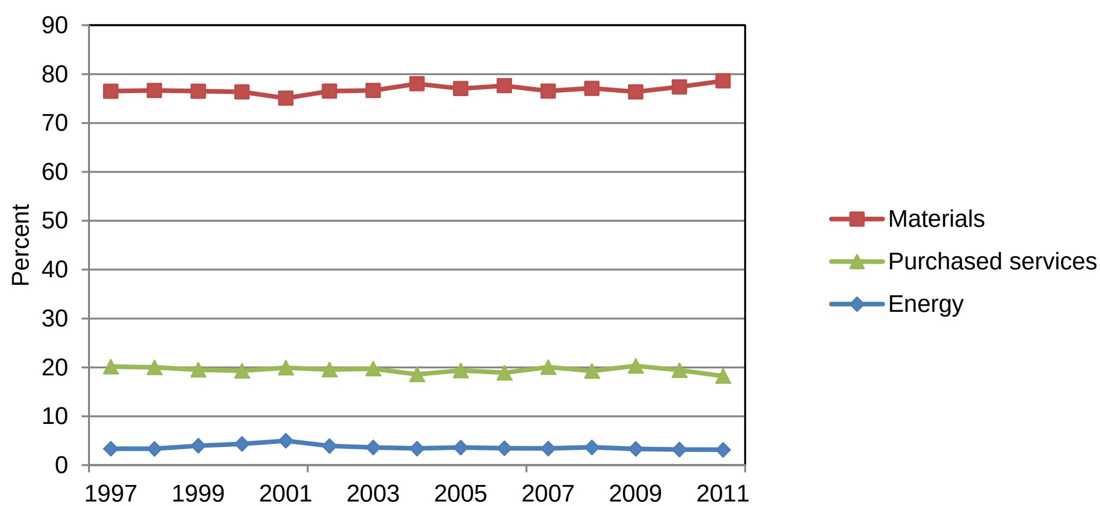
TABLE 3.4 Share of business services occupations in total U.S. manufacturing employment

Sector[a]	Percent 2002	Percent 2012	Change,[b] 2002–12
Computer and electronic products	59.5	67.2	7.7
Other transportation equipment	46.8	47.7	1.0
Chemical products	45.7	43.7	–2.0
Petroleum and coal products	35.5	38.7	3.2
Miscellaneous manufacturing	33.7	38.4	4.7
Printing and related support activities	36.6	38.3	1.7
Machinery	35.8	37.2	1.4
Electrical equipment, appliances, and components	29.0	35.6	6.6
Apparel and leather and allied products	20.3	28.7	8.4
Fabricated metal products	25.3	26.5	1.2
Furniture and related products	20.2	23.6	3.4
Motor vehicles, bodies and trailers, and parts	17.2	22.8	5.6
Plastics and rubber products	20.4	22.8	2.4
Paper products	21.1	22.6	1.5
Nonmetallic mineral products	20.5	21.9	1.4
Textile mills and textile product mills	18.6	20.9	2.3
Primary metals	18.8	19.5	0.7
Food and beverage and tobacco products	19.1	18.6	–0.5
Wood products	16.4	17.5	1.1
Average	29.8	32.6	2.8

Sources: USDOL, BLS, Occupational Employment Statistics (accessed June 20, 2013); Commission calculations.

[a]Sorted by the share of business services occupations in 2012.
[b]Percentage point difference.

FIGURE 3.4 Intermediate inputs of the manufacturing sector



Sources: Fleck et al., “A Prototype,” 2012; Commission calculations.

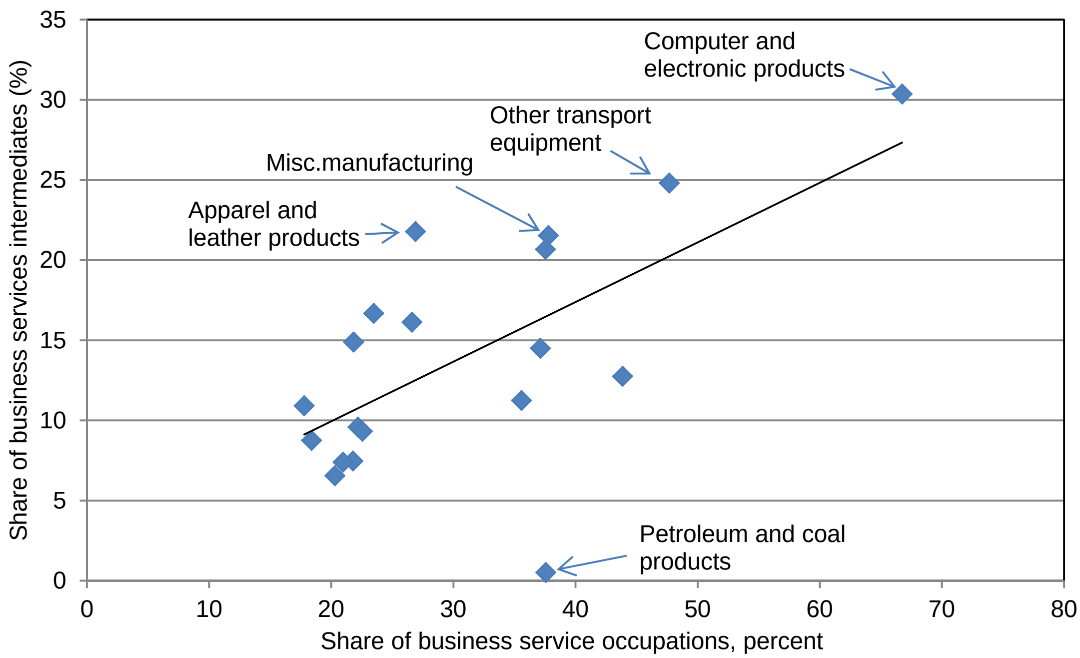
TABLE 3.5 Use of business services intermediates in manufacturing sectors

Sector[a]	Percent 2002	Percent 2011	Change,[b] 2002–11
Computer and electronic products	26.8	30.4	3.6
Other transportation equipment	19.1	24.8	5.7
Apparel and leather and allied products	17.8	21.8	4.0
Miscellaneous manufacturing	20.8	21.5	0.8
Printing and related support activities	19.8	20.7	0.8
Furniture and related products	17.8	16.7	–1.1
Fabricated metal products	18.1	16.1	–1.9
Nonmetallic mineral products	14.8	14.9	0.1
Machinery	15.8	14.5	–1.3
Chemical products	20.3	12.8	–7.6
Electrical equipment, appliances, and components	13.3	11.2	–2.0
Wood products	10.2	10.9	0.7
Plastics and rubber products	13.2	9.6	–3.6
Paper products	9.7	9.3	–0.4
Food and beverage and tobacco products	10.8	8.8	–2.0
Motor vehicles, bodies and trailers, and parts	7.2	7.5	0.2
Textile mills and textile product mills	9.1	7.4	–1.7
Primary metals	9.6	6.6	–3.1
Petroleum and coal products	2.6	0.5	–2.0
Average	14.0	10.4	–3.6

Sources: USDOC, BEA, Annual Input-Output tables (accessed June 25, 2013); Commission calculations.

[a]Sorted by the share of business services intermediates in 2011.
[b]Percentage point difference.

FIGURE 3.5 Manufacturing sectors that buy more business services also employ more workers in business services occupations, 2011



Sources: USDOL, BLS, Occupational Employment Statistics (accessed June 20, 2013); USDOC, BEA, Annual Input-Output tables (accessed June 25, 2013); Commission calculations.

employment. Leaving computers and electronics aside, the correlation between business services purchases and employment is more modest, but remains positive.

The Value Added of Business Services Has Remained Stable or Is Rising in Several Manufacturing Sectors

Services' full contribution to manufacturing is most accurately measured in terms of value added. Value added measures how much value (in terms of employee compensation and company profits) was generated by each sector. Consider the manufacture of a motor vehicle. The input-output (I-O) tables describe the production value of motor vehicles and their direct intermediate inputs, which may include auto parts, metal, glass, and electronics. However, embedded in each of these manufactured products may be accounting services provided to the auto parts company, computer services to the electronics manufacturer, and steel to the metals manufacturer; each of these sectors has in turn purchased goods and services embedded within them; and so on. The embedded values created by each sector can be summed up by transforming I-O tables, using certain assumptions, to recover the estimates of total value added (both direct and indirect) generated by each sector along the entire value chain.[65] In the discussion below, the total value added by all sectors of the economy in production of final manufactured goods is referred to as "manufacturing value added."[66]

Performing such calculations shows that as a share of value-added input into the aggregate U.S. manufacturing industry, services have remained relatively stable at approximately 34 percent (table 3.6). For the aggregate manufacturing sector, the share of services has decreased by 0.9 percent from 1995 to 2008, while the share of business services (at approximately 16 percent) has expanded slightly, by 0.2 percent, due to the expanded use of foreign business services.

At a more disaggregated level (table 3.7), manufacturing sectors differ substantially in the value added that is attributable to business services. Such value added ranges from as little as 8.2 percent of the share of total value added to the refined petroleum, coke, and other fuels sector to 23.2 percent for the pulp, paper, printing, and publishing sector. In the latter sector, a large part of business services value added is professional services. [67]

This is likely driven by the publishing segment, which requires extensive professional services in the production of content. The sector has also experienced the fastest growth of any manufacturing sector in the use of services, which reflects both the increased use of professional services by digital publishers and the decline in physical media.

[65] National-level I-O tables stop tracing value added at the border. As goods production has become increasingly fragmented across countries and sectors, an accurate assessment of value added requires I-O tables that link production processes within and across countries. To meet this need, the World Input-Output Database (WIOD) (a European Commission-funded program) has constructed a set of international I-O tables. The WIOD tables permit the tracing of value added across countries. See Timmer, "The World Input-Output Database," 2012. Because of international differences in the classification of services sectors, activities included in business services by WIOD differ slightly from those included by BEA. See box 3.1 for a comparison. A detailed explanation is provided in appendix F.

[66] This measure is distinct from GDP by industry, which would include only value added by firms and workers in the manufacturing sector, and is also known as "manufacturing value added."

[67] Professional services include activities such as legal, accounting, architectural, engineering, research and development, as well as the renting of machinery and equipment.

TABLE 3.6 Total services' contribution to U.S. manufacturing value added

Category	Percent 1995	Percent 2008	Change,[a] 1995–2008
Total services	34.7	33.7	–0.9
Domestic services	30.2	27.3	–2.9
Foreign services	4.5	6.5	2.0
Business services	15.7	15.9	0.2
Domestic business services	13.9	13.4	–0.5
Foreign business services	1.8	2.5	0.7

Sources: WIOD; Commission estimates.

[a]Percentage point difference.

TABLE 3.7 Business services' contribution to U.S. manufacturing value added[a]

	Percent						Change,[b] 1995–2008		
	1995			2008					
Sector[a]	Dom.	Foreign	Total	Dom.	Foreign	Total	Dom.	Foreign	Total
Pulp, paper, printing and publishing	16.9	1.5	18.4	21.0	2.2	23.2	4.1	0.6	4.7
Chemicals and chemical products	15.4	1.9	17.3	16.4	3.1	19.5	1.0	1.2	2.2
Transport equipment	12.1	2.2	14.3	14.2	3.3	17.5	2.1	1.1	3.2
Other nonmetallic mineral products	11.6	1.2	12.8	15.2	2.0	17.2	3.6	0.8	4.4
Rubber and plastics	13.2	1.8	15.0	13.8	2.9	16.7	0.6	1.1	1.7
Wood and wood products	10.8	1.3	12.1	14.3	2.0	16.3	3.6	0.7	4.3
Electrical and optical equipment	16.9	2.3	19.2	13.5	2.4	15.9	–3.4	0.1	–3.3
Basic metals and fabricated metal	11.9	1.6	13.5	13.3	2.4	15.7	1.4	0.8	2.2
Manufacturing n.e.c.	12.0	1.5	13.5	13.5	2.2	15.7	1.5	0.7	2.2
Machinery n.e.c.	13.1	1.8	14.9	13.0	2.6	15.6	–0.1	0.8	0.7
Food, beverages, and tobacco	14.2	1.4	15.6	13.6	1.9	15.5	–0.6	0.5	–0.1
Textiles and apparel	13.9	1.6	15.5	9.9	2.1	12.0	–4.1	0.4	–3.7
Footwear and leather products	16.1	2.2	18.3	9.0	2.0	11.0	–7.1	–0.2	–7.3
Refined petroleum, coke, and other fuel	9.3	2.0	11.3	5.5	2.7	8.2	–3.8	0.7	–3.1
Total manufacturing	13.9	1.8	15.7	13.4	2.5	15.9	–0.5	0.7	0.2

Sources: WIOD; Commission estimates.

Notes: Includes services value used directly and indirectly in the production of manufactured goods. n.e.c. means "not elsewhere classified."

[a]Sorted by total business services contribution in 2008.
[b]Percentage point difference.

Two other sectors also contain a large share of value added by business services, primarily due to high levels of R&D. The chemicals sector includes the highly R&D-intensive pharmaceutical manufacturers, while transportation equipment has a large share of embedded R&D in components and new materials, as well as in the development of new final goods such as motor vehicles and airplanes.

The footwear and leather products sector, one of the least business services-intensive sectors, has experienced the greatest decline in business services use since 1995. This decline is due primarily to the reduced use of professional services.

Foreign services inputs are used at similar rates across U.S. manufacturing sectors. Foreign business services accounted for 1.9–3.3 percent of sectoral output value in 2008 (table 3.7). Sectors with relatively high use of foreign business services include chemicals and transport equipment. This likely reflects the importance of intellectual property in these sectors,[68] and the significant presence of foreign-owned affiliates in these sectors.

Consistent with the increased globalization of value chains, foreign business services have grown increasingly important to U.S. manufacturing: use of foreign services rose in nearly every sector between 1995 and 2008, albeit from a low base. Although there is nothing to keep a sector from being an intensive user of both foreign and domestic services, in practice this is uncommon. Only three sectors (chemicals, transport equipment, and rubber and plastics) had above-average use of both types of services in 2008.[69]

International Comparisons and Services Trade in GVCs

Globally, business and distribution services are much more important to manufacturers than other types of services. In 2008, business services accounted for 12.6 percent of the value of manufacturing output; distribution services such as retail trade and transportation for an additional 14.0 percent; and other services, such as utilities, hotels, and government services, for a smaller 6.8 percent (figure 3.6 and appendix table F.5).[70]

There are stark differences across countries in the use of services by manufacturers. Among the countries in the dataset created by the World Input-Output Database (WIOD), services use ranges from a low of 20 percent in Indonesia to a high of 44 percent in Ireland. European countries dominate the ranks of countries with high services use, occupying the top 10 positions on the list in 2008. In the United States, services contributed one-third (33.7 percent) of U.S. manufacturing value added. The U.S. value was almost identical to the global average of 33.4 percent. In part, European prominence is due to the composition of countries in the WIOD dataset used to produce these estimates—27 of the 40 countries in the dataset are European. But the OECD, using a more inclusive (though non-public) dataset, largely confirms these findings. For example, OECD ranks France as the second-highest user of services in manufacturing (behind Iceland) in 2009, and it estimates that 9 of the 10 top services users are in Europe.

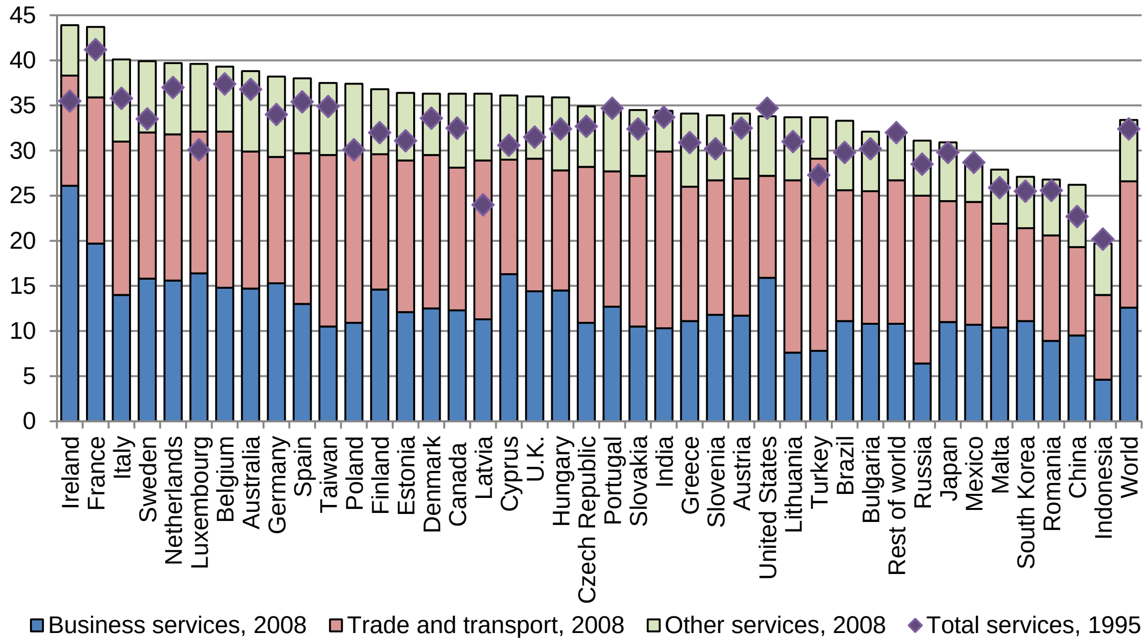
Although U.S. manufacturers use services less overall than their European counterparts, they use more business services inputs. In fact, the United States ranks fifth globally in the share of business services in manufacturing value added, behind only Ireland, France,

[68] Barefoot and Koncz-Bruner find that these sectors generated the most services imports among all manufacturing sectors, noting that for these sectors, "intellectual property forms an important part of firms' competitive advantage, which gives rise to transactions in royalties and license fees and R&D and testing services." Barefoot and Koncz-Bruner, "A Profile of U.S. Exporters and Importers of Services," 2012, 71–2.

[69] Rubber and plastics had only slightly above-average use of services.

[70] These estimates are generated using the WIOD database as described in appendix F and exclude construction. They are broadly confirmed by the OECD, which also finds that services contributed over 30 percent of the total value added in manufactured output, using a separate database. Miroudot and Rouzet, "Trade Policy Implications," 2013.

FIGURE 3.6 Services' contribution to manufacturing value added in each country, percent, 2008



Sources: WIOD; Commission estimates.

Note: Includes services in output of final goods only.

Luxembourg, and Cyprus. The United States also uses more business services (15.9 percent of manufacturing value added) than the EU as a whole (15.1 percent). High U.S. business services inputs may reflect both the nature of the advanced products produced by U.S. companies, which require these inputs, and the highly educated U.S. manufacturing and services workforce that provides them.

The higher value of overall services in Europe may reflect the high prices of many services there. Overall, services prices are 11 percent higher in the EU than in the United States, and prices for some types of services—such as utilities and transportation services—are much higher (about 25 and 50 percent, respectively).[71] Hence, the lower U.S. input share for trade and transportation services may simply be due to the lower U.S. cost of these inputs.

Although the differences in services use across countries can be at least partly attributed to services prices and the types of products produced by each country, the change over time is more difficult to explain. Figure 3.6 shows that while manufacturers in all of the countries with the highest services-to-manufacturing ratio increased their use of all services between 1995 and 2008, this ratio did not increase for the United States, which is

[71] According to 2008 benchmark purchasing power parity (PPP) data from the Eurostat-OECD PPP Programme, http://stats.oecd.org/Index.aspx?DataSetCode=PPP2008 (accessed August 1, 2013). "Overall services" excludes government services.

consistent with prior analysis in this chapter.[72] U.S. use of business services rose in the period, but by a very small amount (0.2 percent of manufacturing value added). The largest U.S. change in the period is a 1.1 percent decline in the share of trade and transportation services. Again, it is possible that this decline reflects better U.S. price performance in these sectors than in Europe in the period. International comparisons of services prices generally do not exist for the 1990s, however, so no definite conclusions can be reached.

The supply chain logistics literature emphasizes that more extensive global supply chains raise management and organization costs, but also allow companies to take advantage of economies of scale in trade and transportation.[73] At the country level, there appears to be some support for this conclusion. There is a positive correlation between a country's global engagement in 2008 and its use of business services in manufacturing.[74] The need for additional business services to coordinate international networks provides another reason why the business services share is high in tightly integrated Europe. In contrast to business services, there is no correlation between global engagement and the use of trade and transportation services. [75]

The Role of Services Trade in Manufacturing

Many manufacturers rely on both domestic and foreign goods and services. Worldwide, foreign services providers account for a small but growing share of services inputs.[76] As with total services inputs discussed above, the importance of imported services varies widely across countries; in some countries, such as Sweden, the importance of imported services is fairly substantial.[77]

Measured by the direct import of services, U.S. manufacturer's use of imported services appears quite low: direct services imports account for about 0.5–1 percent of the value of all U.S. manufacturing inputs.[78] However, as noted above, direct flows can present a misleading picture of total input use. A key source of indirect services inputs are the foreign services embedded in imports of parts and components used by U.S. manufacturers. Another important source of indirect inputs are services imported by

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[72] Appendix table F.5 shows a 1 percentage point decline in U.S. services use in manufacturing *output*. Stehrer et al., "Value Added and Factors in Trade," 2012, 17, shows a small decline in U.S. services use in manufacturing *exports* in this period, while the OECD estimates a larger increase in services use in U.S. exports, particularly in the wood and transportation equipment sectors. See OECD and WTO, "OECD/WTO Trade in Value Added," 2013, 4. Though not all estimates agree, the overall change in U.S. services use has likely been minor.

[73] See Hesse and Rodrigue, "The Transport Geography of Logistics and Freight Distribution," 2004; Rodrigue, "Transportation and the Geographical and Functional Integration," 2006.

[74] Global engagement is measured by the share of imported intermediates that are used in exported products, as reported by the OECD. Business services use is given in figure 3.7. The correlation between engagement and services use is 0.32, and it is significant at the 5 percent level. This correlation does not imply causation. While global engagement may increase organizational complexity and the need for business services, it is also possible that greater use of business services generates products that succeed in the global marketplace.

[75] There is no evidence that it lowers use of these services as implied by the supply chain logistics literature. This correlation is 0.03, and it is far from significant. Trade and transportation use is given in figure 3.6 and appendix table F.5.

[76] Gonzales et al., "Globalisation of Services and Jobs," 2012.

[77] Kommerskollegium, *Servicification of Swedish Manufacturing*, 2010.

[78] Even in detailed manufacturing industries, this share rarely rises above 2 percent. For a review of manufacturing use of direct services imports, see USITC, *Import Restraints*, 2011, 3-13.

companies in other sectors of the economy (e.g., mining or services) to produce domestic inputs to manufacturing. Incorporating these sources of indirect services considerably raises the share of foreign services in U.S. manufacturing. Including indirect flows, foreign business services accounted for 2.5 percent of U.S. manufacturing value added, or about 16 percent[79] of all business services used by U.S. manufacturers in 2008 (table 3.6). This comes to just over 3 percent of the value of all U.S. manufacturing inputs. Hence, accounting for indirect inputs raises the importance of foreign business services to U.S. manufacturers at least threefold.[80]

U.S. services firms also provide inputs that are used abroad by foreign manufacturers. In 2008, the value of U.S. business services used by domestic manufacturers was about 2.5 times the value of U.S. business services used by manufacturers abroad.[81] However, foreign manufacturers have become more important to U.S. services providers as their purchases of U.S. services have risen steadily over time.

There are four channels by which U.S. services are used in goods consumed abroad. The first two channels constitute direct services exports, and the last two are indirect exports. They include:

1. direct U.S. services exports to foreign manufacturers;
2. direct U.S. services exports to foreign services firms that provide services to foreign manufacturers;
3. U.S. services used by U.S. goods producers that are subsequently exported to foreign manufacturers and consumers; and
4. U.S. services used by U.S. services providers that are subsequently exported to foreign manufacturers.

Of these channels, the first two (direct exports) have shown the most growth in recent years. According to services trade data compiled by the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce, U.S. direct exports of business, professional, and technical services doubled in value between 2003 and 2011, and tripled between 1998 and 2011.[82] In comparison, BEA annual I-O tables imply that indirect services exports grew only 4 percent overall from 1998 to 2011. Indirect exports through services sectors rose 44 percent, but indirect exports embodied in manufactured goods fell 16 percent (figure 3.7).

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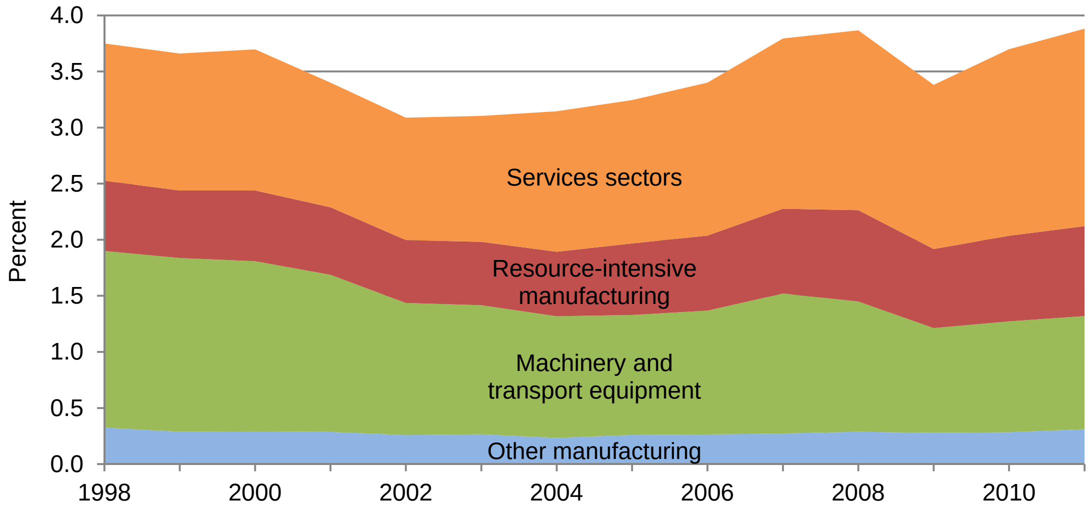
[79] Calculated as the ratio of foreign services (2.5 percent) to total services (15.9 percent) in 2008 (table 3.6).

[80] Including other embodied foreign services, such as the value of utilities used to produce foreign goods, raises the foreign services' share to 5 percent of the value of U.S. manufacturing inputs.

[81] According to Commission estimates using WIOD data, U.S. manufacturers used $265.3 billion of U.S. business services in the production of final manufactured goods, while foreign manufacturers used $106.7 billion of U.S. business services. Although foreign use is substantially less than domestic use of business services, this nevertheless indicates that a significant amount of U.S. business services is used by manufacturers abroad.

[82] Because of changes to U.S. export classifications over time, no precise match to business services as defined in box 3.1 is possible before 2006. The export category "business, professional, and technical services" is largely a subset of the services included in box 3.1. It excludes publishing, motion picture and sound recording, broadcasting and telecommunications, financial services, and royalties and license fees. It also includes some unrelated sectors such as medical services, construction, and mining services, though there is relatively little trade (less than $20 billion, or about 3 percent of total services exports in 2011) in these sectors.

FIGURE 3.7 Indirect exports of services, share of U.S. services value added, 1998–2011



Sources: USDOC, BEA, Annual Input-Output tables (accessed June 25, 2013); Commission estimates.

Notes: "Resource-intensive manufacturing" includes wood, metal, mineral, paper, petroleum, chemical, plastic, and rubber products. "Machinery and transport" includes machinery, electrical equipment, computer and electronic products, motor vehicles, and other transportation equipment; "other manufacturing" includes food, furniture, textiles and apparel, and miscellaneous manufacturing.

Most indirect U.S. services exports pass through U.S. manufacturers, and thus indirect services exports strongly reflect the export performance of U.S. manufacturers that use services intensively. As noted in table 3.7, these sectors include natural resource sectors, chemicals, and transport equipment. U.S. manufacturing exports respond to changes in global demand, and can rise or fall rapidly, leading to shifts in indirect services exports. For example, recession-driven manufacturing export declines in 2001–02 and 2009 resulted in declines in indirect services exports. Indirect exports are also driven by increases or decreases in manufacturers' use of services inputs, though this factor evolves more gradually.

Previous sections of this chapter have started by identifying specific manufacturing sectors, then have looked upstream at the types of services inputs that they use. A complementary picture emerges by starting with specific services sectors, and looking downstream at the ways they are used by manufacturers. Table 3.8 presents figures for direct exports of U.S. services sectors and the downstream sectors that use services and that account for indirect services exports.

The sector with the highest direct exports of services, as a share of total sectoral value, is "rental, leasing, and lessors of intangible assets" (23.5 percent). This sector includes royalties and license fees paid by foreign firms and U.S. affiliates to access U.S. intellectual property. Another sector with high direct exports of services is management (19.8 percent). These sectors are among the major contributors to U.S. services exports and the U.S. services trade surplus.[83]

Direct services exports account for a substantial share (3.7 percent) of the services sector's total value added, yet indirect exports account for an even greater share (3.9

[83] For a discussion of cross-border exports in these sectors, see USITC, *Recent Trends*, 2013, 1-8, 2-4.

TABLE 3.8 Direct and indirect exports of services, share of sectoral value added, percent, 2011

Sector	Direct exports[a]	Indirect exports: Manufacturing: Resource-intensive	Machinery and transport	Other	Total mfg.	Services
Business services						
Management	19.8	3.1	5.1	1.1	9.3	3.2
Miscellaneous professional, scientific, and technical	2.5	1.8	2.2	0.6	4.5	4.2
Rental, leasing, and lessors of intangible assets	23.5	1.8	1.8	0.6	4.2	3.4
Legal services	3.1	0.8	1.2	0.4	2.4	3.1
Information and data processing	0.5	0.8	1.3	0.3	2.3	2.8
Computer systems design	2.9	0.7	1.2	0.2	2.1	1.8
Financial services	5.0	0.6	1.0	0.4	2.0	3.1
Publishing, motion pictures	10.3	0.4	1.1	0.1	1.6	2.1
Broadcasting and telecoms	1.3	0.6	0.8	0.2	1.6	2.5
Insurance	2.5	0.2	0.3	0.1	0.7	2.6
Other services						
Wholesale trade	12.0	1.8	2.5	0.8	5.1	1.2
Utilities	0.1	2.5	1.4	0.6	4.6	1.0
Transportation and storage	13.8	2.1	1.7	0.7	4.5	3.4
Administrative and support	0.4	1.2	1.7	0.5	3.3	4.4
Waste management	0.8	1.1	1.0	0.4	2.4	1.8
Entertainment, food, hotel	0.1	0.3	0.4	0.1	0.9	1.3
Real estate activities	0.0	0.2	0.3	0.1	0.6	0.9
Retail trade	0.0	0.1	0.1	0.0	0.3	0.1
Social services	0.1	0.0	0.0	0.0	0.0	0.0
All services	3.7	0.8	1.0	0.3	2.1	1.8

Sources: USDOC, BEA, Annual Input-Output tables (accessed June 25, 2013); Commission estimates.

Notes: "Resource-intensive manufacturing" includes wood, metal, mineral, paper, petroleum, chemical, plastic, and rubber products. "Machinery and transport" includes machinery, electrical equipment, computer and electronic products, motor vehicles, and other transportation equipment; "other manufacturing" includes food, furniture, textiles and apparel, and miscellaneous manufacturing.

[a]Includes only added value generated by the exporting sector.

percent).[84] For the overall services sector, and in 13 of 19 individual sectors, indirect value added through manufacturing exceeds services value added in direct exports.[85] Sectors that have the highest indirect exports through U.S. manufacturing include management (9.3 percent of sectoral value added), wholesale trade (5.1 percent), and utilities (4.6 percent). Management is used at every stage of the supply chain, from conception to delivery. Utilities, too, are required at all stages, particularly in resource-intensive manufacturing sectors such as rubber and plastics, other nonmetallic minerals, and basic metals and fabricated metals. Wholesale trade is another widely used service, often required when physical goods are transferred. Hence, indirect exports of these

[84] Including 2.1 percent of sectoral value added exported indirectly through manufacturing sectors and 1.8 percent through services sectors.

[85] For comparability, table 3.8 reports only each sector's value added for both direct and indirect exports. Thus direct exports exclude some value reported in official services export statistics. For example, direct exports in the second row exclude the value of legal services used to produce exports of computer systems design.

services are high because they are important inputs to the production of intermediate inputs and final goods that are subsequently exported.

U.S. services firms also indirectly export a substantial amount of value generated by other services firms, though such exports are not generally as large as indirect services exports by manufacturers. Services sectors that see a large share of their value added exported by other services firms include administrative and support services (4.4 percent), miscellaneous professional, scientific, and technical services (4.2 percent), and rental, leasing, and lessors of intangible assets (3.4 percent). Miscellaneous professional services include activities such as accounting, advertising, specialized design, technical services, and scientific research. U.S. services companies, like U.S. manufacturers, require substantial amounts of these services to produce their highly technical and specialized exports, along with the inputs of intellectual property and administrative services provided by the other sectors on this list.

There are also substantial indirect exports of transportation and storage services (3.4 percent of total value added in the sector). Although direct exports by wholesalers, logistics, and transport firms account for the majority of trade in these services, they may also be exported indirectly if goods that are shipped abroad have been transported or stored domestically at an earlier stage of production. Since these goods may be used by foreign manufacturers, a portion of this value will reenter manufacturing supply chains abroad.[86]

Manufacturing Case Studies

To illustrate in greater detail some of the ways in which services are being used in U.S. manufacturing, the Commission conducted case studies of three industries: semiconductors, medical devices, and performance textiles.[87]

As discussed above, innovations in information technology have enabled services to improve efficiency and cut costs in manufacturing sectors. A prime example of this is the semiconductor industry. Software-enabled services have given the semiconductor industry an important avenue to improving efficiency. The case study on the semiconductor industry presents an in-depth look at this effect; in addition, it presents an example of the use of services to enhance its customer relationships. The sector to which the semiconductor industry belongs—computers and electronics products—is generally a high user of services, and has experienced strong productivity growth as a result of technological innovation. Semiconductor manufacturing remains strong in the United States, and many of the world's largest semiconductor companies maintain headquarters and operations in the United States.[88] This case study describes the semiconductor industry from the point of view of the factory floor to provide some context about the changes in manufacturing that result in the aggregated statistical movements.

The case study on medical devices manufacturing presents another segment of the U.S. market in which software-enabled services have become critical to competitiveness.

[86] One limitation of using a single-country (U.S.) I-O table is that it cannot distinguish whether exports are ultimately used by foreign consumers, manufacturers, or services firms.

[87] For the purpose of this report, "performance textiles" includes textiles commonly referred to as technical, specialty, and/or industrial fabrics.

[88] Lineback et al., *McClean Report*, 2013, figure 3-2.

Software-enabled services assist medical device firms throughout each step of the value chain, from designing a new product to helping firms comply with regulations. The economic activity of medical devices manufacturing is scattered among several industry categories, and cannot be easily seen in the data.

The case study on performance textiles highlights the role of R&D in manufacturing. R&D is a service that directly produces technological innovation. Performance textiles are an interesting case study for exploring the use of services in manufacturing as a growth area in an industry hard hit by global competition. The U.S. textiles industry overall has experienced a significant decline in the contribution of services to its value added—as seen in table 3.7, the industry has reduced its use of services by 3.7 percent, more rapidly than any other sector besides footwear and leather products. By contrast, the positive outlook for the U.S. performance textile industry can be attributed to the vigorous use of services such as R&D to complement manufacturing capabilities. Unlike many other segments of the textiles industry, performance textiles have been able to retain manufacturing facilities in the United States due to substantial investments in R&D services to create new products.

Semiconductor Industry

The semiconductor industry buys, provides internally, or sells services along each step of the design and manufacturing process. These services include utilities and logistics, R&D, testing and validation, contract manufacturing, packaging and assembly, and marketing and sales. The semiconductor industry uses services to increase yield and output and to reduce the costs of producing semiconductor devices.

The semiconductor industry is highly globalized; companies in the United States have access to the same services as companies manufacturing in other countries, and semiconductor trade flows are almost entirely tariff free under the WTO's Ministerial Agreement on Trade in Information Technology Products.[89]

This case study describes two specific business services, offered at different steps of the production process, to demonstrate the importance of services in semiconductor manufacturing today. It first describes electronic design automation (EDA) providers, which offer test and validation tools and processes related to product design. The remainder of the case study describes services offered by semiconductor equipment suppliers, which also sell services that increase the performance of tools used in a semiconductor fabrication facility (fab).

Factors of Competition

The semiconductor industry designs and produces the integrated circuits that enable the operation of almost all electronic devices, industrial and consumer.[90] Computers and telecommunications devices account for nearly 60 percent of semiconductor usage. In

[89] WTO, Information Technology Agreement, http://www.wto.org/english/tratop_e/inftec_e/inftec_e.htm (accessed August 1, 2013).

[90] Semiconductor is a generic term for integrated circuits and discrete devices, such as transistors, resistors, capacitors, and diodes. Semiconductors are almost universally fabricated from a base of silicon.

2012, the value of worldwide semiconductor production accounted for 23 percent of electronic system production.[91]

Distinctive competitive challenges for semiconductor producers arise partially from the industry's own production cycle. The costs to produce semiconductors are enormous. Fabrication equipment and tools cost tens of millions of dollars,[92] while the average selling price per unit is relatively low.[93] The combination of large capital outlays and low product unit prices requires semiconductor companies to construct fabs that produce high volumes to achieve sufficient economies of scale. As a result, when a new fab enters service, the added capacity may overload the market or depress demand for technologies produced by older fabs, driving down selling prices across the industry.

To address these challenges, one strategy has been the separation of design and production. "Fabless" companies design semiconductors only, and "foundry" companies operate fabs to produce semiconductors only. Fabless designers share production capacity at foundries, a strategy which effectively increases fab utilization. In 2012, IC Insights reported that fabless companies accounted for nearly 30 percent of worldwide sales, and have grown at a faster rate than integrated device manufacturers.[94] A complementary strategy is pursued by integrated device manufacturers, which design and fabricate chips in a vertically integrated process and own their fabs. These companies have responded to the industry's challenges by building high-volume fabs allowing them to increase their economies of scale.[95] Both of these business strategies rely on the use of services, and this case study describes two specific services below.

Electronic Design Automation Services

EDA providers sell services that give access to proven simulation models, enabling designers to advance semiconductor capabilities. EDA companies offer services in five categories: software to engineer chips, software to lay out printed circuit boards, software to test and certify integrated circuits, consulting services, and access to semiconductor patents or intellectual property.[96] EDA is not a specific process, but rather a services sector "involved in developing and supplying highly specialized software- and hardware-based tools for the automated design of electronic products of all kinds."[97]

Two of the five EDA product categories—integrated circuits software testing and semiconductor intellectual property access—offer clear examples of services used in semiconductor manufacturing. One of the basic software offerings of EDA companies is Verilog hardware description language, which designers use to model integrated circuits. While early semiconductor designers could lay out the circuit designs by hand, the microscopic scale of advanced chips can only be tested using software. Semiconductor

91 Lineback et al., *McClean Report*, 2013, 2–4.

92 For example, the average selling price of a tool from ASML, a Dutch company that makes photolithography tools, is $20 million (ASML, *Annual Report*, 2012, F-38).

93 Examples of prices: less than $0.50 for an analog chip, more than $3.50 for NAND flash memory units, and around $30.00 for top-level application-specific integrated circuit chips. See IC Insights, "May Update," 2013; Rassweiler, "Many iPhone 5 Components Change," 2012.

94 IC Insights, "Fabless Companies Play Increasing Role," 2013.

95 Naeher et al., "The Evolution of Business Models," 2011.

96 For a description of software programs in each of the five categories, view the product category list at http://edac.org/initiatives/committees/mss.

97 EDAC, "EDA Glossary," http://edac.org/industry/glossary (accessed July 24, 2013).

designers could not design new integrated circuits for manufacture without EDA test and validation tools. Another EDA offering is access to existing design patents. New integrated chips include, for example, "systems on a chip," which integrate both memory and logic processors. EDA companies acquire semiconductor patents and then license the intellectual property to other circuit designers. This service allows designers to use a proven design that they can modify or integrate with their new design. At the same time, it helps the semiconductor industry because it reduces design engineering labor needs by hundreds of hours and reduces costs by millions of dollars.[98]

Leading companies that offer all or some of these services include Cadence Design Systems, MentorGraphics, ARM, and Synopsys. In 2012, the EDA industry surpassed $6 billion in revenue, with nearly 40 percent in computer-aided engineering services. Since 1996, EDA revenues have increased steadily, around 4 percent annually on average and 6.7 percent in 2011–12.[99] However, EDA is a small sector, with revenues around 2 percent of the semiconductor industry's revenues annually over the past 15 years.[100]

Services Offered by Equipment Manufacturers

Semiconductor equipment manufacturers have in the past decade begun to offer specific services to help fabs operate their equipment and tools optimally and in concert. These services help fabs generate a higher yield of good semiconductor chips and therefore increase revenue. An analysis of public revenue data from three major tool and equipment suppliers shows that services revenue rose by about 4 percent on average annually during 2008–12.[101]

Services offered by equipment and tool manufacturers perform functions in two general categories: helping integrate the equipment into the manufacturing system, and ensuring that the equipment is working when it should. In the past, when a fab ramped up a new process, the yield of usable chips was low during the initial stages of its use. Therefore, equipment manufacturers started to offer models and simulations that accelerate the initial yield rates.[102] The second category of equipment manufacturer services places skilled technicians and certified engineers at or near customer sites to solve process problems.[103] Many equipment manufacturers provide services that ensure that tools operate correctly and do not go out of service unexpectedly. Equipment manufacturers can collect dozens to thousands of data points from all of their tools, and study the data to uncover trends indicating that a tool may fail.[104] When the trends are detected using millions of data points from thousands of machines—the Big Data analytics described earlier in the chapter—they enable still greater confidence in predicting the tool's future operating status.

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[98] EDAC representative, telephone interview by USITC staff, July 30, 2013.

[99] EDAC, "Market Statistics Service 2012," n.d. (accessed June 26, 2013).

[100] Commission analysis using data from the World Semiconductor Trade Statistics and EDA Consortium.

[101] This analysis used all revenue not from the sale of physical equipment as a proxy indicator for services revenue. Data taken from 2012 annual reports of AMAT, ASML, KLA-Tencor, LAM, and Tokyo Electron.

[102] Tribula, "The Evolution of the Semiconductor Service," 2013; KLA-Tencor, *Annual Report*, 2012.

[103] Lam Research website, ValuePoint Expert Support, http://www.lam-research.com/CSBG_2.cfm (accessed June 26, 2013).

[104] Tribula, "The Evolution of the Semiconductor Service," 2013.

Finally, some services used in semiconductor manufacturing are not captured in revenue data or economic statistics. One such service offered by semiconductor equipment manufacturers is the installation of machinery. An equipment manufacturer will send an engineer or team of engineers to install the equipment as part of the price of the equipment sale. Another example is the creation of a manufacturing execution system, a complex program that runs wafers through processing steps. A fab manager will design a manufacturing execution system internally, where it is considered a cost of manufacturing and most likely would not be captured or reported as a services purchase. These two examples show that many services may not be captured by corporate financial analysts and reported for statistical purposes.

Medical Device Industry

Software-enabled services—the principal services used in the global medical device industry—have contributed significantly to the manufacturing of medical devices across various phases of the product lifecycle. This section will first identify the factors of competition in the global industry and then describe the ways in which software solutions enable firms to remain competitive.

Healthcare professionals use medical devices to treat, diagnose, and prevent various ailments and injuries.[105] Many medical devices fall within the computer and electronic products and miscellaneous manufacturing sectors, which according to table 3.5 are intensive users of services. The medical device industry is also highly capital intensive; the industry's capital intensity was measured at 40 percent by one survey.[106] Further, due to the complexity of some medical devices—for instance, diagnostic imaging technologies—the industry relies on a highly skilled workforce to develop, design, and test products. Employees' wages in the U.S. medical device industry exceed the national average.[107]

The medical device industry is highly regulated, owing to the potentially significant health risks associated with various devices. In the United States, the Food and Drug Administration categorizes devices into three classes, with the lowest-risk devices receiving a class one rating. Most manufacturers seek class two approvals for their devices, reflecting the relatively lower regulatory burden on these devices compared to class three devices.[108] Class two and three devices make extensive use of software services throughout the product life cycle, particularly with respect to software solutions, and will be the focus of this section.

[105] Relevant NAICS codes for these devices include 325413, in vitro diagnostic substances and devices; 334510 and 334517, electromedical equipment; 339112, surgical and medical instruments; 339113, orthopedic devices and hospital supplies; and 339114, dental equipment.

[106] Only four industries surveyed ranked higher in capital intensity than the medical device industry: chemicals (50 percent); refining petroleum, coke, nuclear (56 percent); computers and office machinery (41 percent); and basic metals (41 percent). McKinsey, *Manufacturing the Future*, November 2012.

[107] In 2008, the average salary in the medical device industry was $58,000, well over the national earnings average of about $42,000. Lewin Group, "State Economic Impact of the Medical Technology Industry," June 7, 2010.

[108] Zhong, "Primer," 2012. Manufacturers of class two devices are required to demonstrate that their device is fundamentally similar to an existing device that has been approved for sale, while manufacturers of most class three devices are required to submit data from clinical trials in order to demonstrate the efficacy of the device; trials can run more than a year. Most implantable devices, including orthopedic devices, are class three devices, while many non-implantable devices, such as diagnostic equipment, are generally considered class two.

Factors of Competition

Innovation and R&D

Innovation is one of the principal determinants of competitiveness in the global medical device industry; a McKinsey survey ranked the industry's R&D intensity at 35 percent, the highest among all the industries surveyed.[109] Further, in the United States, leading U.S. medical device manufacturers commonly devote between 9 and 10 percent of their annual revenues to R&D, in contrast to an average of 3–4 percent for other domestic manufacturers.[110] R&D spending is generally devoted to developing innovative (in particular, less invasive) technologies; designing prototypes; testing products; and improving existing devices.[111] To achieve these ends, R&D teams are generally composed of engineers, computer scientists, biologists, and other highly skilled professionals.[112]

Time to market

The life cycles of most advanced medical devices are relatively short, making the speed with which products are approved another critical factor affecting competitiveness.[113] However, the approval process for medical devices can be lengthy, commonly exceeding one year and, in some cases, reaching as high as five years, during which time a firm receives no income from the device.[114] Because of the long approval process and the short product life cycles, approved devices may enjoy success on the market for as little as a year before being made obsolete by a newer product.[115] As a result, firms that are able to efficiently move through each stage of the life cycle while maintaining detailed records for regulators are more likely to launch a successful product. One study suggested that lateness getting to market was the principal reason that devices failed in the marketplace.[116]

Reimbursement

Reimbursement for the use of medical devices is a critical determinant of the type of devices an end user chooses to acquire. In the United States, hospitals and other consumers of medical devices base much of each purchasing decision on the likelihood of being reimbursed by the government or third-party insurers—the principal U.S. reimbursement entities.[117] This factor is one reason that medical device manufacturers

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[109] R&D intensity was measured as R&D expenditures as a share of value added. McKinsey, *Manufacturing the Future*, 2012.

[110] S&P, "Healthcare," 2013. R&D investment in the sector remained high during the economic recession of 2007–09, increasing by 11 percent during this time. Holtzman and Figgatt, "R&D," 2012.

[111] Johnson & Johnson, "Form 10-K" (accessed August 8, 2013); Zimmer Holdings, "2012 Form 10-K" (accessed August 8, 2013); Medtronic, "Form 10-K" (accessed August 8, 2013).

[112] S&P, "Healthcare," 2013.

[113] The estimated product life cycle for advanced medical devices is two years; USITC, *Medical Devices*, March 2007.

[114] Industry association conference (M2M), May 9, 2013, Cambridge, MA; industry representative, telephone interview by USITC staff, Washington, DC, February 24, 2010; industry representative, interview by USITC staff, Boston, MA, March 2, 2010.

[115] USITC, *Medical Devices*, March 2007.

[116] Matlis, "Design for Manufacturability," 2007.

[117] S&P, "Healthcare," 2013.

have become increasingly focused on reducing costs throughout the product life cycle, as affordability and efficacy can facilitate timely reimbursements.

Use of Services

Software-enabled services are used throughout the value chain

Software-enabled services have been the services most commonly used within the medical device industry over the past 30 years.[118] As previously stated, given the industry's competitiveness, manufacturers often try to achieve rapid time to market while keeping their costs low. To that end, software-enabled services are increasingly used throughout the value chain to facilitate production planning, parts procurement, supply chain management, product design and development, and manufacturing.[119] Although medical device firms have relied on software to manage inventories since the 1980s, the increasingly strict regulatory environment has led many manufactures to use software to document and manage risk throughout the value chain, a trend which has taken root within the past 20 years.[120] This approach, most commonly called enterprise resource planning, helps firms immediately detect and quantify the extent of problems incurred during production and digitally submit these data to regulators.[121]

Within the past 20 years, software has also become increasingly integrated into the product design and development phase, where innovation and planning often translates into eventual commercial success.[122] During this phase, computer-aided design (CAD) is commonly used to create and transmit 3-D images onto a computer screen, while also allowing sensitive data to be stored digitally.[123] 3-D modeling of prototypes has been one of the most critical drivers of manufacturing efficiencies, allowing designers to dramatically reduce the time needed to generate highly detailed designs.[124] The use of CAD became prevalent around 1995, when the software became accessible to users of personal computers.[125]

3-D printing services

Within the past decade, 3-D printing has emerged as a service used in the manufacturing of implantable devices in particular. Digitally produced designs generated during the prototyping phase can be translated into usable parts or finished products—both customized to meet a specific user's needs—using 3-D printing.[126] For instance, hearing aid manufacturers are able to use this service to create customized components that will perfectly fit a user's ear. Similarly, 3-D printing enables leading orthopedic manufacturers in the United States, such as Stryker and Zimmer, to produce joint implants that are specifically tailored to a particular user, taking into account users with a

[118] Barbella, "Agents of Change," 2013.
[119] Barbella, "Agents of Change," 2013.
[120] Barbella, "Agents of Change," 2013.
[121] Barbella, "Agents of Change," 2013.
[122] McKinsey, "Manufacturing the Future," 2012; Samuel, "The Value of High End," 2011; Delporte and Barbella, "Full-Service Outsourcing," 2013.
[123] Whitney, "The Computer Age," 2006.
[124] Bell, "Outwit," 2007.
[125] Freiherr, "CAD/CAM and Beyond," October 1, 1995.
[126] Marsh, "Technology: Game Changer," 2013.

weak bone structure, for example. With the personalized medicine market projected to double to $450 billion by 2015, customized medical solutions are expected to grow in significance.[127]

Cloud computing services

Cloud computing has also gained in popularity within the past decade, enabling users to manage each phase of the product's life cycle while achieving flexibility not allowed through other platforms. For example, whereas many of the software solutions previously discussed require installation, cloud computing is accessible from any location with an Internet connection.[128] During the product development phase, prototypes can be uploaded onto the cloud and immediately made accessible to suppliers and related partners. Similarly, data from clinical trials for certain class three medical devices can be accessed in real time by multiple users in various locations. Once the device is sold, the cloud-based service can continue; data generated from a patient with a cardiac defibrillator or an infusion pump, for example, can be transferred directly to the healthcare provider via the cloud. Additionally, the cloud enables manufacturers to give technical assistance to users of the device.[129]

Performance Textiles

In the highly competitive global textile industry, higher-cost manufacturers such as the United States must differentiate their products to remain competitive.[130] R&D services produced by private firms, collaborative organizations, and research institutions have enabled U.S. manufacturers in performance textiles to become leading producers and exporters. The traditional U.S. textile industry producing inputs for apparel and home furnishings has faced intense international competition over the past two decades; however, performance textiles have emerged as a growth area, built upon traditional textile expertise in states such as North Carolina.[131] Investments in R&D are important to the industry and result in differentiated products with technical characteristics that are not easily produced elsewhere (e.g., fireproof, water-resistant, and antiballistic products). [132]

Performance textiles are manufactured for their technical performance and functional properties rather than their aesthetic or decorative characteristics.[133] End users are found in a wide variety of industries, including the aerospace, automotive, farming, marine, medical, military, safety, transport, and construction industries.[134] The global performance textile industry is highly competitive, yet U.S. manufacturers are able to maintain a competitive advantage through innovation in highly specialized products. The

[127] Barbella, "Agents of Change," 2013.

[128] Bockrath, "Medical Devices Begin to Drift into the Cloud," n.d. (accessed July 10, 2013).

[129] Bockrath, "Medical Devices Begin to Drift into the Cloud," n.d. (accessed July 10, 2013).

[130] Nelson, "Building the Performance Cluster in North Carolina," 2007.

[131] Nelson, "Building the Performance Cluster in North Carolina," 2007.

[132] NC Textile Connect, "Summary," n.d. (accessed July 25, 2013).

[133] Textiles Intelligence, "Textile Outlook International," 2012, 187.

[134] Performance textiles are commonly divided into 12 functional areas: sport, agriculture, construction, apparel, geotextiles, industrial, home, hygiene, transportation, environmental, packaging, and protection/military. See Techtextil (International Trade Fair for Technical Textiles and Nonwovens), http://techtextil.messefrankfurt.com/ (accessed August 8, 2013). Geotextiles reinforce the soil or permit drainage in civil engineering applications, such as the construction of roads or dams.

U.S. performance textiles industry has been adding and improving production capacity in the past few years, which stands in contrast to the U.S. textile industry as a whole.[135]

Nonwovens

Nonwoven fabrics are a helpful focus for a case study in performance textiles, as they encompass a wide range of applications, including automotive, construction, personal care, and medical uses.[136] Well adapted to filtration and protection functions, common nonwoven products include medical masks and gowns; industrial filters; hygienic products such as diapers, pads, and wipes; and insulation wrap for construction. Engineered nonwovens also impart desired protection characteristics such as resistance to abrasion, impacts, ballistics, and fire. Reportedly, textiles for high-end markets, such as safety and technical textiles, are less affected by import competition than commodity-type fabrics.[137]

In 2011, the U.S. nonwoven fabrics industry employed about 17,000 workers in 228 establishments.[138] The performance textile industry is capital intensive, requiring few employees to manage large and complicated production machinery. However, while labor inputs are low, the sector requires skilled operators.[139] The value of nonwoven production rose from $7.7 billion in 2010 to $8.2 billion in 2011, accounting for roughly one-quarter of all U.S. textile production that year.[140] By volume, production of nonwoven fabrics has grown, on average, about 5 percent annually over the past 10 years and is forecast to grow 28 percent between 2012 and 2017.[141]

While the traditional U.S. textile industry has moved operations offshore, one industry source has predicted that advanced-technology manufacturing of textiles such as nonwovens will remain in the United States, as many lower-cost foreign producers are not able to produce these specialized materials.[142] In 2012, U.S. exports of nonwoven fabrics totaled $1.9 billion, or 2.3 times the value of U.S. imports of these goods.[143]

Factors of Competition

Lower shipping costs, robust domestic demand, the perceived high quality of U.S. manufacturing, and relatively low U.S. energy costs encourage domestic production and render the U.S. performance textiles industry globally competitive.[144]

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[135] See discussion, chapter 2. *Technical Textiles International*, “Signs of Recovery,” March/April 2012.

[136] Nonwoven fabric mills are provided for under NAICS 31323 and classified under HTSUS 5603. A nonwoven fabric is a manufactured sheet of directionally or randomly oriented fibers bound together through heat or an adhesive. Textiles Intelligence, “Textile Outlook International,” 2012, 180.

[137] Rasmussen, “2013 State of the Industry,” 2013.

[138] Employment in nonwovens accounted for 14 percent of total U.S. textile employment in 2011. USDOC, Census, County Business Patterns (accessed July 8, 2013).

[139] Cotton Incorporated, telephone interview by USITC staff, June 13, 2013.

[140] USDOC, “Annual Survey of Manufacturers (ASM)” (accessed July 8, 2013).

[141] Association of the Nonwoven Fabrics Industry (INDA), telephone interview by USITC staff, June 5, 2013.

[142] Panteva, “Textile Mills in the U.S.,” 2012, 4.

[143] USITC DataWeb/USDOC (accessed July 8, 2013).

[144] Reichard, “Capital Spending Perks Up,” 2013; *Technical Textiles International,* “Signs of Recovery,” March/April 2012.

Proximity to market

Though many nonwoven fabrics are lightweight, their bulk makes it cost prohibitive to ship such materials long distances. Therefore, manufacturing of nonwovens is concentrated near their end markets.[145] Both consumer and industrial demand drive growth in U.S. production of nonwoven fabrics. Consumer demand has diversified from diapers and feminine hygiene products in recent years as more nonwoven products are incorporated into everyday life. Consumer wipes and nonwoven cleaning products such as Swiffer products are now commonplace.[146] As baby boomers age, demand for adult incontinence products will likely grow as well.[147] U.S. demand for nonwovens is forecast to increase 5.7 percent annually through 2016.[148]

Nonwoven fabrics are also inputs used widely in a number of major U.S. industries. For example, nonwoven fabrics meet the increased demand in automotive manufacturing for lightweight materials to increase fuel efficiency.[149] They are also used to insulate vehicle interiors from noise and engine heat. In home construction, to take another example, durable nonwovens are used externally in insulation wraps, roofing products, and geotextiles, as well as internally in carpets, blinds, and rugs.[150]

Innovation

U.S. firms invested $1.2 billion in textile mills and textile product mills in 2011, up from $1.1 billion in 2010.[151] An industry source noted that the performance textile industry focuses its resources on “perpetual innovation,”[152] enabling the U.S. performance textile industry to be a global leader. One researcher found that R&D and the development of brands and markets are the highest value-adding activities in textile manufacturing.[153]

Research and Development

As indicated earlier in this chapter, high-tech textiles manufacturing involves complex production processes where R&D plays an important role. Such strategic business services are typically kept in-house and are put to use before or during product development. Private firms, collaborative organizations, and research institutions engage in R&D services that enhance the industry’s competitiveness. Two examples are discussed below.

[145] Cotton Incorporated, telephone interview by USITC staff, June 13, 2013; INDA, telephone interview by USITC staff, June 5, 2013.
[146] INDA, telephone interview by USITC staff, June 5, 2013.
[147] INDA, telephone interview by USITC staff, June 5, 2013.
[148] Gangloff, “U.S. Nonwovens Fabric Demand,” 2013.
[149] Cotton Incorporated, telephone interview by USITC staff, June 13, 2013.
[150] Cotton Incorporated, telephone interview by USITC staff, June 13, 2013.
[151] USDOC, Census, Annual Capital Expenditures Survey (accessed July 8, 2013).
[152] Reportedly, firms focus on developing new and better products, investment in new plants and equipment, and better marketing of their products to remain ahead of the competition. Rasmussen, “2013 State of the Industry, Part I,” 2013.
[153] Frederick et al., “A Descriptive Analysis,” 2007.

Cotton Incorporated

Cotton Incorporated (Cotton Inc.) is a private, not-for-profit organization based in Cary, North Carolina.[154] It has research projects throughout the entire cotton supply chain, from farm to market, and collaborates with private firms in their development of new technology to encourage increased use of cotton. For work on nonwovens in particular, Cotton Inc. has collaborated with the U.S. Department of Agriculture (USDA), academic research institutions, and private firms. The USDA's five-year-old research facility in New Orleans contains state-of-the-art equipment for developing and testing high-value-added nonwovens.[155]

Cotton Inc. has worked with USDA and private entities to develop cotton nonwovens for insulation (insulation is typically fiberglass);[156] with Texas Tech University, the USDA research center, and Sellars Absorbent Materials Inc. (Sellars) to develop nonwoven cotton booms for oil spill cleanup;[157] and with labs and academic institutions to develop nonwoven fabric treatments that wick moisture and perspiration, with the intention of sharing them across the textile and apparel industry.

The Nonwovens Institute

The Nonwovens Institute (NWI), housed within the North Carolina State University College of Textiles, is the largest cooperative research center in North America.[158] According to an industry source, NWI is valuable because it trains students and allows the industry access to new science.[159] NWI's research services focuses on nonwovens materials and processes technology, surface and bulk engineering, and analysis of material structure and performance.[160] NWI has spent over $30 million on its research over the past 10 years.

The NWI has facilities for product development and testing services. Its members, which include companies such as 3M, DuPont, and Procter & Gamble, as well as organizations such as Cotton Inc., can sponsor proprietary research at NWI's facilities. NWI product development examples include durable nonwovens for use in uniforms, 3-D nonwovens, and acoustical nonwovens for speakers.[161] NWI partners with a manufacturing incubator, Leaders in Innovation and Nonwovens Commercialization (LINC), that is also based at the university. LINC focuses on commercializing high-value technical nonwoven products, helping firms introduce and test new products.[162]

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[154] Cotton Inc. website, http://www.cottoninc.com/ (accessed June 4, 2013).
[155] Nonwovens Industry, "USDA-Agricultural Research Service," 2011.
[156] Cotton Inc., telephone interview by USITC staff, June 13, 2013.
[157] Cotton is naturally hydrophobic and oleophilic; therefore, cotton booms repel water, absorb oil, and float when saturated so that the boom can be picked up. Cotton Inc., telephone interview by USITC staff, June 13, 2013; Nonwovens Industry, "TTU Research Proves Power of Cotton," 2013; Sellars website, http://www.sellarscompany.com/ (accessed June 13, 2013).
[158] NWI website, http://www.thenonwovensinstitute.com/about-nwi/ (accessed June 12, 2013).
[159] Cotton Inc., telephone interview by USITC staff, June 13, 2013.
[160] NWI website, http://www.thenonwovensinstitute.com/about-nwi/ (accessed June 12, 2013).
[161] NWI, email message to USITC staff, June 7, 2013.
[162] NWI, email message to USITC staff, June 7, 2013.

Bibliography

Aberdeen Group. "Service Excellence and the Path to Business Transformation," May 2012. http://www.oracleimg.com/us/dm/aberdeen-service-transformation-1653351.pdf (accessed July 10, 2013).

Advantest. *Form 20-F (FY2012)*. Annual report for Securities and Exchange Commission. https://www.advantest.com/cs/groups/public/documents/document/zhzw/mda2/~edisp/advp006601.pdf (accessed July 10, 2013).

Antipa, Pamfili, and Marie-Elisabeth de la Serve. "International Comparisons of Industry-based Productivity Levels in the Financial and Business Services Sectors." *International Productivity Monitor* 66, no.19 (Spring 2010): 66–81.

Applied Materials. *2012 Annual Report*. http://www.appliedmaterials.com/investor-relations/annual-reports-proxy-materials (accessed July 10, 2013).

Arkell, Julian. "The Essential Role of Insurance Services for Trade Growth and Development: A Primer from the Geneva Association's Programme on Regulation and Supervision (PROGRES)." Geneva: The Geneva Association for the Study of Insurance Economics, December 2011.

ASM International. *2012 Annual Report including Form 20-F*. http://www.asmi-annualreport.com/2012/ (accessed July 10, 2013).

ASML. *Annual Report 2012*. http://www.asml.com/doclib/investor/annual_reports/2012/asml_20130213_Annual_Report_on_Form_20-F_2012.pdf (accessed July 10, 2013).

Baiman, Stanley, Serguei Netessine, and Howard Kunreuther. "Procurement in Supply Chains When the End-Product Exhibits the 'Weakest Link' Property." University of Pennsylvania. Working Paper, February 2004. http://opim.wharton.upenn.edu/risk/downloads/archive/arch145.pdf.

Barbella, Michael. "Agents of Change." *Medical Product Outsourcing (MPO)*, March 2013.

Barefoot, Kevin, and Jennifer Koncz-Bruner. "A Profile of U.S. Exporters and Importers of Services." *Survey of Current Business* 92, no. 6 (June 2012): 66–87. http://www.bea.gov/scb/pdf/2012/06%20June/0612_MNC.pdf.

Baumol, William J. "Health Care, Education, and the Cost Disease: A Looming Crisis for Public Choice." *Public Choice* 77, no. 1 (September 1993): 17–28.

Bell, Stacey L. "Outwit, Outplay, Outlast." *Orthopedic Design and Technology (ODT)*, January 2007. http://www.odtmag.com/articles/2007/01/outwit-outplay-outlast.

Berkeley Engineering. "1972: The Release of SPICE, the Industry Standard for Circuit Design," n.d. http://coe.berkeley.edu/about/history-and-traditions/1972-the-release-of-spice.html (accessed August 14, 2013).

Bernhofen, Daniel M., Zouheir El-Sahli, and Richard Kneller. "Estimating the Effects of the Container Revolution on World Trade." University of Nottingham. Working paper, February 2012.

Bhidé, Amar. *The Venturesome Economy: How Innovation Sustains Productivity in a More Connected World.* Princeton, New Jersey: Princeton University Press, 2008.

Bockrath, Melissa. "Medical Devices Begin to Drift into the Cloud." Kelly Services, n.d. http://www.kellyocg.com/uploadedFiles/Content/Knowledge/Ebooks/Medical%20Devices%20Begin%20to%20Drift%20Into%20Cloud.pdf (accessed May 31, 2013).

Boulton, Clint. "H-P Using Its Analytics Software to Grow Sales." *Wall Street Journal*, January 11, 2013. http://blogs.wsj.com/cio/2013/01/11/h-p-using-its-analytics-software-to-grow-sales/.

Bresnahan, Timothy F., and Manuel Trajtenberg. "General Purpose Technologies: 'Engines of Growth?'" *Journal of Econometrics* 65, no. 1 (1996): 83–108.

Brodkin, Jon. "Ten Cloud Computing Companies to Watch." *NetworkWorld*. May 18, 2009. http://www.networkworld.com/supp/2009/ndc3/051809-cloud-companies-to-watch.html.

Brynjolfsson, Erik. "The Productivity Paradox of Information Technology: Review and Assessment." *Communications of the ACM* 36, no. 12 (1993): 66–77.

———. "The 4 Ways IT is Revolutionizing Innovation." *MIT Sloan Management Review*, April 1, 2010. http://sloanreview.mit.edu/article/it-innovation-brynjolfsson-article/?use_credit=0084ae4bc24c0795d1e6a4f58444d39b.

Bughin, Jacques, Michael Chui, and James Manyika. "Ten IT-Enabled Business Trends for the Decade Ahead." *McKinsey Quarterly*, May 2013.

Canon Inc. *Canon Annual Report 2012*. http://www.canon.com/ir/annual/index.html (accessed July 10, 2013).

Careless, James. "The Aircraft Composites Revolution." *Aviation Maintenance*, September 4, 2012.

Champagne, Christine. "How Lay's Got Its Chips to Taste like Chicken and Waffles." *Fast Company*, February 2013.

Clarke, Peter. "Intel Confirms Ireland for 14-nm Silicon." *EE Times*, May 27, 2012. http://www.eetimes.com/electronics-news/4373886/Intel-confirms-Ireland-for-14-nm-silicon.

Copeland, Ella. "Identifying the Potential of Logistics Technology." *Supply Chain Digital*, June 2013. http://www.supplychaindigital.com/outsourcing/identifying-the-potential-of-logistics-technology.

Corrado, Carol, Charles Hulten, and Daniel Sichel. "Measuring Capital and Technology: An Expanded Framework." In *Measuring Capital in the New Economy*, ed. Carol Corrado, John Haltiwanger, and Dan Sichel, 11–46. Chicago: University of Chicago Press, 2005.

Cusumano, Michael, Steve Kahl, and Fernando Suarez. "A Theory of Services in Product Industries." MIT Sloan School of Management, Working Paper No. 242, 2008. http://ebusiness.mit.edu/research/papers/242_Cusumano_Theory%20of%20Services.pdf.

Delporte, Christopher, and Michael Barbella. "Full-Service Outsourcing: The Same, Only More So." *Medical Product Outsourcing (MPO)*, May 2013.

Ebner, Gunnar, and Jochen Bechtold. "Are Manufacturing Companies Ready to Go Digital? Understanding the Impact of Digital." Capgemini Consulting, 2012. http://www.capgemini.com/sites/default/files/resource/pdf/Are_Manufacturing_Companies_Ready_to_Go_Digital_.pdf.

Economist. "The New Industrial Revolution," April 19, 2013.

———. "The Third Industrial Revolution," April 21, 2012.

EDA Consortium (EDAC). Market Statistics Service 2012, n.d. http://www.edac.org/initiatives/committees/mss (accessed June 26, 2013).

Eurostat. "NACE Rev. 1: Statistical Classification of Economic Activities in the European Community," May 1996. http://datalib.chass.utoronto.ca/other/E0032_en.pdf.

Falk, Martin, and Elena Jarocinska. "Linkages between Services and Manufacturing in EU Countries." Servicegap Review Paper 1, November 2010. http://servicegap.org/images/Publications/rp1_falk_etal.pdf.

Fleck, Susan, Steven Rosenthal, Matthew Russell, Erich H. Strassner, and Lisa Usher. "A Prototype BEA/BLS Industry-Level Production Account for the United States." Conference paper presented at the 2nd World KLEMS conference, August 9–10, 2012.

Francois, Joseph, and Bernard Hoekman. "Services Trade and Policy." *Journal of Economic Literature* 48, no. 3 (2010): 642–92.

Francois, Joseph, and Julia Woerz. "Producer Services, Manufacturing Linkages, and Trade." *Journal of Industry, Competition, and Trade* 8, no. 3 (2008): 199–229.

Frederick, Stacy, Nancy Cassill, Blan Godfrey, and Trevor Little. "A Descriptive Analysis of North Carolina Textile Complex: 2006." *Journal of Textile and Apparel Technology and Management* 5, no. 4 (2007). http://www.textileconnect.com/documents/resources/descriptive_analysis_nc_textile_complex.pdf.

Freiherr, Greg. "CAD/CAM and Beyond: New Engineering Software Opens Doors for Medical Device Manufacturers." *Medical Device & Diagnostic Industry*, October 1995.

Gangloff, Corinne. "U.S. Nonwovens Fabric Demand." Nonwovens Industry, March 2013.

Gonzales, Frédéric, J. Bradford Jensen, Yunhee Kim, and Hildegunn Kyvik Nordås. "Globalisation of Services and Jobs." In *Policy Priorities for International Trade and Jobs*, ed. Douglas Lippoldt, 175–92. Paris: OECD, International Collaborative Initiative on Trade and Employment, 2012. http://www.oecd.org/site/tadicite/50287724.pdf.

Hesse, Markus, and Jean-Paul Rodrigue. "The Transport Geography of Logistics and Freight Distribution." *Journal of Transport Geography* 12, no. 3 (2004): 171–84.

Holtzman, Yair, and Tom Figgatt, Sr. "R&D and Investment: How Biomedical Companies Navigated Turbulent Economic Times." *Medical Device and Diagnostic Industry (MDDI)*, January 30, 2012.

IBM. "IBM THINK Booth | James Owens of Caterpillar Discusses the Effect of Big Data on Leadership." Video presentation, September 2011.

———. "IBS and IBM Optimize ERP for Midmarket Distributors," 2010. http://public.dhe.ibm.com/common/ssi/ecm/en/pos03034usen/POS03034USEN.PDF.

IC Insights. "Fabless Suppliers Play Increasing Role in IC Market," May 1, 2013. http://www.icinsights.com/news/bulletins/Fabless-Suppliers-Play-Increasing-Role-In-IC-Market/.

———. "May Update to the McClean Report." Scottsdale, Arizona: IC Insights, May 2013.

Infor. "Supporting the Lean Value Stream with Technology Solutions: A Proactive Approach to Manufacturing." Infor White Paper, n.d. http://207.54.49.46/golean/frm_wp3.html (accessed August 30, 2013).

Intel. "Accelerating Business Growth through IT: 2012–2013 Intel IT Performance Report," 2013. http://www.intel.com/content/www/xa/en/it-management/intel-it-best-practices/intel-it-annual-performance-report-2012-13.html.

Johnson & Johnson. "Form 10-K." Annual report for Securities and Exchange Commission. http://www.2012annualreport.jnj.com/sites/default/files/2012_Johnson_Johnson_Form10-K.pdf (accessed August 8, 2013).

Jorgenson, Dale W., Mun S. Ho, and Kevin J. Stiroh. "A Retrospective Look at the U.S. Productivity Growth Resurgence." *Journal of Economic Perspectives* 22, no. 1 (Winter 2008): 3–24.

KLA-Tencor. *2012 Annual Report and 10-K.* http://ir.kla-tencor.com/annuals.cfm (accessed July 10, 2013).

Knowledge@Wharton. "'Power by the Hour': Can Paying Only for Performance Redefine How Products Are Sold and Serviced?" February 21, 2007. http://knowledge.wharton.upenn.edu/article.cfm?articleid=1665.

Kommerskollegium (Swedish National Board of Trade). *Servicification of Swedish Manufacturing*. Kommerskollegium Report 2010:1, 2010. http://www.kommers.se/In-English/Global-value-Chains/.

———. *At Your Service: The Importance of Services for Manufacturing Companies and Possible Trade Policy Implications*. Kommerskollegium Report 2010:2, 2010. http://www.kommers.se/In-English/Global-value-chains/.

———. *Everybody Is in Services: The Impact of Servicification in Manufacturing on Trade and Trade Policy*. Kommerskollegium Report 2012:6, 2012. http://www.kommers.se/In-English/Global-value-chains/.

Koten, John. "A Revolution in the Making." *Wall Street Journal*, June 10, 2013.

Kox, Henk LM. "Unleashing Competition in EU Business Services." *CPB Policy Brief*, September 2012.

Kretschmer, Tobias. "Information and Communication Technologies and Productivity Growth." OECD Digital Economy Papers no. 195. Paris: OECD Publishing, 2009.

Krishnan, Suresh, Richard Sica, Lucia Fedina, and Aaron Maguire. "Structuring Multinational Insurance Programs." Ace Group and KPMG working paper, February 2011. http://www.acegroup.com/us-en/assets/multinational-insurance-programs-addressing-the-taxation-transfer-pricing-challenge.pdf.

LAM. *2012 Proxy & Annual Report*. http://investor.lamrc.com/annuals.cfm (accessed July 10, 2013).

Lesher, Molly, and Hildegunn K. Nordås. "Business Services, Trade and Costs." *OECD Trade Policy Papers*, no. 46. Paris: OECD Publishing, 2006.

Lewin Group. "State Economic Impact of the Medical Technology Industry." Prepared for AdvaMed, June 7, 2010. http://www.lewin.com/publications/publication/410/.

Lind, Michael, and Joshua Freedman. "Value Added: America's Manufacturing Future." New America Foundation, April 2012.

Lineback, Rob, Bill McClean, Brian Matas, and Trevor Yancey. *The McClean Report*. Scottsdale, Arizona: IC Insights, 2013.

Liu, Xuepeng, Aditya Mattoo, Zhi Wang, and Shang-Jin Wei. "Embodied Services and Manufacture Export Performance." Paper presented at the European Central Bank-CompNet-Peterson Institute for International Economics-World Bank conference "National Competitiveness, Scalability of International Value Chains, and Location of Production," Washington, DC, April 16–7, 2013.

Lopez, Maribel. "What You Need to Know about the New Industrial Revolution." *AT&T Networking Exchange* (blog), May 16, 2013.

Marsh, Peter. "Technology: Game Changer." *Financial Times*, March 21, 2013. http://www.ft.com/intl/cms/s/0/ae998edc-85ba-11e2-bed4-00144feabdc0.html#axzz2UsEKG0Gz.

Matlis, Daniel R. "Design for Manufacturability: Building Quality by Design." Axendia Inc., White Paper for the Medical Device Industry, June 2007. http://www.ptc.com/WCMS/files/141875/en/Design_for_Manufacturability_Building_Quality_by_Design.pdf.

Medtronic. "Form 10-K." Annual report for Securities and Exchange Commission. http://annualreport.medtronic.com/form-10k/index.htm (accessed August 8, 2013).

McCulla, Stephanie H., Alyssa E. Holdren, and Shelly Smith. "Improved Estimates of the National Income and Product Accounts: Results of the 2013 Comprehensive Revision." *Survey of Current Business* 93, no. 9 (September 2013): 14–45.

McGuire, Tim, James Manyika, and Michael Chui. "Why Big Data Is the New Competitive Advantage." *Ivey Business Journal*, July/August 2012. http://iveybusinessjournal.com/topics/strategy/why-big-data-is-the-new-competitive-advantage.

McKinsey Global Institute and McKinsey Operations Practice (McKinsey). *Manufacturing the Future: The Next Era of Global Growth and Innovation*. McKinsey & Company, November 2012. http://www.mckinsey.com/insights/manufacturing/the_future_of_manufacturing.

Medical Product Outsourcing (MPO). "The Top 30 Global Medical Device Companies," July 30, 2013. http://www.mpo-mag.com/issues/2013-07/view_features/the-top-30-global-medical-device-companies-564773/.

Miroudot, Sébastien, Rainer Lanz, and Alexandros Ragoussis. "Trade in Intermediate Goods and Services." OECD Trade Policy Papers no. 93, 2009. http://www.oecd.org/std/its/44056524.pdf.

Miroudot, Sébastien, and Dorothée Rouzet. "Trade Policy Implications of Global Value Chains: Contribution to the Report on Global Value Chains." OECD Trade Policy Papers no. 31, 2013.

Naeher, Ulrich, Sakae Suzuki, and Bill Wiseman. "The Evolution of Business Models in a Disrupted Value Chain." McKinsey & Co., Autumn 2011.

National Science Foundation (NSF). Business Research and Development and Innovation Survey. http://www.nsf.gov/statistics/industry/ (accessed July 15, 2013).

North Carolina Textile Connect (NC Textile Connect). "Summary," n.d. http://www.textileconnect.com/documents/resources/Summary.pdf (accessed July 25, 2013).

Neely, Andy. "The Servitization of Manufacturing: An Analysis of Global Trends." Paper presented at the 14th European Operations Management Association Conference, Ankara, Turkey, June 2007.

Neely, Andy. "Why Servitize: Alternative Rationales." *Andy Neely Blog*, March 5, 2013. http://andyneely.blogspot.com/2013/03/service-as-pre-sale-opportunity.html.

Nelson, Holli. "Building the Performance Cluster in North Carolina: Providing Assistance to Enhance Global Market Competitiveness of the North Carolina Textile Industry." *Journal of Textile and Apparel, Technology and Management (JTATM)*, August 28, 2007. http://www.tx.ncsu.edu/jtatm/volume5issue4/performance_tex.html.

Nikon Inc. *2012 Annual Report*. http://www.nikon.com/about/ir/ir_library/ar/index.htm (accessed July 10, 2013).

Nonwovens Industry. "TTU Research Proves Power of Cotton in Absorbing Oil." *Nonwovens Industry* 44, no. 6 (2013): 22. http://www.nonwovens-industry.com/contents/view_breaking-news/2013-05-15/ttu-reserach-proves-power-of-cotton-in-absorbing-oil/.

———. "USDA-Agricultural Research Service Makes Initiatives in Nonwovens," July 14, 2011. http://www.nonwovens-industry.com/issues/2011-07/view_online-exclusives/online-exclusive-usda-agricultural-research-s/.

Nordås, Hildegunn K. "Business Services: A Source of Comparative Advantage." Paper presented at the 13th Annual GTAP Conference, 2010. https://www.gtap.agecon.purdue.edu/resources/download/4797.pdf.

———. "Trade in Goods and Services: Two Sides of the Same Coin." *Economic Modeling* 2, no. 2 (2010): 496–506.

Nordås, Hildegunn K., and Yunhee Kim. "Interaction between Goods and Services Trade: Case Studies." OECD. Working Party of the Trade Committee. TAD/TC/WP(2013)15, June 4, 2013.

———. "Interaction between Goods and Services Trade: The Role of Services as Intermediate Inputs in Manufacturing." OECD. Working Party of the Trade Committee. TAD/TC/WP(2012)33, November 19, 2012.

———. "The Role of Services for Competitiveness in Manufacturing." OECD. *OECD Trade Policy Papers*, no. 148. Paris: OECD Publishing, 2006. http://dx.doi.org/10.1787/5k484xb7cx6b-en.

Notteboom, Theo, and Jean-Paul Rodrigue. "The Future of Containerization: Perspectives from Maritime and Inland Freight Distribution." *Geojournal* 74, no. 1 (2009): 7–22.

Oliver Wyman. "Social Media Management," 2013. http://www.oliverwyman.com/media/Oliver_Wyman_POV_Social_Media_Management_ENG.pdf .

Oracle. "Managing the Product Value Chain for the Industrial Manufacturing Industry." Oracle White Paper, June 2011.

Organisation for Economic Co-operation and Development (OECD). "Global Value Chains (GVCs): United States," May 2013. http://www.oecd.org/sti/ind/GVCs%20-%20UNITED%20STATES.pdf.

Organisation for Economic Co-operation and Development (OECD) and World Trade Organization (WTO). "OECD/WTO Trade in Value Added (TiVA) Indicators: U.S. Country Note," 2013. http://www.oecd.org/sti/ind/TiVA_USA_MAY_2013.pdf.

Panteva, Nikoleta. "Textile Mills in the U.S." IBISWorld Industry Report 31310, June 2012.

PepsiCo. "Lay's Potato Chips Teams Up with Eva Longoria and Iron Chef Michael Symon to Invite Consumers to Create the Next Great Potato Chip Flavor." Press release, July 2012.

Pilat, Dirk, and Anita Wolf. "Measuring the Interaction between Manufacturing and Services." OECD Science, Technology and Industry Working Papers 5, 2005.

PricewaterhouseCooper (PwC). "Customer Collaboration Designs Excellence," 2011. http://www.pwc.com/en_GX/gx/industrial-manufacturing/pdf/industrial-manufacturing-customer-collaboration-designs-excellence-2.pdf.

Rasmussen, Jeff. "2013 State of the Industry, Part I." *Specialty Fabrics Review*, February 2013. http://specialtyfabricsreview.com/articles/0213_f3_industry_2013.html.

Rassweiler, Andrew. "Many iPhone 5 Components Change, but Most Suppliers Remain the Same, Teardown Reveals." Press release. IHS iSuppli, September 25, 2012. http://www.isuppli.com/Teardowns/News/pages/Many-iPhone-5-Components-Change-But-Most-Suppliers-Remain-the-Same-Teardown-Reveals.aspx.

Reichard, Robert S. "Capital Spending Perks Up." *Textile World*, June 25, 2013. http://www.textileworld.com/Articles/2013/June/Web_issue/Business_And_Financial.html.

Rodrigue, Jean-Paul. "Transportation and the Geographical and Functional Integration of Global Production Networks." *Growth and Change* 37, no. 4 (2006): 510–25.

Rolls-Royce. “Rolls-Royce Celebrates 50th Anniversary of Power-by-the-Hour.” Press release, October 30, 2012.

Ruttan, Vernon. *Technology, Growth, and Development: An Induced Innovation Perspective*. New York: Oxford University Press, 2000.

Samuel, Stephen. “The Value of High End Computer Aided Design Software.” Medical Design Technology (MDT), August 8, 2011. http://www.mdtmag.com/articles/2011/08/value-high-end-computer-aided-design-software.

SAP. “Riding the Growth Wave: Leveraging Economies of Scale.” SAP White Paper, 2008. http://www.sap.com/community/flash/SAP-Authored-WP-Riding-the-Growth-Wave-Leveraging-Economies-of-Scale.pdf.

Shactman, Brian A. “UPS, FedEx Growing by Tapping ‘Adjacent Business.’” CNBC, January 23, 2012.

Solow, Robert M. “We’d Better Watch Out.” *New York Times*, January 12, 1987, 36.

Standard & Poor’s (S&P). “Healthcare: Products and Supplies,” January 30, 2013.

Stehrer, Robert, Neil Foster, and Gaaitzen de Vries. “Value Added and Factors in Trade: A Comprehensive Approach.” WIOD Working Paper 7, April 20, 2012. http://www.wiod.org/publications/papers/wiod7.pdf.

Strassner, Erich H., Gabriel W. Medeiros, and George M. Smith. “Annual Industry Accounts: Introducing KLEMS Input Estimates for 1997–2003.” *Survey of Current Business*, 85, no. 9 (September 2005): 31–65.

Technical Textiles International. “Signs of Recovery in North American Market Boost Techtextil,” March/April 2012.

Textiles Intelligence Limited. “Textiles Outlook International: Business and Market Analysis for the Global Textile and Apparel Industries.” No. 159, December 2012.

Timmer, Marcel (ed.). “The World Input-Output Database (WIOD): Contents, Sources and Methods.” WIOD Working Paper 10, 2012. http://www.wiod.org/publications/papers/wiod10.pdf.

Timmer, Marcel, Bart Los, Robert Stehrer, and Gaaitzen de Vries. “Fragmentation, Incomes, and Jobs: An Analysis of European Competitiveness.” WIOD Working Paper 9, 2012. http://www.wiod.org/publications/papers/wiod9.pdf.

Tokyo Electron. *2012 Annual Report.* http://www.tel.com/ir/library/ar/index.htm (accessed July 10, 2013).

Tribula, Dana. “The Evolution of the Semiconductor Service Model.” *Applied Materials Blog*, March 20, 2013. http://blog.appliedmaterials.com/service-3point0.

Triplett, Jack E., and Barry Bosworth. *Productivity in the U.S. Services Sector: New Sources of Economic Growth*. Washington, DC: Brookings Institution Press, 2004.

———. "Productivity Measurement Issues in Services Industries: 'Baumol's Disease' Has Been Cured." *Federal Reserve Bank of New York Economic Policy Review*, September 2003: 23–33.

U.S. Department of Commerce (USDOC). Bureau of Economic Analysis (BEA). Annual Input-Output Data. http://www.bea.gov/industry/io_annual.htm (accessed June 25, 2013).

———. GDP-by-Industry Data. http://www.bea.gov/industry/gdpbyind_data.htm (accessed July 11, 2013).

———. National Economic Accounts. http://www.bea.gov/national/index.htm (accessed July 16, 2013).

U.S. Department of Commerce (USDOC). U.S. Census Bureau (Census). Annual Capital Expenditures Survey. http://www.census.gov/econ/aces/ (accessed July 8, 2013).

———. County Business Patterns. http://www.census.gov/econ/cbp/ (accessed July 8, 2013).

———. Annual Survey of Manufactures (ASM). http://www.census.gov/manufacturing/asm/ (accessed July 8, 2013).

U.S. Department of Labor (USDOL). Bureau of Labor Statistics (BLS). Multifactor Productivity Tables. http://www.bls.gov/oes/tables.htm (accessed May 22, 2013).

———. Occupational Employment Statistics. http://www.bls.gov/oes/tables.htm (accessed June 20, 2013).

———. "Technical Information about the BLS Multifactor Productivity Measures," September 26, 2007. http://www.bls.gov/mfp/mprtech.pdf.

U.S. International Trade Commission (USITC). *Medical Devices and Equipment: Competitive Conditions Affecting U.S. Trade in Japan and Other Principal Foreign Markets*. USITC Publication 3909. Washington, DC: USITC, 2007.

———. *The Economic Effects of Significant U.S. Import Restraints: Seventh Update 2011*. USITC Publication 4253. Washington, DC: USITC, 2011. http://www.usitc.gov/publications/332/pub4253.pdf.

———. *Recent Trends in U.S. Services Trade: 2013 Annual Report*. USITC Publication 4412. Washington, DC: USITC, 2013. http://www.usitc.gov/publications/332/pub4412.pdf.

———. *Digital Trade in the U.S. and Global Economies, Part 1*. USITC Publication 4415. Washington, DC: USITC, July 2013. http://www.usitc.gov/publications/332/pub4415.pdf .

Venkatraman, Archana. "The Battle for the Cloud." *ComputerWeekly.com*, August 13–19, 2013. http://www.computerweekly.com/feature/The-battle-for-the-cloud .

Weiss, Mitchell. "Increasing Productivity in Existing Fabs by Simplified Tool Interconnection." In *Semiconductor Fabtech*. 12th ed. ICG Publishing, 2000.

Whitney, Jennifer. "The Computer Age: Simplifying Manufacturing Processes." *Orthopedic Design and Technology (ODT)*, November 2006.

World Economic Forum (WEF). *The Shifting Geography of Global Value Chains: Implications for Developing Countries and Trade Policy*. WEF, 2012.

Young, Jeffrey R. "The New Industrial Revolution." *Chronicle of Higher Education*, March 25, 2013.

Zimmer Holdings. "2012 Form 10-K Annual Report." Annual report for Securities and Exchange Commission. http://investor.zimmer.com/orderDocuments.cfm?id=21 (accessed August 8, 2013).

Zhong, Han. "Primer: The Medical Device Industry." *American Action Forum*, June 2012. http://americanactionforum.org/sites/default/files/OHC_MedDevIndPrimer.pdf.

Zurich Insurance. "Supply Chain Risk." *Insights*, 2012. http://www.zurichna.com/zna/corporatebusiness/supplychain.htm.