THE SUPPLY CHAIN ECONOMY: NEW POLICIES TO DRIVE INNOVATION AND JOBS

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This paper is an update of the MIT Innovation Initiative Policy Briefing: «The Supply Chain Economy: A New Framework for Understanding Innovation and Services» by Mercedes Delgado and Karen Mills (2017). We draw on the foundational paper Delgado and Mills (2020) and on a forthcoming article Delgado, Kim, and Mills (2020). We are grateful to Annie Dang, Rich Bryden, Gabriella Elanbeck, Aaron Mukerjee, Stefan Sorg, and Christopher Rudnicki for excellent research assistance. We thank Scott Stern, Susan Helper, Cathy Fazio, Fiona Murray, Shane Greenstein, and Manuel Trajtenberg for their helpful suggestions.

THE DOMINANT NARRATIVE: MANUFACTURING DRIVES INNOVATION

A long academic and policy debate has focused on the impact of the manufacturing capacity of a country on its economic and innovative performance. The predominant view is that the capacity to manufacture goods drives innovation because of externalities associated with the production process that improve the ability to innovate (Rosenberg, 1963; Dertouzos *et al.*, 1989; Pisano and Shih, 2009). Recently, the debate has focused on supporting «advanced manufacturing»: innovative manufacturing technologies and related processes, such as advanced materials, nanotechnology, and smart production processes (Berger, 2013; Bonvillian, 2013) (1).

The innovation debate has remained largely centered on manufacturing because it accounts for the vast majority of patents (86%), while services tend to be viewed as low-technology and lower-wage. Indeed, manufacturing has a greater intensity of Science (Figure 1), Technology, Engineering and Math (STEM) jobs than services (the percentage of employment in STEM was 9.3% vs. 5.3%) (2)

But the focus on manufacturing has resulted in a pessimistic view of the economy reflecting the decline in higher-wage manufacturing jobs (Acemoglu *et al.*, 2016) (3). During 1998-2015, manufacturing employment declined by 32%, while services grew by 25% (Figure 2).

The policy response—perhaps misguided—has been to focus on initiatives for «bringing manufacturing back» in order to create good jobs. However, manufacturing currently comprises only around 9% of employment (Figure 1). On the other hand, services account for 91% of employment, and are extremely heterogeneous – ranging from engineering and cloud computing to retail and restaurants. In this policy briefing, we present a new framework that allows us to characterize the different types of services in the economy, and show the potential in some of the service subcategories for fostering innovation and creating a growing number of high-wage, high-technology jobs.

A NEW AND COMPLEMENTARY FRAMEWORK: THE SUPPLY CHAIN ECONOMY

To better understand the drivers of innovation and economic performance, we propose a new framework that focuses on the suppliers of goods and services to businesses and the government: *the supply chain economy*. Suppliers have three attributes that make them particularly important for innovation and the growth of a country.

FIGURE 1
MANUFACTURING VERSUS SERVICES FRAMEWORK

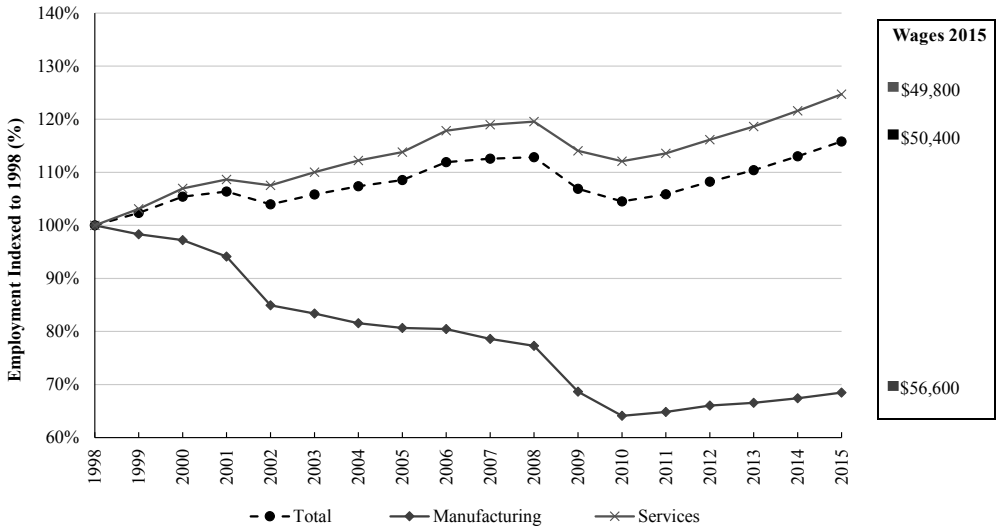
All Industries, 2015	
Employment	124M
Average Wage	$50.400
STEM Intensity	5,7%

Manufacturing	
Employment	12M (9%)
Average Wage	$56.600
STEM Intensity	9,3%
Patents	86%

Services	
Employment	112M (91%)
Average Wage	$49.800
STEM Intensity	5,3%
Patents	14%

Sourced from Delgado and Mills (2020). Note: Private employment and wages (excluding self-employed). Manufacturing includes NAICS codes 31-to-33.

FIGURE 2
PESSIMISTIC VIEW OF THE ECONOMY: BRINGING MANUFACTURING BACK



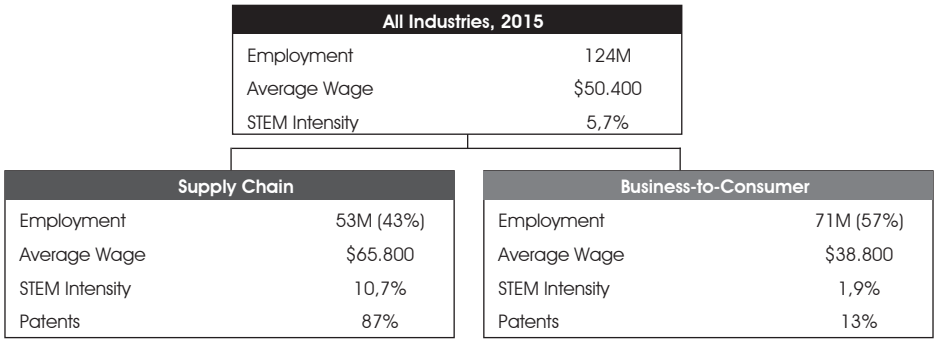
Sourced from Delgado and Mills (2020). Note: Private employment and wages (excluding self-employed).

First, they produce *specialized inputs* that are integrated in the value chain of firms. The knowledge generated in the creation and integration of these specialized inputs can create learning externalities and improve the efficiency (speed, cost, and diffusion) of the innovation process (Rosenberg, 1963, Carlsson and Jacobsson, 1991). While these specialized inputs have traditionally been manufactured products like machine tools and semiconductors, in today's world they increasingly include services like enterprise software and artificial intelligence.

Second, suppliers tend to have more downstream linkages with other industries than firms whose products are sold for personal consumption (e.g., data processing and hosting versus breakfast cereals). Hence, innovations developed by suppliers may cascade and diffuse more broadly to other industries. At the extreme, some innovative inputs can become general purpose technologies (GPTs) (Bresnahan and Trajtenberg, 1995) like semiconductors. In today's economy, service industries such as cloud computing and artificial intelligence are becoming the next wave of potential GPTs (Cockburn, Henderson, and Stern, 2018; Trajtenberg, 2019; Delgado and Mills, 2020).

A third important attribute of suppliers is that they fuel industry clusters, which spur innovation through the generation of agglomeration benefits. This attribute of suppliers rests on the theory that innovation is facilitated by links with nearby customers (Marshall, 1920; Saxenian, 1994; Porter, 1998). Suppliers' business customers are more geographically concentrated than consumers. Therefore, suppliers particularly benefit from co-location with their customers in industry clusters, exploiting and generating externalities that contribute to innovation, growth, and resilience (see e.g., Chinitz, 1961; Delgado, Porter, and Stern, 2014, Delgado and Porter, 2017).

FIGURE 3
SUPPLY CHAIN VERSUS BUSINESS-TO-CONSUMER FRAMEWORK



Source: Delgado and Mills (2020).

FIGURE 4
THE SUPPLY CHAIN VERSUS B2C SUBCATEGORIES IN MANUFACTURING AND SERVICES, 2015

	Supply Chain 2015		Business-to-Consumer 2015	
Manufacturing	Employment Average Wage STEM Intensity Patents	8.9M (7%) $59.000 10,9% 77%	Employment Average Wage STEM Intensity Patents	2.7M (2%) $48.700 4,0% 9%
Services	Employment Average Wage STEM Intensity Patents	44.4M (36%) $67.200 10,6% 9%	Employment Average Wage STEM Intensity Patents	68.0M (55%) $38.400 1,8% 5%

Source: Updated from Delgado and Mills (2020). Private employment in millions (% of US Employment, excluding self-employed) and wages (2015 USD).

To quantify the economic importance of suppliers, we introduce a new industry categorization that separates supply chain (SC) industries (i.e., those that sell their goods and services primarily to businesses or government) from business-to-consumer (B2C) industries (i.e., those that sell primarily to consumers). We use measures of industry-level sales for personal consumption from the Benchmark Input-Output Accounts to categorize narrowly defined industries as SC versus B2C (Delgado and Mills, 2020). (4)

We also combine our framework with the Manufacturing versus Services, and Traded versus Local industry categorizations to analyze specific subcategories of the economy (Porter, 2003). (5) In particular, we divide the supply chain economy into SC Traded Manufacturing industries (like *Semiconductor Manufacturing*), SC Traded Services industries (like *Engineering Services*), and SC Local industries (like *Janitorial Services*). Using this framework, we offer new insights on suppliers as a distinct segment of the economy.

THE SUPPLY CHAIN ECONOMY MATTERS FOR ECONOMIC PERFORMANCE

While there is an important literature that focuses on the management of the supply chain of particular industries and firms (Cusumano and Takeishi, 1991; Gereffi *et al.*, 2005; Helper and Kuan, 2016), there is a lack of quantification of the suppliers to the economy and their types. We find that the supply chain economy is a distinct category in terms of size, average wages, and innovative activity (Figure 3). Supply chain industries are a large segment of the economy, with 43% of U.S. private employment in 2015. They have wages 70% higher than those in B2C industries ($65,800 versus $38,800). They also have a greater STEM intensity (10.7% in SC industries versus 1.9% in B2C industries), and they account for the majority of STEM jobs and patents. Our estimates are the first comprehensive attempt to measure the economic importance of the supply chain economy.

In Today's U.S. Economy, Suppliers Are Not Just Manufacturers

We combine our categorization with Manufacturing versus Services to assess different subcategories of suppliers (Figure 4). One key finding is the economic importance of the SC Services industries versus SC Manufacturing industries: they are nearly five times larger in terms of employment; they also have almost 14% higher wages and similar STEM intensity (10.6%). This result challenges most prior work focusing on a narrow view of suppliers as manufacturers.

Our framework also helps to explain the heterogeneity in services. SC Services have significantly higher wages and

FIGURE 5
THE SUPPLY CHAIN VERSUS B2C SUBCATEGORIES WITHIN THE TRADED ECONOMY, 2015

	Supply Chain Traded 2015		Business-to-Consumer Traded 2015	
Manufacturing	Employment	8.3M (7%)	Employment	2.5M (2%)
	Average Wage	$59.800	Average Wage	$49.900
	STEM Intensity	11,4%	STEM Intensity	4,3%
	Patents	76%	Patents	9%
Services	Employment	24.5M (20%)	Employment	9,5M (8%)
	Average Wage	$83.500	Average Wage	$55.100
	STEM Intensity	17,1%	STEM Intensity	6,4%
	Patents	9%	Patents	3%

Source: Delgado and Mills (2020). Private employment in millions (% of US Employment, excluding self-employed) and wages (2015 USD).

STEM intensity than B2C Services (75% higher wages and nearly 6 times higher STEM intensity). The lower wages and technology intensity of the B2C Services are in part due to «Main Street» services that serve the local markets (like beauty salons, car repair, retail, and restaurants).

Supply Chain Traded Services Have the Highest Wages and STEM Intensity

The importance of SC Services is amplified when we examine the traded economy (i.e., industries that sell their output across regions and countries). By separating traded suppliers into manufacturing and services (Figure 5), we find that the subcategory of SC Traded Services is large and has the highest wages ($83,500, which is 66% higher than the average wage in the economy) and STEM intensity (17.1%) in the U.S. economy.

While these services are technologically advanced (with 59% of all the STEM jobs), they have few patents because innovations in services are not easily patentable. Therefore, patent-based indicators will underestimate the increasingly important contribution to innovation of high-tech services (e.g., engineering, design, R&D, software, financial, and logistics services) (Gawer and Cusumano, 2002; Sheffi, 2012; Bitner *et al*., 2008; Helper and Kuan, 2016).

The Supply Chain Economy Has Evolved towards Well-Paid Traded Services

In terms of growth, employment in the supply chain economy has been evolving away from manufacturing and towards services for the period under examination (1998-2015). Suppliers of traded services have been experiencing high growth in employment and wages. While many jobs were lost in SC Manufacturing, many high-wage jobs were created in SC Traded Services (Figure 6). This compositional change reflects the increasing importance of some service industries, like data processing and hosting, design, engineering, marketing, logistics, and software services.

By separating high-tech and high-wage SC Traded Services from low-tech and low-wage B2C Main Street Services (like retail and restaurants), we are able to offer a more optimistic view of today's service-oriented economy.

The Growth in Supply Chain Traded Services is Concentrated in Incumbent Firms

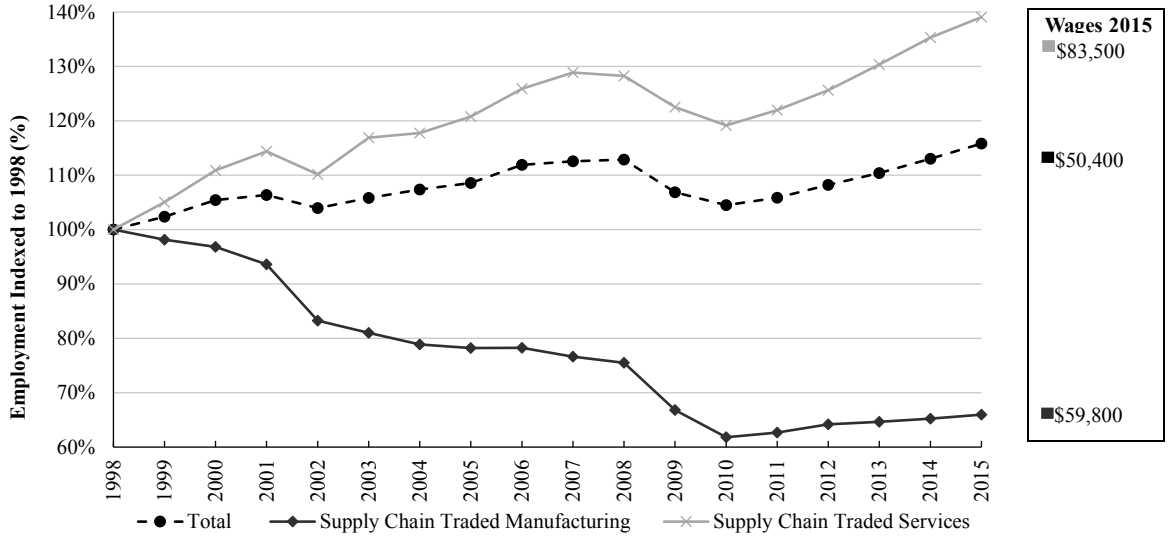
While we have documented the shift in the U.S. economy from manufacturing to innovative services, little is known regarding the types of firms that are driving the transition to SC Traded Services. In a recent paper, Delgado, Kim, and Mills (2020) explore the role of startups and established firms as potential drivers of the growth in these innovative services between 1998 and 2015.

Using the Longitudinal Business Database of the U.S. Census Bureau, they find that the growth of jobs in SC Traded Services is concentrated in established firms and has two major sources. The first source is the transformation of manufacturing firms towards services, a phenomenon referred to as «servicification» in the economic literature (Low, 2013) and «servitization» in the strategy literature (Vandermerwe and Rada, 1988; Visnjic *et al*., 2013).

As many large, incumbent manufacturing firms turned towards services, the loss of manufacturing jobs was only partially offset by the creation of fewer, yet high-wage service jobs. IBM is one example of a large, incumbent manufacturing firm that has undergone gradual servicification (Rothaermel *et al*., 2015), shifting its primary industry from manufacturing to SC Traded Services. Intel, another example, created a GPT and entire industry around semiconductors. While the company's primary industry remains in semiconductor manufacturing, it has continuously increased its presence in SC Traded Services with products in cloud and smart computing.

Incumbent service firms are the second important source of growth in SC Traded Services. These firms range from enterprise software and consulting firms like Salesforce and SAP to engineering and design service firms like Aecom and IDEO. This segment experienced high net job creation during the 1998-2015 period, capitalizing on the increasing use of data and the Internet, cloud computing, and AI technology to drive expansion. Microsoft is a prominent example: It began by building software for the emerging PC industry. However, as consumers adopted other devices like smartphones and tablets, Microsoft shifted to a «mobile-first, cloud-first» strategy under the leadership of Satya Nadella (Foley *et al*., 2017), developed Microsoft

FIGURE 6
OPTIMISTIC VIEW OF THE ECONOMY: SERVICE SUPPLIERS HAVE CREATED MANY WELL-PAID JOBS



Source: Delgado and Mills (2020).

Azure, its widely-used cloud service, and expanded its software-as-a-service (SaaS) platform, demonstrating the scalability of SC Traded Services.

The Number of Startups in Supply Chain Traded Services is Large but Declining

Data and new service GPTs are driving many innovative venture-backed startups in the area of SC Traded Services, including in financial technology («fintech»), where data infrastructure and aggregation firms supply large financial services firms (e.g., Plaid); in cybersecurity (e.g., Okta); in healthcare digital solutions (e.g., Color); and in logistics (e.g., ShipHawk), among many others. Yet Delgado, Kim, and Mills (2020) find a decline over time in the employment created by new and young firms in SC Traded Services, related to a decline in new firm entry from 1998 to 2015. One possible explanation is the acquisition of young, high-quality firms by established competitors (Kim, 2020), which may obscure their impact on employment. In the fintech space, the acquisition of innovative startups by established firms competing for the best technology and data capabilities is becoming increasingly common (Mills, 2019). For example, American Express recently acquired Kabbage, which specializes in automated lending to small businesses.

Still, SC Traded Services startups continue to play an important role in innovation and employment, accounting for a steady 19% of all U.S. startups during the 1998-2015 period. This indicates that a significant share of new ideas and new firms reside in SC Services industries and signals the importance of removing barriers to new firm entry and growth. These barriers may include impediments to access to skilled labor, capital, and buyers, as well as the protection of innovations in the absence of patents. For many of these data-centric startups, access to data will be another major policy area requiring new «smart» regulatory approaches (Mills 2019; Mills and Dang, 2021).

PROPOSED POLICY AREAS TO FOSTER THE SUPPLY CHAIN ECONOMY

Given the importance of the supply chain economy, there is an opportunity for policy makers to ask a new set of questions: What are the particular needs of different kinds of firms in the supply chain economy, and how do proposed policy initiatives affect this critical segment? Over the past decades, efforts across multiple administrations with bipartisan support have recognized the importance of manufacturing suppliers, including: the Manufacturing Extension Partnership (created in 1988); (6) the more recent American Supplier Initiative; and programs to foster innovation in the supply chain of automakers (The Executive Office of the President and the U.S. Department of Commerce, 2015). (7) In this paper, we broaden the discussion by considering the unique challenges that both manufacturing and particularly service suppliers may face with regard to accessing four critical resources: skilled labor, buyers, capital and data.

Access to Skilled Labor

The supply chain economy has a distinct labor composition with a high concentration of STEM jobs. It is well-established that STEM jobs are important for innovation and growth (Moretti, 2012). Supply chain industries, particularly those in traded services, rely heavily on skilled STEM workers who have been in short supply. This suggests that further policy emphasis on STEM training is warranted, including public and private sector efforts to train a larger and diverse talent pool and to increase the program levels on high skilled immigration.

Because of the pace of technological progress, such training opportunities should be made available and accessible to workers at all stages of their careers, rather than treated as one-time events (MIT Work of the Future Task Force, 2020). This approach will help ensure that the workforce keeps up-to-date with the skills needed for new STEM-oriented jobs within the rapidly evolving SC Traded Services subcategory.

Inter-firm collaboration in creating a talent pool. Rather than competing for talent, partnerships among suppliers and lead buyers in hiring and training could support suppliers (Cusumano and Takeishi, 1991; Helper and Henderson, 2014). (8) More broadly, policies that promote collaboration between employers and the local colleges and universities that provide training could lead to a more effective talent pipeline. Engaging large firms who have successfully transitioned towards SC Traded Services in the design of skills and training initiatives could benefit workers as well, since those who are displaced by technological change would have the opportunity to reskill for jobs that are in high demand.

Access to Buyers

Supplier-buyer co-location and collaboration. Suppliers produce inputs that are part of the value chain of other businesses. Hence, suppliers could benefit especially from co-locating with their buyers within regional clusters (Delgado and Porter, 2017). Industry clusters cannot be created, but can be catalyzed and strengthened by supporting institutions (i.e., collective efforts by firms, public entities and other institutions to improve the competitiveness of regional clusters). Regional and cluster initiatives could foster supplier-buyer networks in a location in ways that ensure both collaboration and fair competition among established and startup firms. For example, organizations like the Massachusetts Biotechnology Council (MassBio) have a long tradition of creating opportunities for suppliers and buyers to connect and collaborate. (9)

Access to Capital

Capital for STEM-intensive suppliers of services. Access to capital can be particularly difficult for young firms that produce innovative services because they often cannot be patented. Thus, it may be harder to signal quality and raise capital. Possible solutions include guarantees or credit support for suppliers seeking capital from local or federal governments or industry partners.

Relatedly, new and young innovative firms need access to capital to fund research, growth, and many other aspects of their business. Policy options that might support this goal include increasing regional support for venture capital and scale up capital, and building inclusive innovation ecosystems with accelerators and incubators where entrepreneurs can receive tailored support.

Vulnerability to demand shocks. Suppliers are vulnerable to shocks faced by their buyers (import shocks, economic crises) because these shocks can be amplified from the buyers to the suppliers (Forrester, 1961). Public initiatives that mitigate suppliers' working capital costs—like the QuickPay and SupplierPay federal programs—and policies that encourage larger companies to create partnerships with their domestic supply chains could foster growth and resilience in this critical part of the economy (Helper *et al*., 2015).

Access to Data

Finally, access to data will be crucial, particularly for new and young firms in SC Services that aim to provide innovative services for their business customers. As customers increasingly demand specialized and adaptive offerings from their suppliers, technologies like AI, which rely on the availability of vast, high-quality datasets, are taking on greater importance (Cockburn, Henderson, and Stern, 2018; Trajtenberg, 2019; Iansiti and Lakhani, 2020). This puts young firms at a disadvantage against very large and «superstar» firms, where the majority of data is concentrated. In order to foster healthy competition and entrepreneurship, policymakers should therefore embrace «smart» regulatory approaches that facilitate the secure and standardized sharing of data, while clearly defining rules around ownership and transparency.

One example of this regulatory approach is Open Banking in the fintech sector, where the United Kingdom has been a leader. The United Kingdom's Open Banking Standard mandates that banks share their data with permitted third parties (Open Banking Implementation Entity, 2021). These explicit regulations may be a major factor explaining the country's thriving fintech environment, home to many of the most innovative startups providing services to both large and small business customers (Mills, 2019; Mills and Dang, 2021). Similar «smart,» data-centric regulations are needed in many other sectors, like digital health care and supply chain logistics, to support the continued growth of new competitors who will drive more innovation in SC Traded Services.

By supporting the supply chain economy through targeted policies, government and businesses could both do their part to create the innovation and well-paying jobs that the American economy needs. What practices would be most effective in achieving these goals is a fruitful area for future research.

CONCLUSION

A new categorization of U.S. industries has revealed a large and dynamic supply chain economy which plays a crucial role in innovation and in the creation of well-paid jobs. The traditional emphasis on manufacturers misses the high wages and STEM intensity of Supply Chain Traded Services. These new insights change the innovation narrative from being focused primarily on manufacturing to being centered on the chain of suppliers of goods and services. We believe that policy options that support suppliers and their access

to skilled labor, buyers, capital, and data could have an important role in fostering innovation and economic growth.

An important question will be how different policies can support different types of firms within the larger SC Services category. With much of the job growth in these services driven primarily by mature firms—either the servicification of manufacturing firms or the growth of incumbent service firms—it will be crucial to provide workers with the skills and training that enable these firms to respond to the evolving competitive environment.

Addressing the declining number of new firms in SC Traded Services is also of the utmost importance for spurring innovation. Like incumbents, these firms have a high demand for high-skilled labor. But they also have more unique needs related to accessing capital, finding buyers, accessing data, and protecting their innovations.

Additional research is needed to shed light on the attributes of locations that can foster the growth of new and established firms in supply chain services, including the role of industry clusters and specialized skills (Delgado and Porter, 2017), the organization of supplier-buyer networks (Saxenian, 1994; Storper *et al*., 2015), and the concrete initiatives that state and local governments can take to support collaborations.

Finally, policymakers must take into consideration how COVID-19 will shape the future of supply chain businesses. How will the sudden uptick in remote work affect new firms that are building key relationships with potential employees, investors, and buyers? If some of these interactions continue to take place virtually in the long-term, how should that change policies around training initiatives and cluster development? Will these impacts differ for the most innovative businesses, who tend to need close proximity to inputs and high-skilled labor? The pandemic has also shed light on broader questions of supply chain resilience, the potential for innovation in supply chain logistics, and the extent to which some strategic products and services should be produced domestically rather than internationally. Researchers and policymakers should keep innovation front and center in these discussions, given the capacity of certain supply chain businesses to create many higher-wage jobs and drive competitiveness.

With the supply chain economy holding vast potential, an optimistic narrative around the opportunities for increased innovation and high-wage job growth can replace the dominant and pessimistic narrative rooted in the decline of manufacturing.

NOTES

[1] The Advanced Manufacturing Partnership (AMP) was created in 2011 by the White House to foster collaboration between industry, universities, and the government in innovative manufacturing. See Berger (2013) and Bonvillian (2013).

[2] The STEM intensity (or percent of employment in STEM) of an industry category captures its technological intensity. Delgado and Mills (2020) uses the STEM occupation definition developed by Hecker (2005).

[3] This decline in manufacturing employment has been in part attributed to an increase in imports from China. See Acemoglu et al., 2016.

[4] In Delgado and Mills (2020), industries (6-digit NAICS codes) that sell less than 35% of their output to Personal Consumption Expenditure (PCE) are classified as SC, and the rest are classified as B2C. They implement an extensive validation analysis that considers alternative SC vs. B2C definitions. The large economic importance of the supply chain economy, and especially traded services, is very robust to using the alternative definitions. Data with the detailed Supply Chain vs B2C industry categorization can be accessed at http://www.delgadom.com/publications/.

[5] Traded industries are those that sell their output across regions and countries versus industries that primarily serve the local market (e.g., retail). This categorization was developed by Porter (2003).

[6] The Manufacturing Extension Partnership (MEP) is part of the Department of Commerce's National Institute of Standards and Technology. Information on the MEP is available at https://www.nist.gov/mep.

[7] These initiatives are discussed at The Executive Office of the President (EOP) and the U.S. Department of Commerce (2015).

[8] Successful partnerships between Japanese automakers and their suppliers have long been documented in the supply management literature (Cusumano and Takeishi, 1991). Toyota's relational contracts with their suppliers have been associated with more effective innovation by the automaker and its suppliers, in contrast to General Motors' short-term, arm's length relationships with suppliers (See Helper and Henderson, 2014). Lead firms should consider methods that allow them to foster and value collaborations with suppliers.

[9] The Massachusetts Biotechnology Council is a not-for-profit organization founded in 1985 that supports companies in biopharmaceuticals and related life sciences clusters. See http://www.massbio.org.

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