



# The supply chain economy: A new industry categorization for understanding innovation in services

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## ABSTRACT

An active debate has centered on the importance of manufacturing for driving innovation in the U.S. economy. This paper offers an alternative framework that focuses on the role of suppliers of goods and services (the “supply chain economy”) in national performance. We identify three conceptual attributes of suppliers that make them important for innovation: they produce specialized inputs; have more downstream linkages with other industries; and benefit especially from co-locating with their customers, creating externalities. Using the 2002 Benchmark Input-Output Accounts, we estimate a new industry categorization that separates supply chain (SC) industries (i.e., those that sell primarily to businesses or government) from business-to-consumer (B2C) industries (i.e., those that sell primarily to consumers). We find that the supply chain economy is a distinct and large segment of the economy that includes primarily service providers. The SC industries, especially traded services, have higher average wages than B2C industries. The supply chain economy also has higher innovative activity as captured by the concentration of the vast majority of STEM jobs (primarily in traded services) and patents (in manufacturing). Finally, we find that employment in the economy has evolved from manufacturing into two distinct types of services (1998–2015): SC Traded Services (with the highest STEM intensity and wages) versus B2C Main Street (with the lowest STEM intensity and wages).

## 1. Introduction

A long academic and policy debate has focused on the role of the manufacturing capacity of a country in its economic and innovative performance (see e.g., Rosenberg, 1963; Dertouzos et al., 1989; Carlsson and Jacobsson, 1991; Pisano, 1996; Berger, 2013). This question has become even more relevant as the U.S. economy has shown a large decline in manufacturing employment in recent decades, in part due to increased import competition (Acemoglu et al., 2016). In this debate, the predominant view is that a country's manufacturing capacity drives innovation because of externalities associated with the production of intermediate goods (e.g., machine tools, automation equipment, and semiconductors) that improve the efficiency of the innovation process (Rosenberg, 1963; Carlsson and Jacobsson, 1991).

Most prior work on innovation focused on a narrow view of suppliers as producers of intermediate goods. However, in today's economy suppliers increasingly produce services (e.g., enterprise software). To better understand the drivers of innovation and economic performance, we offer a new framework that focuses on the suppliers of goods and

services to businesses and the government (i.e., the “supply chain economy”).

Building on economic and strategy studies, we identify three related attributes of suppliers that make them particularly important for innovation. First, they produce specialized inputs that can make the innovation process more efficient (Rosenberg, 1963). Second, suppliers tend to have more downstream linkages with other industries than firms whose products are sold for personal consumption (e.g., semiconductors versus breakfast cereals). Hence, inventions developed by suppliers may diffuse more broadly to other downstream industries (Bresnahan and Trajtenberg, 1995). Third, suppliers particularly benefit from co-location with their customers in industry clusters and generate externalities that contribute to innovation and growth (see e.g., Chinitz, 1961; Saxenian, 1994; Porter, 1998; Delgado and Porter, 2017).

The goals of this paper are to quantify and characterize the suppliers in today's economy, and to examine their role in national innovation and economic performance. A significant literature has focused on the management of the supply chain of particular (manufacturing)

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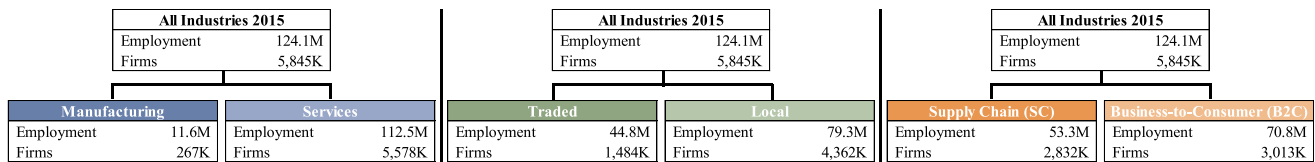


Fig. 1. Industry categorizations of the U.S. economy: employment and number of firms

Note: Private-sector non-agricultural employment (excluding self-employed). Employment in millions (M) is sourced from CBP 2015 data, and the number of firms in thousands (K) is sourced from the 2012 Economic Census (available at 5-year intervals). The Services category includes Non-Manufactured Goods.

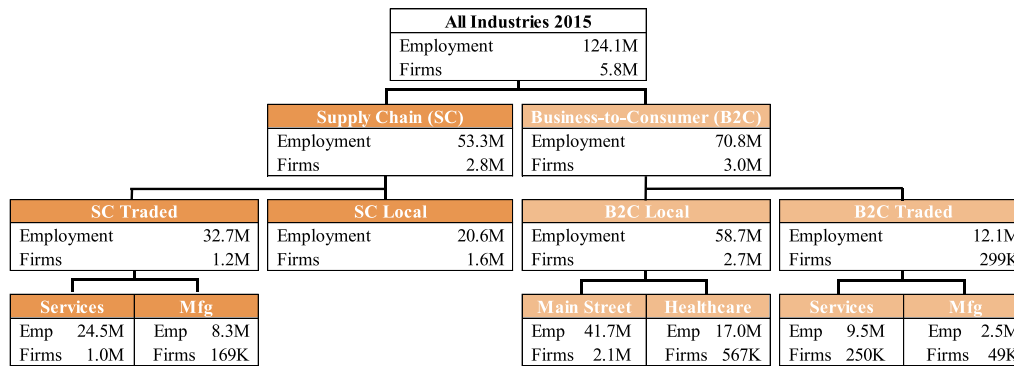


Fig. 2. The Supply chain versus B2C categorization: employment and number of firms

Note: See note in Fig. 1.

industries and firms (see e.g., Cusumano and Takeishi, 1991; Gereffi et al., 2005; Pisano and Shih, 2009; Delbufalo, 2012; Helper and Henderson, 2014), but there has been a lack of work on the size and attributes of the suppliers in the U.S. economy (Bernhardt et al., 2016). Therefore, we develop a new industry categorization that separates “supply chain” (SC) industries (i.e. those that sell primarily to businesses or the government) from business-to-consumer (B2C) industries (i.e., those that sell primarily to consumers).<sup>1</sup>

We use the 2002 Benchmark Input-Output Accounts from the U.S. Bureau of Economic Analysis (BEA) to systematically identify SC and B2C industries (six-digit NAICS codes) based on measures of industry-level sales for personal consumption. This industry categorization complements the Manufacturing versus Services categorization (Fig. 1). The innovation debate has centered on manufacturing because it accounts for the vast majority of patents. However, manufacturing currently comprises only around 9% of U.S. employment, and services are very heterogeneous. Our categorization also complements the Traded versus Local categorization introduced by Porter (1998, 2003). This work separates traded industries, which are geographically concentrated and trade across regions and countries, from local industries. The traded economy has been associated with higher innovation than the local economy because it can exploit economies of agglomeration (Delgado et al., 2014). We separate SC and B2C industries into important subcategories — Traded versus Local and Manufacturing versus Services (Fig. 2). In particular, we divide the SC category into SC Traded Manufacturing industries (e.g., *Semiconductor Manufacturing*), SC Traded Services industries (e.g., *Engineering Services*), and SC Local industries (e.g., *Security Guards and Patrol Services*).

There are four components to our contribution. First, we create a framework describing why suppliers are conceptually important for innovation. Second, we quantify the U.S. supply chain economy. Third, we show that the SC versus B2C categorization is meaningful in two

dimensions. The SC industries have a unique labor composition and statistically higher wages and innovative activity than B2C industries. Relatedly, the suppliers’ conceptual attributes that make them important for innovation seem more prominent in the SC industries. Fourth, we find that suppliers of services are distinct from suppliers of goods, and are particularly relevant for innovation and growth in high-wage jobs. We explain our main findings next.

The supply chain industries are a large and distinct segment of the economy. In 2015, they accounted for 43% of U.S. employment. These estimates are the first comprehensive attempt to measure the size of the supply chain economy.

The SC industries have statistically higher average wages than B2C industries. This is related to the presence of science and technology jobs (innovation input). Building on Hecker (2005), we estimate that the STEM intensity (i.e., percentage of employment in STEM occupations) is significantly higher in SC than B2C industries. Importantly, the same findings of higher wages and STEM intensity hold for the SC versus B2C subcategories when we condition on Traded Manufacturing, Traded Services, and Local industries. A traditional measure of innovation outcome, patenting, is also highly concentrated in the supply chain economy, which represents 87% of the U.S. utility patents granted in 2015.

A key finding of this paper is the size and economic importance of the suppliers of traded services – a result that challenges most prior work that focuses on a narrower view of suppliers as manufacturers. Suppliers of traded services accounted for three times as many jobs than the suppliers of traded manufactured goods (20% versus 7% of U.S. employment). Surprisingly, the SC Traded Services subcategory has the highest wages and STEM intensity in the economy. While most patents are held by manufacturing suppliers, the suppliers of traded services have the highest prevalence of STEM occupations (59% of STEM jobs and only 9% of patents). This large STEM-patenting gap suggests that the contribution of services to innovation may be much higher than would be predicted based on their lower patenting levels.

The importance of supply chain services for innovation is associated with their linkages with customers in multiple industries. Building on the measure of industry upstreamness of Antràs et al. (2012), we find that SC industries, and especially SC Traded Services, have more layers of buyer industries than B2C industries. This can increase their ability

<sup>1</sup> We do not examine the supply chain of individual firms (e.g., the suppliers of General Motors) or individual industries (e.g., the suppliers to the *Automobile Manufacturing* industry). Instead, our framework focuses on businesses that create inputs (e.g., engines) that are sold to other organizations or used for own-firm consumption.

to produce specialized inputs for distinct industries, and cascade and diffuse innovation (e.g., cloud computing services).

When we examine the growth trends of the SC and B2C economies (1998–2015), we find that the supply chain economy is more cyclical and its employment composition has been evolving away from manufacturing and towards services for the entire period. Suppliers of traded services have experienced high growth in employment and wages. This compositional change reflects the increasing importance of some service industries like computer programming, cloud computing, software publishers, R&D, design, engineering, and logistics services (Gawer and Cusumano, 2002; Bitner et al., 2008; Sheffi, 2012; Low, 2013; Lodefalk, 2017). It is also consistent with the evolution from manufacturing towards supply chain services that some firms have experienced over the past few decades (e.g., Cisco, IBM, Intel, and Dell Technologies).

The B2C economy has also experienced a decline in manufacturing employment, with high growth in primarily local services (Healthcare and “Main Street”). The B2C Main Street subcategory (i.e., traditional consumer-facing services, such as retail stores and restaurants) grew quickly in terms of employment, but experienced the lowest wage growth.

The analysis of the growth trends of the SC versus B2C subcategories contributes to explaining the job polarization in services identified in prior work (Autor and Dorn, 2013; Autor, 2015). The two subcategories that have created more jobs during 1998–2015 are: SC Traded Services (with the highest STEM intensity and wages) and B2C Main Street (with the lowest STEM intensity and wages).

The remainder of the paper is organized as follows: Section 2 describes the literature on the role of suppliers in innovation. Section 3 presents the methodology and data used to define SC and B2C industries. Section 4 describes the size and wages of the SC versus B2C industry categories. Section 5 examines their distinct labor occupations. The role of the supply chain economy in innovation is discussed in Section 6. The employment and wage growth trends of the SC and B2C categories are the subject of Section 7. A final section concludes and offers implications for future research.

## 2. The role of suppliers in innovation and economic performance

In the academic and policy debate, the predominant view is that manufacturing drives innovation and growth (see e.g., Rosenberg, 1963; Dertouzos et al., 1989; Pisano and Shih, 2009; Berger, 2013). We propose a new and complementary innovation framework that focuses on the suppliers of goods and services to businesses and the government: the supply chain economy. There are three conceptual attributes of suppliers that make them particularly important for the innovative activity of a country: they produce specialized inputs; they have more downstream linkages with other industries; and their customers tend to be more geographically clustered than personal consumers. Our framework emphasizes that these attributes apply to the suppliers of both goods (e.g., semiconductors) and services (e.g., software publishers).

One key attribute of suppliers is that they produce tailored inputs that are integrated into the value chain of other businesses, and these inputs must offer tangible benefits to the customers. In the economic literature, the production of specialized inputs has been linked to the innovative capacity of a country (see e.g., Rosenberg, 1963; Dertouzos et al., 1989; Carlsson and Jacobsson, 1991). Specifically, there can be learning externalities from producing specialized inputs that improve the efficiency (speed, cost, and diffusion) of the innovation process. For example, Rosenberg (1963) highlights the crucial role of the suppliers of capital goods (“machine producers”) in the process of technological innovation. A country needs a large capital goods sector (supported by domestic demand) in order for suppliers of capital goods to specialize in creating tailored machines for their buyers. This specialization among suppliers creates learning externalities that can

improve the national innovative capacity. Rosenberg's (1963) work influenced later studies of the potential negative effects of offshoring manufacturing on innovation (see e.g., Dertouzos et al. (1989) who studied multiple countries and industries; Carlsson and Jacobsson (1991) for the automation industry; Pisano (1996) for the biopharmaceutical industry; and Fuchs and Kirchain (2010) for the optoelectronics industry). Since the 2011 Advanced Manufacturing Partnership, the innovation debate has focused on increasing domestic “advanced manufacturing”: innovative manufacturing technologies and related processes, like advanced materials, nanotechnology, and smart production processes (Berger, 2013).<sup>2</sup>

In these manufacturing-centric frameworks, services often play a secondary role in innovation. The underlying assumption is that services only grow to the extent that they are tied to manufactured goods (e.g., software for smart machines). However, many service industries produce specialized inputs that are highly scalable independently of manufactured goods (e.g., enterprise software). Our supply chain framework considers that suppliers of services (e.g., design, engineering, data processing, R&D services) are important in their own right for the innovation capacity of a country. Similarly to traditional manufacturing equipment and tools, these services can make workers more productive (Haskel et al., 2012).

A second attribute of suppliers is that they tend to have more downstream linkages with other industries than firms whose products are sold for personal consumption (e.g., semiconductors versus breakfast cereals; or data processing services versus retail stores). Hence, inventions developed by suppliers may diffuse more broadly to other downstream industries, thereby generating more innovation opportunities. The intensity of downstream linkages can be particularly high in service inputs (e.g., cloud computing), reflecting the broad use of services and their potential for cascading innovation (see Section 6). At the extreme, this multiplier effect of innovative inputs can be similar to that of general purpose technologies (GPTs), such as semiconductors (the Intel 4004 microprocessor) or the Internet. GPTs are characterized by their use as inputs in many industries (“pervasive use”). This allows the knowledge embedded in the technological input to be re-used and transformed many times, generating knowledge externalities (Romer, 1990) and spawning innovations to the economy that foster productivity gains over time (Bresnahan and Trajtenberg, 1995).

A third unique attribute of suppliers rests on the theory that innovation is facilitated by the links with nearby customers (Marshall, 1920; Saxenian, 1994; Porter, 1998). Suppliers' business customers tend to be more geographically concentrated than consumers (i.e., people are everywhere, but businesses are geographically clustered by economic field). Therefore, suppliers particularly benefit from being co-located with their customers and are able to generate and exploit more economies of agglomeration. When suppliers are clustered together and located near their buyers, they can create agglomeration benefits (through shared pools of skills, technologies, knowledge, and the production of specialized inputs) fostering entrepreneurship and innovation (Marshall, 1920; Chinitz, 1961; Saxenian, 1994; Feldman and Audretsch, 1999; Helsley and Strange, 2002; Glaeser and Kerr, 2009; Delgado et al., 2014). Recent work using our categorization shows that supply chain industries benefit (in terms of growth) more than B2C industries from participating in an industry cluster (Delgado and Porter, 2017).<sup>3</sup>

<sup>2</sup> The Advanced Manufacturing Partnership was created in 2011 by the White House to foster collaboration between the industry, universities, and the government in advanced manufacturing. See Berger (2013).

<sup>3</sup> While not explored in this paper, effective collaboration between suppliers and buyers could enhance the three attributes of suppliers described in this paper. A firm's innovation process can leverage specialized inputs from its suppliers (see e.g., Cusumano and Takeishi, 1991; Helper et al., 2000; Helper and Henderson, 2014, in automotive; Primo and Amundson, 2002, in electronics industries). On the other hand, a supplier's innovations also can

Overall, the prior economic and strategy literature has suggested that suppliers are important for the innovativeness and performance of firms, regions, and countries. But *who are the suppliers to the economy?* While there are important studies that characterize the supply chain of particular industries and firms (see e.g., Cusumano and Takeishi, 1991; Gereffi et al., 2005; Ali-Yrkkö et al., 2011; Helper and Kuan, 2018), there is a lack of quantification of the size and types of suppliers in the U.S. economy (Bernhardt et al., 2016). This may have led to an underestimation of suppliers' role in innovation. In particular, much of the prior work has focused on manufactured goods and their suppliers of parts (e.g., automakers and their suppliers of auto parts). This does not capture the increasingly important role of service suppliers (e.g., design, engineering, and software services) in the value of final goods and final services.

Some studies have indeed examined the contribution of service suppliers to innovation. For example, Gawer and Cusumano (2002) showed the importance of industry-wide service platforms like Microsoft Windows for innovation. Within the traditional definition of supply chain services, Sheffi (2012) examined the importance of capital-intensive logistical and transportation services (or "logistics clusters") for driving job growth. Other studies have focused on the role of professional business services on innovation (see review by Muller and Doloreux, 2009). Recent global value chain (GVC) studies show an increasing use of services for the production of final manufactured goods (Low, 2013; Lodefalk, 2017). Most of these studies refer to the value chains of particular products. For example, the Ali-Yrkkö et al. (2011) study of the Nokia N95 smartphone found that final assembly accounted for only 2% of the value added, while services and other intangibles accounted for most of the value generated. In these GVC studies, services are often classified as "intangibles," and their contribution to the value added of final goods or final services is not properly measured due to poor data (see the reviews by Timmer et al., 2014 and Lodefalk, 2017).<sup>4</sup>

Building on prior work, we develop a systematic method to quantify the U.S. supply chain economy and the distinct subcategories of manufacturing and service suppliers, and examine their potential for innovation and creating high-wage jobs.

### 3. The supply chain categorization of the U.S. economy

In this section, we first explain prior industry categorizations: Manufacturing versus Services and Traded versus Local. Then we describe the method for defining SC industries and B2C industries. A comprehensive explanation of this methodology is offered in Appendix A.

#### 3.1. Prior categorizations of the U.S. economy

The Manufacturing versus Services categorization of industries has been broadly used in economics and policy since the creation of the Standard Industrial Classification (SIC) by the U.S. government in 1937. The later NAICS industry classification (as well as the prior SIC)

(footnote continued)

benefit from the innovative activities of its buyer firms (see e.g., work on user innovation by De Jong and von Hippel, 2009; Isaksson et al., 2016; among others). These buyer firms may be selling their products to other businesses (i.e., they are suppliers themselves), further diffusing and transforming innovative inputs. These inter-firm collaborations can be facilitated within industry clusters.

<sup>4</sup> Our paper is in line with the efforts of the GVC literature to identify and provide more empirical analysis of supply chains and their skill content. These studies use the World Input-Output Database (WIOD) and OECD-WTO Trade in Value Added data (TiVA), which are very aggregated. For instance, WIOD only includes 34 sectors and does not allow the detailed examination of supply chain services and their labor occupations that we implement in this paper.

separates out manufacturing and services industries based on what they produce. The two-digit NAICS codes 31-to-33 correspond to manufactured goods; the other codes correspond to services. In total, there are 978 (six-digit NAICS-2012) industries (excluding farming and some government activity), which are classified into 364 manufacturing and 614 service industries. Manufacturing industries accounted for 9% of total U.S. employment in 2015 (Fig. 1).<sup>5</sup>

The Traded versus Local categorization developed by Porter (2003) classifies industries based on their patterns of spatial concentration and competition. Traded industries are geographically concentrated because of agglomeration economies, and they sell their goods and services across regions and countries (e.g., automotive and financial services). Local industries are geographically dispersed (i.e., their employment in a region is proportional to the size of the population) and they sell their services primarily in the local market (e.g., retail stores and restaurants). In this paper, we use the most recent traded categorization used in Delgado et al. (2016). In the six-digit NAICS-2012 code, there are 675 traded industries and 303 local industries. In 2015, the traded industries accounted for 36% of total U.S. employment (Fig. 1). This framework has helped to examine the role of the traded economy in innovation, and shed light in particular on the role of industry clusters in regional performance (see e.g., Delgado et al., 2014).

#### 3.2. New categorization: supply chain and business-to-consumer industries

To identify and characterize the suppliers in the U.S. economy, we distinguish between Supply Chain (SC) and Business-to-Consumer (B2C) industries. Conceptually, SC industries primarily sell goods and services to businesses and the government. In contrast, B2C industries primarily sell final goods and services to personal consumers. To measure the extent to which industries sell for personal consumption, we use the 2002 U.S. Benchmark Input-Output (IO) Accounts of the Bureau of Economic Analysis (BEA). The IO Accounts allow for capturing input-output flows between industries and output flows from each industry into final use for personal consumption (see e.g., Antràs et al., 2012; McElheran, 2015; Delgado et al., 2016).

To our knowledge, we offer the most systematic and comprehensive classification of industries into SC and B2C. All six-digit NAICS industries are classified as SC or B2C based on the percent output sold to Personal Consumption Expenditure (PCE). The PCE is a final use item in the IO Accounts that captures the value of the goods and services that are purchased by households, such as food, cars, and college education. We identify industries as SC if they sell less than 35% of their output to PCE; the rest are classified as B2C (i.e., PCE score  $\geq 35\%$ ). The methodology and extensive sensitivity analyses are described in Appendix A.

Table 1 shows some representative examples of SC and B2C industries. In traded manufacturing, *Biological Product Manufacturing* is a SC industry that sells 0% of its value to PCE; *Breakfast Cereal Manufacturing* is a B2C industry that sells 90% of its value to PCE. Among traded services, *Engineering Services* is a SC industry that sells 0% of its value to PCE; *Computer Training* is a B2C industry that sells more than 86% of its value to PCE. Among local services, there are also both SC industries (e.g., *Temporary Help Services* with a PCE score of 0.5%) and B2C industries (e.g., *Full-Service Restaurants* with a PCE score of 79%).

Appendix A describes a series of sensitivity tests for validating our supply chain categorization. We explored the size distribution of the supply chain economy for different PCE scores (Fig. A1). Our estimate

<sup>5</sup> Note that Non-Manufactured Goods are part of the Services category: *Agriculture, Forestry, Fishing, and Hunting* (NAICS 11 – except *Crop and Animal Production and Aquaculture* (NAICS 111-112) because they are not part of the County Business Pattern data); *Mining* (NAICS 21); and *Construction* (NAICS 23). They represented only 6% of U.S. employment in 2015, and are dropped in the sensitivity analysis (see Section A1.3 in Appendix A).



**Table 1**  
Examples of SC and B2C industries

Industry name	Traded manufacturing		Traded services		Local	
	SC Biological product	B2C Breakfast cereal	SC Engineering services	B2C Computer training	SC Temporary help services	B2C Full-service restaurants
NAICS-2012	325414	311230	541330	611420	561320	722511
% sold to PCE	0%	90%	0%	86%	0.50%	79%

Note: PCE is Personal Consumption Expenditure. Source: 2002 Input-Output Accounts of the BEA.

of the size of the SC economy is robust for values around our baseline PCE score with small changes in employment size. Importantly, in addition to our baseline definition of SC versus B2C industries (SC if PCE < 35% and B2C if PCE ≥ 35%), we use two alternative definitions: we re-define B2C industries as those with more than 65% of their output sold to PCE to better contrast SC and B2C industries (SC if PCE < 35% and B2C if PCE ≥ 65%); and we develop a “proportional” definition of SC industry that uses the PCE score to proportionally allocate each industry's outcome (e.g., employment) to the SC and B2C categories (e.g., using the SC Proportional-PCE definition, if the PCE is 25%, then 75% of the industry employment is allocated to the SC category and the rest to the B2C category). Our core findings on wages, STEM intensity, patenting, and growth dynamics are robust to these alternative SC versus B2C categorizations (see Table A4 in [Appendix A](#)).

### 3.3. Combining industry categorizations

We examine the three pairs of industry categories described above: Manufacturing versus Services, Traded versus Local, and SC versus B2C ([Fig. 1](#)). We then separate SC and B2C industries into Traded and Local because traded industries exploit agglomeration economies and can be particularly important for innovation and jobs ([Porter, 2003](#); [Delgado et al., 2014](#)). In doing so, we create four mutually exclusive subcategories that add up to the total economy: SC Traded, B2C Traded, SC Local, and B2C Local ([Fig. 2](#)).

In the traded economy, we further separate SC and B2C industries into Manufacturing and Services, creating four subcategories (SC Traded Manufacturing, SC Traded Services, B2C Traded Manufacturing, and B2C Traded Services). In the local economy, we divide the B2C industries into Healthcare services (e.g., hospitals) and “Main Street” (e.g., retail). Hence, there are three local subcategories: SC Local, B2C Main Street, and B2C Healthcare. This distinction allows us to shed some light on the labor composition and dynamics of local services.<sup>6</sup>

At the most disaggregated level of analysis, the total economy is divided into seven mutually exclusive subcategories ([Fig. 2](#)). The full classification of the six-digit industries (NAICS-2012 definition) into these SC and B2C subcategories is available in the supplemental online [Appendix B: Supply Chain and Business-to-Consumer Industry Categorization](#) ([www.delgadom.com](http://www.delgadom.com)).

### 3.4. Data

We use the County Business Patterns (CBP) dataset produced by the U.S. Census Bureau to measure the employment and wages of the industry categories (and subcategories) over the 1998–2015 period. The CBP is a publicly available database that assigns each establishment to its primary industry to compute annual county-level measures of private-sector non-agricultural employment (excluding self-employed) and payroll at the level of six-digit NAICS codes (which we refer to as industries). Data on the number of firms by industry is sourced from the U.S. Census Bureau's 2012 Economic Census (available at 5-year

intervals).<sup>7</sup> We use the Occupational Employment Statistics (OES) Survey administered by the Bureau of Labor Statistics (BLS) to calculate the labor occupation composition of each industry (see [Section 5](#)). The employment, number of firms, payroll data, and labor occupation data is aggregated from individual industries into our categories and subcategories.

Patent data is drawn from the U.S. Patent and Trademark Office (USPTO). Our analysis uses utility patents of U.S. origin that are granted to organizations. Constructing patenting measures for each of our industry categories is complicated because patents are assigned to patent classes but are not directly matched to industry codes. Building on [Delgado et al. \(2016\)](#), we have created a bridge between the four-digit SIC-1987 codes and our NAICS code based industry subcategories. We then use a revised version of the patent class-SIC code concordance algorithm developed by [Silverman \(2002\)](#): patents are assigned, on a fractional basis, to four-digit SIC codes in a consistent (but somewhat noisy) manner.<sup>8</sup>

## 4. The supply chain economy matters: many high-wage jobs

Our new categorization allows for a better understanding of the supply chain economy across several metrics: the size in terms of employment and number of firms ([Section 4.1](#)); wages ([Section 4.2](#)); labor occupation composition ([Section 5](#)); innovation ([Section 6](#)); and national growth ([Section 7](#)).

### 4.1. Size of the supply chain economy: employment and firms

[Fig. 2](#) shows the size, in terms of employment in 2015 and number of firms in 2012, across the SC and B2C industry subcategories.<sup>9</sup> In our industry categorization, the underlying data is at the establishment level (see [Section 3.4](#)). A firm's employment is distributed across its establishments and allocated to the industry of each establishment. Thus, our industry categorization does not map perfectly into firm-level data because some firms have establishments in multiple industries in SC and B2C. To calculate the number of firms in each of our subcategories, we use the 2012 Economic Census, which assigns each firm to one primary NAICS and then reports the number of firms by industry (see [Section A1.2](#) in [Appendix A](#)).

We find that suppliers are a large part of the economy. SC industries accounted for 53 million jobs (43% of U.S. employment), and roughly

<sup>7</sup> More detail about the Economic Census data can be found at <https://bhs.econ.census.gov>.

<sup>8</sup> In this paper, we revised the [Silverman \(2002\)](#) algorithm in two ways. First, we included new International Patent Classification (IPC) groups reported by the USPTO but not in the Silverman algorithm. These new IPC groups accounted for around 7% of the patents. Second, we broke out the IPC G06F group (*Electric Digital Data Processing*), which has the largest number of patents (15% in the most recent year), into its 12 subgroups to better assign patents to software versus hardware. This allows us to identify a larger number of software patents.

<sup>9</sup> We use the year 2012 for the analysis because the data on the number of firms is only available at 5-year intervals.

<sup>6</sup> The vast majority of Local industries are services. See [Appendix B](#).

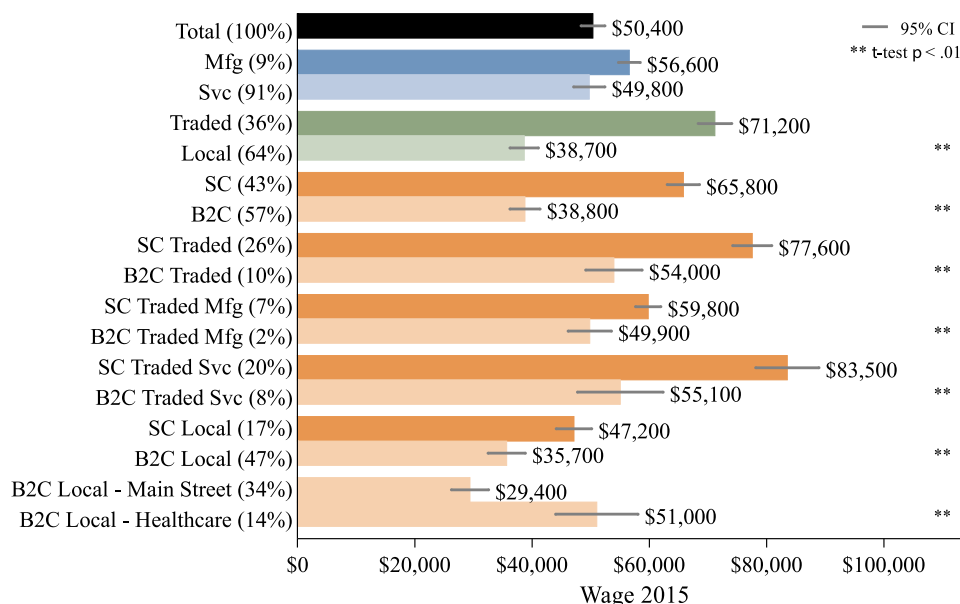


Fig. 3. Where are the good jobs?: Average wages, 2015

Note: Wages in 2015 USD. The %s in parentheses represent percent of total private employment in 2015. The *t*-test of the differences of means between selected pair of categories and subcategories are reported in Table 3.

2.8 million firms (48% of U.S. firms). The estimates of the size of the SC economy are slightly larger if we use the SC Proportional-PCE definition (49% of employment; Table A4b in Appendix A).

We separate SC industries into Traded and Local. Traded suppliers account for 33 million jobs (26% of U.S. employment) and 1.2 million firms. Prior work on the role of suppliers in the economy has focused primarily on manufacturers, but Fig. 2 shows that suppliers of traded services account for 24.5 million jobs (20% of U.S. employment), while suppliers of traded manufactured goods account for around 8 million jobs (7% of U.S. employment). Furthermore, there are six times as many traded supplier firms in services as in manufacturing (1 million versus 169,000). Examples of large SC Traded industries (and firms) are *Aircraft* (e.g., Boeing) and *Surgical and Medical Instruments* (e.g., Boston Scientific) in Manufacturing; and *Engineering Services* (e.g., Aecom) and *Computer Systems Design Services* (e.g., Accenture) in Services (see Table A2).

Local suppliers are also important, with about 21 million jobs (17% of U.S. employment) and 1.6 million firms. Large SC Local industries (and firms) include *Janitorial Services* (e.g., Blackmon Mooring) and *Security Guards and Patrol Services* (e.g., Universal Protection), among others (see Table A2).

#### 4.2. Wages in the supply chain economy versus B2C economy

What types of jobs are created in the supply chain economy? Fig. 3 shows the average wages (weighted by industry employment) for the total economy and for each industry subcategory in 2015. The average wage in the total economy (\$50,400) is computed by dividing total payroll by total employment. We find that the jobs in the supply chain economy have wages 70% higher than those in B2C industries (\$65,800 versus \$38,800). Importantly, this wage premium is statistically significant at the 1% level, as illustrated in Fig. 3 (the *t*-test of the difference in means is reported in Table 4). In addition, the same findings hold for the SC versus B2C subcategories when we condition on Traded Manufacturing, Traded Services, and Local industries. Furthermore, the findings are robust to using simple means (Table 4) and wages in the initial year (1998). Thus, the wage premium of the SC category and subcategories is not driven by particular industries or years.

Where are the best paid jobs? Surprisingly, Fig. 3 shows that the SC Traded Services subcategory has the highest average wage of \$83,500 (i.e., 66% higher wages than in the total economy). In contrast, B2C

Local Main Street industries have the lowest average wage, \$29,400 (42% lower wages than in the total economy). Thus, there is much heterogeneity across services in terms of wages that has persisted over time (Section 7).

The statistically higher average wages in the SC subcategories, and in particular in the traded services, are robust to a series of sensitivity analyses. First, this finding holds for our alternative definitions of SC and B2C categories (see Table A4 in the Appendix). Interestingly, the average wages of B2C industries are lower for those with a higher consumer orientation (PCE  $\geq$  65%), especially for Main Street industries (including retail stores, restaurants, and repair shops, among others).<sup>10</sup>

Second, we exclude Finance, Insurance, and Real Estate (FIRE) services because they include the SC industries with the highest wages in the economy (e.g., *Investment Banking and Securities Dealing* that has average wages of \$349,000). Excluding these services, wages decline slightly for both the SC and B2C categories (\$63,400 and \$36,700), but SC wages continue to be about 70% higher (Table A4c). The SC Traded Services remains the subcategory with the highest wages (\$78,600).<sup>11</sup> This subcategory includes many industries with high-paying jobs beyond financial services (e.g., software, business, marketing, design, transportation and logistics, energy, and R&D services).

Importantly, these findings – higher wages in SC versus B2C subcategories – hold when we compute the wages separately for the subgroups of small firms (1–500 jobs) and large firms (more than 500 jobs) using the 2012 Economic Census. As expected, average wages are higher for large firms. But when we compare within the subset of large and small firms, large SC firms have average wages about 58% higher than large B2C firms (\$73,000 vs. \$46,100 in 2012; 2015 USD); and small SC firms have wages about 69% higher than small B2C firms (\$54,500 vs. \$32,200).

The SC wage premium findings seem to be in contrast to the findings in prior work on domestic outsourcing that suggests that wages are lower for suppliers (see review by Bernhardt et al., 2016). There are several explanations for this. First, these studies often focus on the supply chain

<sup>10</sup> The B2C Main Street wage declines to \$23,300 for industries with PCE > 65% (Table A4c).

<sup>11</sup> The sensitivity analysis that excludes FIRE industries is explained in Section A1.3 in Appendix A.

of a large ‘lead firm’ in manufacturing (e.g., the suppliers of Boeing). In our categorization, large firms can be part of the supply chain economy: Boeing, Intel, and Microsoft are examples of firms in SC industries.

Second, wages for suppliers will depend on the governance structure of the supplier-buyer networks (Gereffi et al., 2005). Wages for suppliers will be lower if the large lead firms are able to exert power over their smaller suppliers, and force them to reduce costs by paying lower wages. In contrast, suppliers can have bargaining power when they produce specialized inputs that improve the performance of their customers. In this case, the human capital required and the value of the input should be high, leading to higher pay for supplier workers. Indeed, recent studies suggest that advanced countries have been increasingly trading service inputs (like software and design) that require high-skilled labor (Timmer et al., 2014).

Another potential explanation for the SC wage premium is based on efficiency wage theory (Krueger and Summers, 1988) that shows that industries may pay higher wages for equally skilled workers to lower turnover and elicit more effort. If knowledge and innovations related to the production of specialized inputs are increasingly embedded in STEM workers, firms may be using wages to attract, retain, and increase the effort of these workers. If so, similar STEM occupations could have higher wages in SC than B2C industries. This logic would be consistent with our findings of highest wages in the Supply Chain Traded Services subcategory, where there are many STEM jobs and it is difficult to protect innovations with patents (see Section 6).

Finally, the main explanation for the SC wage premium is the high concentration of innovative activity in these industries (see Section 6).

## 5. Distinct labor occupation composition of the supply chain economy

We examine the labor occupation composition of the SC and B2C industries to assess whether they have distinct labor pools. In particular, we identify the top narrowly defined labor occupations (Section 5.2) and the subset of Science, Technology, Engineering and Math (STEM) occupations (Section 6.1) in each subcategory of the economy. This analysis helps to explain the observed higher wages in the SC, and especially in traded services industries.

### 5.1. Measuring the labor composition across industry categories

We use the Occupational Employment Statistics (OES) Survey administered by the Bureau of Labor Statistics (BLS), which provides information on the prevalence of over 800 occupations (six-digit Standard Occupational Classification (SOC) codes) within each industry.<sup>12</sup> The OES data provide the percentage of an industry  $i$  total employment in each occupation  $o$  ( $occupation_{oi} = emp_{oi}/emp_i$ ). We compute the percentage of an industry subcategory employment in the occupation using a weighted average of  $occupation_{oi}$  as follows:

$$\text{Occupation Intensity}_o^S = \sum_{i \in S} \frac{emp_i}{emp_S} \times occupation_{oi} \quad (1)$$

where  $o$  indexes the labor occupation (e.g., *Software Developers*) and  $i$  indexes the industries (six-digit NAICS) that belong to the subcategory  $S$  (e.g., SC Traded Services); and  $occupation_{oi}$  is weighted by the industry's share of the subcategory employment ( $emp_i/emp_S$ ).<sup>13</sup> For example, the *Software Developers* occupation accounts for 2.3% of the SC Traded Services employment (Table A5a). We implement this analysis for each

of the occupations to identify the ones that are particularly important in the SC and B2C subcategories (see Section 5.2).

We also identify and aggregate the subset of STEM occupations using Hecker's (2005) definition of high-technology (scientific, engineering, and technician) occupations (84 six-digit SOC codes).<sup>14</sup> This allows us to measure the prevalence of STEM jobs (innovation inputs) in the supply chain and B2C economies. As in Eq. (1), the percentage of employees with STEM occupations (i.e., “STEM intensity”) in each subcategory is computed as follows:

$$\text{STEM Intensity}_S = \sum_{o \in \text{STEM}} \sum_{i \in S} \frac{emp_i}{emp_S} \times occupation_{oi} \quad (2)$$

Then we can approximate the percent of total STEM jobs in each subcategory as follows:

$$\text{STEM Jobs}_S(\% \text{Total}) = \frac{emp_S \times \text{STEM Intensity}_S}{\text{STEM Jobs}_{\text{Total}}} \quad (3)$$

The STEM Intensity and STEM Jobs of each of the SC and B2C subcategories are reported in Table 2 (see Section 6).

### 5.2. Top labor occupations in SC versus B2C industries

What labor occupations are particularly important in the supply chain economy? Table A5 in Appendix A shows the top ten occupations for the SC and B2C subcategories in the traded (Table A5a) and local economy (Table A5b). Comparing subcategory pairs where the only definitional difference is the SC/B2C designation (e.g. SC Traded Manufacturing vs. B2C Traded Manufacturing) reveals that SC industries are composed of distinct labor occupations. Conditioning on Traded Manufacturing, five out of the ten top occupations are unique to the SC versus B2C subcategory. SC Traded Manufacturing's unique top occupations are the traditional goods-producing jobs: *Machinists*, *Welders*, and *Electrical Equipment Assemblers* (7% of the subcategory employment), and *General and Operations Managers* (2%). However, B2C Traded Manufacturing occupations are weighted more towards jobs in packaging (8%) and food processing activities (11%).

In Traded Services, seven (out of ten) top occupations are unique to the SC versus B2C subcategory. The SC Traded Services industries (the subcategory with the highest wages) have top occupations in STEM (*Software Developers* with 2% of the employment) and non-STEM fields, including logistics (*Laborers and Movers* (4%) and *Truck Drivers* (3%)) and managerial and accounting activities (7%). In contrast, the B2C Traded Services have a large presence of hospitality occupations like *Maids and Housekeeping Cleaners* (5%) and *Hotel, Motel, & Resort Desk Clerk* (3%).

Finally, there are also relevant differences in the labor occupation composition of the subcategories of the local economy, which have nine (out of ten) non-overlapping top occupations. SC Local industries top occupations cover an array of low-skill jobs, including *Janitors and Cleaners* (4%), *Truck Drivers* (4%) and *Security Guards* (4%). In contrast, in the B2C Main Street industries (the subcategory with the lowest wages), the top occupations are primarily related to low-skill retail and food-services (e.g., *Retail Salespersons* (10%), *Cashiers* (8%) and *Food Preparation & Serving Workers* (7%)). As expected, top occupations in Healthcare include nurses and medical aides, and only one occupation (*Personal Care Aid*) is shared with B2C Main Street.

<sup>14</sup> Hecker (2005; p. 58) identifies as high-technology occupations: *Computer and Mathematical Scientists* (SOC 15-0000); *Engineers* (SOC 17-2000); *Drafters, Engineering, and Mapping Technicians* (SOC 17-3000); *Life Scientists* (SOC 19-1000); *Physical Scientists* (SOC 19-2000); *Life, Physical, and Social Science Technicians* (SOC 19-4000); *Computer and Information Systems Managers* (SOC 11-3020); *Engineering Managers* (SOC 11-9040); and *Natural Sciences Managers* (SOC 11-9120). A broader definition of occupations with STEM knowledge has been used to identify “advanced” industries by Muro et al. (2015). We use the traditional Hecker (2005) definition because it focuses on a smaller set of occupations that may better capture technology-oriented workers.

<sup>12</sup> We are using four-digit NAICS data because of better labor occupation coverage than using less aggregated NAICS. Note that six-digit NAICS industries with the same four-digit NAICS will have the same occupational composition. The OES data can be accessed at <http://www.bls.gov/oes>.

<sup>13</sup> The employment in the industry and its subcategory ( $emp_i$  and  $emp_S$ ) are sourced from the CBP data.

**Table 2**  
STEM occupations and utility patents across subcategories, 2015

	STEM Intensity 2015			STEM Jobs (% Total) 2015			Patents 2015		
	All 1	Computer 2	Engineer 3	All 4	Computer 5	Engineer 6	000s 7	% Total 8	Intensity 9
Total	5.7%	3.0%	1.1%	100%	100%	100%	126.5	100%	1.0
Manufacturing (Mfg)	9.3%	1.7%	4.3%	15%	5%	36%	108.7	85.9%	9.4
Services (Svc)	5.3%	3.2%	0.8%	85%	95%	64%	17.8	14.1%	0.2
Traded	13.0%	6.8%	2.6%	83%	81%	85%	122.9	97.2%	2.7
Local	1.5%	0.9%	0.3%	17%	19%	15%	3.6	2.8%	0.0
Supply Chain (SC)	10.7%	5.5%	2.4%	81%	78%	90%	109.5	86.6%	2.1
B2C	1.9%	1.2%	0.2%	19%	22%	10%	17.0	13.4%	0.2
SC Traded	15.6%	8.1%	3.4%	73%	70%	80%	107.4	84.9%	3.3
B2C Traded	6.0%	3.4%	0.6%	10%	11%	5%	15.5	12.3%	1.3
SC Traded Mfg	11.4%	2.2%	5.5%	13%	5%	32%	96.5	76.3%	11.7
B2C Traded Mfg	4.3%	0.6%	1.3%	2%	0%	2%	11.2	8.9%	4.4
SC Traded Svc	17.1%	10.1%	2.7%	59%	66%	47%	10.9	8.6%	0.4
B2C Traded Svc	6.4%	4.2%	0.4%	9%	11%	3%	4.3	3.4%	0.4
SC Local	2.8%	1.3%	0.7%	8%	7%	11%	2.1	1.7%	0.1
B2C Local	1.1%	0.7%	0.1%	9%	11%	5%	1.5	1.2%	0.0
B2C Main Street	1.1%	0.8%	0.1%	7%	9%	4%	1.2	1.0%	0.0
B2C Healthcare	1.0%	0.6%	0.0%	2%	3%	0%	0.2	0.2%	0.0

Note: *STEM Intensity* is the % of the subcategory jobs that are in STEM (e.g., 10.7 out of 100 SC jobs are in STEM) and *STEM Jobs* is the % of Total STEM jobs in the subcategory. Computer occupations (SOC 15-1000) and Engineer occupations (SOC 17-2000). *Patent Intensity* is the number of patents per 1,000 jobs.

Overall, we find that the SC and B2C subcategories have a different composition of narrowly defined labor occupations. This suggests that our categorization could help policymakers create more targeted skills and training programs directed towards growing jobs in the supply chain economy. We examine next whether the presence of STEM occupations is also distinct in the SC and B2C subcategories.

## 6. The role of the supply chain economy in innovation

Where is innovation taking place in the U.S. economy? To answer this, we examine both innovative inputs (STEM occupations) and outputs (patenting). If the conceptual attributes of suppliers that make them important for innovation are in place (i.e., they produce specialized inputs, have greater intensity of downstream links, and exhibit greater agglomeration economies), we would expect innovation activity to be over-represented in the supply chain economy. In this section, we show that STEM jobs and patenting are concentrated in the SC industries (Section 6.1), and that the conceptual attributes of suppliers that would drive innovation are indeed higher for SC industries (Section 6.2).

### 6.1. Innovation inputs and outputs: supply chain vs. B2C industries

Where are the STEM occupations in the U.S. economy? We estimate that the STEM intensity of the U.S. economy was only 5.7% in 2015 (i.e., 5.7 out of 100 jobs were in STEM), which corresponds to around 7 million STEM jobs. The STEM intensity of the U.S. has increased slowly over the last decade: from 4.9% in 2002 (Hecker, 2005) to 5.7% in 2015 (Table 2).

If STEM skills are important to produce differentiated inputs, we would expect STEM occupations to be particularly relevant for suppliers. Indeed, SC industries account for 81% of all the STEM jobs, and have a much larger intensity of STEM occupations than B2C industries (10.7% versus 1.9%). This difference in STEM intensity is statistically significant at the 1% level (Table 3). The STEM intensity is also statistically higher in the SC Traded Manufacturing industries than in the B2C Traded Manufacturing industries (11.4% versus 4.3%), in the SC Traded Services industries than in the B2C Traded Services industries (17.1% versus 6.4%), and in the SC Local industries than in the B2C Local industries (2.8% versus 1.1%).<sup>15</sup>

<sup>15</sup> The higher STEM intensity of the SC versus B2C subcategories also hold when we use simple means (Table 3).

What subcategory of the supply chain economy has the largest STEM intensity? The economic geography literature predicts that traded industries will be more innovative than local industries because they exploit agglomeration economies (Porter, 2003). This is consistent with our finding of significantly higher STEM intensity in traded versus local suppliers. What is remarkable is that the STEM intensity is the highest in the SC Traded Services (17.1%), not in the SC Traded Manufacturing industries (11.4%).<sup>16</sup> To understand why SC Traded Services are the most STEM intensive, we separate out the two biggest STEM employment categories: Computer occupations (SOC 15-1000) and Engineer occupations (SOC 17-2000). The latter includes the traditional engineer occupations that tend to be associated with manufacturing jobs, while computer occupations include software and web developers and computer programmers, among others. Table 2 shows that the largest STEM intensity for SC Traded Services is driven by Computer occupations intensity, which is statistically higher than for SC Traded Manufacturing (10.1% versus 2.2%). In contrast, Engineer intensity is statistically greater for SC Traded Manufacturing (5.5% versus 2.7%).

Besides having the greatest STEM intensity, suppliers of traded services account for more than 59% of all the STEM jobs. Hence, they have high technology intensity and can play an important role in the innovation and growth of a country by producing specialized inputs for multiple industries (see Section 6.2).

Our findings of higher wages and STEM intensity of SC industries, and in particular of SC Traded Services, add new insights to the literature on increasing intangible capital in trade. In particular, Timmer et al. (2014) examined the Global Value Chain (GVC) of many final manufactured goods (1995-2008 period), tracing the value added by the labor and capital used for the production of a final good.<sup>17</sup> They find that within GVCs, advanced countries increasingly specialize in activities developed by high-skilled workers. They suggest that a

<sup>16</sup> The STEM intensity findings are robust to using earlier years of occupation data; to excluding the STEM manager occupations (e.g., *Natural Sciences Managers*), which are slightly more prominent in services; and to using the alternative definitions of SC vs. B2C industries (see Table A4a in Appendix A).

<sup>17</sup> Timmer et al. (2014) model the GVC of a final product using Leontief's (1936) input-output model that traces the amount of factor inputs needed to produce a certain amount of the final product (i.e., producing output requires capital, labor, and intermediate inputs; and the intermediate inputs require capital, labor and intermediate inputs themselves, and so on, until all intermediates are accounted for).



**Table 3**  
Mean wages and innovative activity: SC vs. B2C industries

	Industries	Wages 2015 (000s)		STEM Intensity 2015		Patent Intensity 2015	
	Obs. 1	Weighted mean 2	Mean 3	Weighted mean 4	Mean 5	Weighted mean 6	Mean 7
SC	592	\$65.8	\$63.6	10.7%	8.6%	2.1	10.9
B2C	380	\$38.8	\$45.4	1.9%	3.0%	0.2	2.8
t-test Diff. of Means		14.1**	9.9**	12.0**	8.6**	2.4*	3.2**
SC Traded Mfg	266	\$59.8	\$60.0	11.4%	10.9%	11.7	20.0
B2C Traded Mfg	89	\$49.9	\$48.6	4.3%	3.9%	4.4	10.7
t-test Diff. of Means		4.5**	5.6**	5.6**	4.8**	1.6	1.4
SC Traded Svc	216	\$83.5	\$74.5	17.1%	8.1%	0.4	0.3
B2C Traded Svc	98	\$55.1	\$63.9	6.4%	5.8%	0.4	0.4
t-test Diff. of Means		5.8**	2.2**	4.7**	1.6	0.0	-0.5
SC Local	110	\$47.2	\$50.7	2.8%	3.6%	0.1	0.5
B2C Local	193	\$35.7	\$34.6	1.1%	1.1%	0.0	0.4
t-test Diff. of Means		4.2**	8.5**	3.5**	3.5**	0.6	0.12

Note: \*\* and \* t-test of the difference of the means is statistically significant at the 1% and 5% significance levels. We report the weighted means over industries in each group (weight is industry employment in 2015) or the simple means. To compute the t-test, we estimate the following equation by OLS (weighted or un-weighted):  $Y_{i,2015} = \alpha + \beta SC_i + \varepsilon_i$ , where  $Y_i$  is *Wages*, *STEM* or *Patent Intensity* of industry  $i$ , and  $SC$  is a dummy variable equal to one for SC industries. The t-test of the estimated  $\beta$  is reported. Findings hold if we re-define B2C (PCE > 65%) and exclude FIRE.

potential explanation is that advanced countries are producing intangible capital (including software, databases, R&D, and design) that requires high-skilled labor (Haskel et al., 2012). In our framework, this intangible capital (previously hidden from view) is part of the supply chain services industries that produce specialized inputs by leveraging a STEM labor force.

We have shown that an important innovation input, STEM jobs, is concentrated in the supply chain economy. We next examine a traditional measure of innovation outcome: patenting. We ask, what segments of the U.S. economy produce more patents? Table 2 reports the number of utility patents granted (column 7), the percentage of total patents (column 8), and the patent intensity (column 9) across the subcategories in 2015. Consistent with prior work, we find that manufacturing has the majority of patents (86% of all patents),<sup>18</sup> and a high patent intensity (9.4 patents per 1,000 jobs).

A new and important finding is that the number and intensity of patents is significantly higher in the SC industries (87% of patents and 2.1 patent intensity) than in the B2C industries (13% of patents and 0.2 patent intensity). In particular, the SC Traded Manufacturing subcategory has most of the patents (76%), and the largest patent intensity (11.7).<sup>19</sup>

Another key finding is the size of the gap between the STEM content and the patenting level of the suppliers of traded services. This subcategory has 59% of all STEM jobs (and 47% of Engineers) and the highest STEM intensity (17.1%), but it only accounts for about 9% of patents in 2015. There are several possible explanations for the STEM-patenting gap. First, a small part of the gap is because of the mismatch between patent classes and industry codes. In particular, the headquarters industry, which accounts for 7% of the STEM jobs, is assigned zero patents.<sup>20</sup> Second, STEM talent may be attracted to high wage but

low-patenting services (e.g., investment banking). Third, not all STEM jobs are the same. Those in traded services versus manufacturing may have lower skill intensity (e.g., fewer PhDs, lower grades in STEM education), and this could result in a lower ability to patent (Shu, 2016). Finally, given the large size of the gap, a more plausible explanation is that services are difficult to patent (Hipp and Grupp, 2005; Helper and Kuan, 2018), and that their patents are more litigated in the existing Intellectual Property regime (see e.g., Allison et al., 2012, study of patents for new methods of doing business on the Internet). Hence, patenting activity will underestimate innovation in services and, more broadly, in industries that do not rely on patents to protect their innovations (Cohen et al., 2000; von Hippel, 2005).

One important area for future research is to develop new measures of service innovation at the firm and industry levels that can map the process of creating and delivering new services (see e.g., Bitner et al., 2008). These new measures could take into account the STEM intensity of service industries, and their linkages with buyer industries (see Section 6.2).

## 6.2. Quantifying the conceptual attributes of suppliers that matter for innovation

To further validate the relevance of our industry categorization, we provide empirical evidence that two attributes that make suppliers important for innovation — product differentiation (6.2.1) and downstream industry links (6.2.2) — are more prominent in the supply chain economy.

### 6.2.1. Differentiated products in SC versus B2C industries

A relevant attribute of suppliers is that they tend to produce *specialized* inputs. To quantify this attribute, we examine the broadly used Rauch (1999) classification of differentiated versus homogenous products. Specialized inputs will likely have a higher degree of differentiation than consumer products because they are tailored for the needs of customers, and involve specific investments to develop innovative inputs that can be integrated into the value chain of the business customers (Section 2). Not all inputs are specialized; some are commodities. However, to the extent that supply chain industries produce specialized inputs, we will expect their products to be more differentiated than those in B2C industries.

Rauch (1999) classifies manufactured goods and a subset of Non-Manufactured Goods in the Standardized International Trade Classification (SITC) into three categories: differentiated products versus

<sup>18</sup> Similarly, Autor et al. (2016) estimate that manufacturing accounts for 71% of all corporate patents with U.S.-based inventors and an application year of 2007. The difference in the estimates may be due to several factors. First, we use U.S. utility patents granted to all organizations versus to Compustat firms. Second, the matching methods are different: from patent to firm name to industry in Autor et al. (2016) versus our patent-industry matching using a revised Silverman (2002) algorithm (Section 3). Our estimates offer a good approximation of the patent size of each subcategory, but they have some noise given the complexity in matching patent classes to industries.

<sup>19</sup> These findings are robust to using alternative definitions of SC industries (see Table A4a in Appendix A).

<sup>20</sup> The Silverman (2002) algorithm assigns zero patents to Headquarters (NAICS 551114), and instead assigns the patents to the industries whose goods or services are closer to the patent technology class.

homogeneous products traded on organized exchanges and reference priced products. For our analysis, we created a bridge from the SITC to six-digit NAICS codes, and calculate the % *Differentiated Products* in each industry.<sup>21</sup> We then compute the average differentiation across industries within SC Manufacturing, B2C Manufacturing, and Non-Manufactured Goods (which are part of the SC Services). We find that the SC Manufacturing subcategory has a statistically higher % *Differentiated Products* than the B2C Manufacturing subcategory (83.2% versus 66.4% weighted mean); and Non-Manufactured Goods have significantly lower differentiation than the Manufacturing subcategories (5.5%).<sup>22</sup>

We need to be cautious with these findings. Rauch (1999) identifies the most obvious commodity industries (e.g., mining industries with zero % *Differentiated Products*).<sup>23</sup> However, it does not seem to capture well the degree of differentiation in other industries because it cannot properly separate pure product (price) proliferation from differentiation, and so, classifies the majority of manufactured goods as differentiated.<sup>24</sup> This finding is consistent with Corsetti et al. (2018), who show that by using Rauch (1999), about 80% of Chinese exports are classified as differentiated.<sup>25</sup>

If we can only use the Rauch (1999) classification to separate goods that are obvious commodities, how can we measure the potential of an industry to produce specialized manufactured and service inputs? This is an area for future work. We could use indicators that capture the complementary knowledge and investments required to integrate specialized inputs into the value chain of the customers, including new business models, STEM skills, and other intangibles (Cohen and Levinthal, 1990; Brynjolfsson et al., 2018). In particular, we propose that one useful indicator is STEM intensity. Science and technology skills have been associated with firm absorptive capacity (Cohen and Levinthal, 1990) that complements R&D collaboration and product or process innovation (Leiponen, 2005). Suppliers with STEM skills may be more capable of creating the absorptive capacity needed for successfully integrating the specialized inputs into the value chain of their customers. This logic is consistent with the significantly higher STEM intensity of SC industries versus B2C industries.

#### 6.2.2. Intensity of downstream industry links in SC versus B2C industries

Another important reason why supply chain industries matter for innovation is that they have more downstream linkages to industries, which allows the innovations they create to diffuse and cascade across the economy (see Section 2). Using the 2002 U.S. IO Accounts, we build two distinct measures of downstream links. The first variable, *Direct Buyers Share*, focuses on direct buyer industries. It is defined as the share of industries buying from the focal industry  $i$  any dollar value:

<sup>21</sup> Rauch (1999) develops conservative and liberal scores (i.e., more products are classified as undifferentiated). We focus on the liberal scores, but the same findings hold with the conservative ones. The % *Differentiated Products* variable works better for industries with 0 or 100% product differentiation. For industries with a mix of differentiated and commodity products, ideally we would weigh each SITC product by its output.

<sup>22</sup> This analysis is based on 354 industries: 241 in SC Manufacturing, 86 in B2C Manufacturing, and 27 in Non-Manufactured Goods. The weighted means are based on industry employment in 2015.

<sup>23</sup> There are 62 industries with zero % *Differentiated Products*. These industries represent 1% of U.S. jobs. Many of them are Non-Manufactured Goods. Our findings are robust to excluding the Non-Manufactured Goods (Section A1.3 in Appendix A).

<sup>24</sup> The median % *Differentiated Products* across manufacturing industries is 100%. Thus, the unweighted mean of % *Differentiated Products* is similar for SC vs. B2C Manufacturing (about 75%), and remains significantly higher than the unweighted mean of Non-Manufactured Goods (9.5%).

<sup>25</sup> Using the Corsetti-Crowley-Han-Song linguistics-based classification (using product description in custom forms), the Chinese exports that are highly differentiated drop from 80% to 39%.

$$\text{Direct Buyers Share}_i = \frac{1}{N} \sum_{j=1}^N I(\text{output}_{ij} > 0) \quad (4)$$

where  $\text{output}_{ij}$  is the output of industry  $i$  supplied to buyer industry  $j$  and  $I$  is an indicator function.

For the innovative products to diffuse, it may not be required that they are sold to many direct buyer industries, but that they are sold primarily to industries that are themselves selling to other industries (buyers of buyers). To capture this, we employ the measure of industry upstreamness (or average distance from final use) developed in Antràs et al. (2012). For the case of a closed economy with  $N$  industries the *Upstreamness* of industry  $i$  is defined as:

$$\text{Upstreamness}_i = 1 + \sum_{j=1}^N \frac{\text{output}_{ij}}{\text{output}_i} \text{Upstreamness}_j \quad (5)$$

where  $\frac{\text{output}_{ij}}{\text{output}_i}$  is the share of industry  $i$ 's output supplied to buyer industry  $j$ . This variable reflects the notion that industries primarily selling to relatively upstream industries should be relatively upstream themselves.<sup>26</sup> Using matrix algebra, the vector of the industries' upstreamnesses  $U$  can be derived as  $U = [I - \Delta]^{-1} \mathbf{1}$ , where  $I$  denotes the identity matrix,  $\Delta$  is a square matrix with  $\frac{\text{output}_{ij}}{\text{output}_i}$  in entry  $(i, j)$ , and  $\mathbf{1}$  denotes a column vector of  $N$  ones.<sup>27</sup>

In our data, this variable ranges from 1 to 4.3. It takes a minimum value of 1 for industries that do not sell intermediate inputs to other industries (e.g., *Religious Organizations*). In contrast, it takes a high value for industries that sell most of their output to buyer industries that have multiple layers of buyers, and so, are farther away from personal consumers (e.g., *Timber Tract Operations* and *Cloud Computing*; see Fig. 4). The correlation between industry PCE score and *Upstreamness* score is high (-0.74). But there is variation in the upstreamness score even among SC industries with zero PCE score (e.g., *Biological Product* versus *Cloud Computing*; Fig. 4).

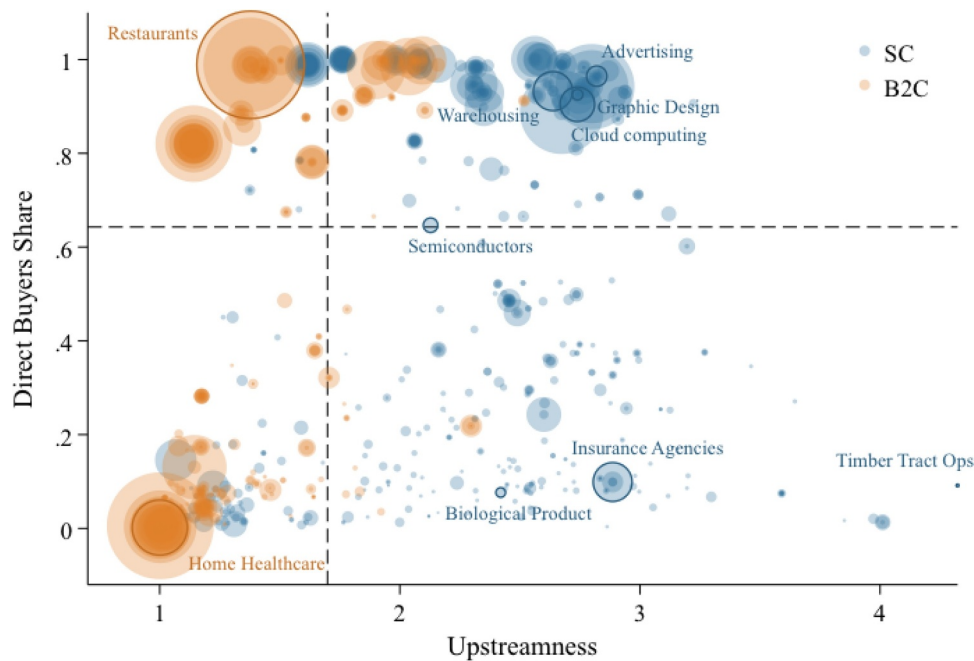
While SC industries tend to have higher *Direct Buyers Share* and *Upstreamness* than B2C industries (Table 4), these two measures of downstream linkages are distinct as illustrated in Fig. 4 (with a correlation coefficient of only 0.14). Some SC industries have high *Upstreamness* but very few *Direct Buyers* (e.g., *Timber Tract Operations*; *Biological Product*). The industries with the highest potential for diffusing and spawning innovation will have both a high number of direct buyers and a high share of output sold to upstream buyers. Fig. 4 shows that the vast majority of these industries are SC ones, including services such as *Cloud Computing*, *Industrial and Graphic Design*, and *Advertising*.

For each of our downstream link variables, we compute the weighted mean (based on industry employment) across the industries in the SC versus B2C subcategories (Table 4).<sup>28</sup> The mean *Direct Buyers Share* is significantly higher for the SC than B2C category (0.80 versus 0.53). The same findings hold for the SC versus B2C subcategories when we condition on Traded Manufacturing, Traded Services, and Local industries. Interestingly, the SC Local subcategory has the highest *Direct Buyers Share* (0.89), which reflects that some services like *Tax Preparation* and *Landscaping* sell to many industries.

<sup>26</sup> The industry definition used in equations 4 and 5 are the 535 industry codes in the 2002 IO Accounts (528 NAICS codes and 7 Government industries). We then bridge the 528 NAICS codes into the 972 NAICS-2012 industries.

<sup>27</sup> The *Upstreamness* measure decomposes an industry's output  $Y_i$  into its use as a final good  $F_i$  and as an intermediate input  $Z_i$  to other industries (potentially including itself) at different positions in the value chain. Specifically, in a closed economy with  $N$  industries (without inventories)  $Y_i = F_i + Z_i = F_i + \sum_{j=1}^N d_{ij} Y_j$ ; where  $d_{ij}$  denotes the amount of industry  $i$  output required to produce one unit of industry  $j$  output (in dollar value). Antràs et al. (2012) show that this system of linear equations can be simplified as equation (5) and solved using simple matrix algebra.

<sup>28</sup> We also compute simple means over industries and the same findings hold (Table 4).



**Fig. 4.** Downstream industry links of SC vs. B2C industries

Note: See Table 4. Plot for 972 NAICS-2012 industries. The size of the circle represents industry employment. The dashed lines mark the weighted mean across all industries for *Upstreamness* (1.7) and *Direct Buyers Share* (0.64).

**Table 4**  
Mean downstream industry links: SC vs. B2C industries

	Industries	Direct buyers share		Upstreamness	
	Obs.	Weighted mean	Mean	Weighted mean	Mean
	1	2	3	4	5
Total	972	0.64	0.52	1.70	1.90
SC	592	0.80	0.57	2.26	2.25
B2C	380	0.53	0.45	1.28	1.36
t-test Diff. of Means		10.8**	4.6**	35.6**	26.5**
SC Traded Mfg	266	0.40	0.31	2.15	2.22
B2C Traded Mfg	89	0.10	0.11	1.32	1.30
t-test Diff. of Means		8.3**	6.6**	12.7**	14.1**
SC Traded Svc	216	0.86	0.73	2.31	2.36
B2C Traded Svc	98	0.62	0.55	1.56	1.59
t-test Diff. of Means		6.5**	3.9**	12.4**	11.7**
SC Local	110	0.89	0.88	2.24	2.12
B2C Local	193	0.53	0.55	1.23	1.28
t-test Diff. of Means		6.8**	7.3**	21.1**	17.3**

Note: Upstreamness (Antràs et al., 2012). Based on 2002 IO tables (528 NAICS codes bridged into 972 NAICS-2012 industries). \*\*t-test of the difference of the means is statistically significant at the 1% level. See Table 3 note. Findings hold if we re-define B2C (PCE ≥ 65%) and exclude FIRE.

The preferred indicator of the connections of an industry to downstream activities is the *Upstreamness* score, since this measure represents the chain of buyers of buyers that can transform an industry's intermediate goods or services. The *Upstreamness* score is statistically higher for the SC versus B2C industries (2.26 versus 1.28 weighted mean), even when we condition on the subcategories of Traded Manufacturing, Traded Services, or Local industries. The subcategory with the highest *Upstreamness* is SC Traded Services (2.31), which is statistically higher than SC Traded Manufacturing (2.15). This suggests that some inventions developed by supply chain services may diffuse more broadly to other downstream industries and in some cases can become potential GPTs. Modern equivalents of GPTs like semiconductors reside increasingly in service inputs like cloud computing and artificial intelligence

(Brynjolfsson et al., 2018). For example, cloud computing services (NAICS 518210) and semiconductors (NAICS 334413) are both SC industries with a PCE score of zero and have high (above the mean) *Direct Buyers Share* and *Upstreamness*, but cloud computing services are sold to 90% of all industries (versus 65% for semiconductors) and have an *Upstreamness* 29% higher than that of semiconductors (2.7 versus 2.1).

## 7. The role of the supply chain economy in national growth

We have shown that the supply chain categorization is relevant in terms of distinct wages, labor composition, and innovation activity. In this section, we compare the growth in employment and real wages of the SC and B2C subcategories to assess if they also have different growth trends.<sup>29</sup> This analysis helps us to better understand the evolution of the U.S. economy from manufacturing into services. We study the overall growth patterns from 1998 to 2015 (Section 7.1) and the vulnerability of the SC and B2C subcategories to economic crises (Section 7.2).

### 7.1. Employment and wage growth, 1998–2015

Table 5 displays the level of employment, real wages (2015 USD), and their growth over the 1998–2015 period for each industry category and subcategory. We find that the employment composition of the economy has changed significantly in the last 18 years. The manufacturing category shows the largest decline (-32% versus 16% for the total U.S. economy) amounting to a loss of 5.3 million jobs. In contrast, the services category has been growing fast over the period (25%) with a gain of 22.3 million jobs.

To explain these different growth trends in manufacturing and services, we examine our SC and B2C subcategories in detail. Employment within the SC Traded subcategory has evolved away from manufacturing and towards services continuously during the period

<sup>29</sup> The growth trend findings across the SC and B2C subcategories presented in this section hold when we use the alternative definitions of SC versus B2C industries (see Appendix A, Table A4).

**Table 5**  
Employment and wage trends across subcategories, 1998–2015

	Employment						Real Wages (2015 USD)		
	1998		2015		1998–2015		1998	2015	1998–2015
	Mill 1	% Total 2	Mill 3	% Total 4	Growth 5	Net Mill 6	\$000 7	\$000 8	Growth 9
<b>Total</b>	<b>107.1</b>	<b>100%</b>	<b>124.1</b>	<b>100%</b>	16%	<b>16.9</b>	<b>\$44.3</b>	<b>\$50.4</b>	<b>14%</b>
Manufacturing	16.9	16%	11.6	9%	-32%	-5.3	\$52.1	\$56.6	9%
Services	90.2	84%	112.5	91%	25%	22.3	\$42.9	\$49.8	16%
Traded	41.4	39%	44.8	36%	8%	3.3	\$58.7	\$71.2	21%
Local	65.7	61%	79.3	64%	21%	13.6	\$35.3	\$38.7	10%
SC	48.2	45%	53.3	43%	11%	5.1	\$55.6	\$65.8	18%
B2C	58.9	55%	70.8	57%	20%	11.8	\$35.2	\$38.8	10%
SC Traded	30.1	28%	32.7	26%	9%	2.6	\$63.6	\$77.6	22%
B2C Traded	11.3	11%	12.1	10%	6%	0.7	\$45.8	\$54.0	18%
SC Traded Mfg	12.5	12%	8.3	7%	-34%	-4.3	\$54.8	\$59.8	9%
B2C Traded Mfg	3.5	3%	2.5	2%	-27%	-1.0	\$44.6	\$49.9	12%
SC Traded Svc	17.6	16%	24.5	20%	39%	6.9	\$69.9	\$83.5	20%
B2C Traded Svc	7.9	7%	9.5	8%	21%	1.7	\$46.3	\$55.1	19%
SC Local	18.1	17%	20.6	17%	14%	2.5	\$42.3	\$47.2	12%
B2C Local	47.6	44%	58.7	47%	23%	11.1	\$32.6	\$35.7	9%
B2C Main Street	34.7	32%	41.7	34%	20%	7.0	\$28.6	\$29.4	3%
B2C Healthcare	12.9	12%	17.0	14%	32%	4.1	\$43.5	\$51.0	17%

Note: Real wages in 2015 USD using CPI-U (All Urban Consumers; BLS).

examined (see Fig. 5a for the annual employment trends). SC Traded Manufacturing registered the lowest growth (-34%) in the economy and low wage growth (9%). In contrast, SC Traded Services had the largest increase in the share of total employment (from 16% in 1998 to 20% in 2015), and registered the strongest growth across all of the subcategories (39%). This growth has been accelerating in the most recent years (Fig. 5a). They also experienced high growth in real wages (20%) despite having the largest initial wages (\$69,900 in 1998). In contrast, the SC Local subcategory growth over the period was lower than the U.S. economy.

Within the B2C Traded subcategory, manufacturing employment also registered a significant decline (-27%), but this was accompanied by a more moderate increase in B2C Traded Services (21%) as compared to the powerful growth of SC Traded Services (39%). The evolution of the B2C economy employment from manufacturing towards services is reflected largely as an increase in *local* services (Main Street and Healthcare). The B2C Healthcare subcategory experienced high growth in wages (17%) and especially in employment (32%). In fact, Healthcare is the only subcategory growing employment every year (see Fig. 5b). In contrast, B2C Main Street, which had the lowest initial wages (\$28,600 in 1998), experienced the smallest growth in real wages during the period (3%), but had high employment growth (20%). This finding is amplified when we focus on Main Street industries with higher value sold to personal consumption, like retail stores and restaurants.<sup>30</sup>

Overall, our analysis suggests that the evolution from manufacturing towards services is especially important in the supply chain economy, which lost 4.3 million manufacturing jobs in the 1998–2015 period. During this period, the SC Traded Services subcategory disproportionately created high-paying jobs (6.9 million), and became the largest contributor to total income in the U.S. economy (with 33% of total payroll by 2015). The superior growth and higher wages of the SC Traded Services is consistent with their high intensity of STEM jobs (Leiponen, 2005; Moretti, 2010), and their multiple linkages with downstream industries (see Section 6.2). This growth reflects the increasing importance of service industries, like data processing and

hosting, design, engineering, marketing, logistics, and software services. It also reflects the fact that some large firms have evolved from being largely manufacturers to providers of services. For example, IBM has invested in artificial intelligence (IBM Watson) and Intel has increased focus on cloud computing services versus semiconductors. Further research is needed to understand the strong growth in supply chain services, and their potential multiplier effect on jobs in the rest of the economy.

Importantly, the supply chain versus B2C framework helps explain the job polarization in services identified in prior work (Autor and Dorn, 2013; Autor, 2015). The two services subcategories that have created more jobs during 1998–2015 are SC Traded Services (with the highest STEM intensity and wages) and B2C Main Street services (with the lowest STEM intensity and wages). Both types of services involve tasks that may be difficult to automate (Autor, 2015): “abstract” tasks in SC Traded Services and “manual” tasks in B2C Main Street. Both subcategories generated a similar number of jobs during the period (about 7 million each), but with very different skills and wages. Understanding where and why these jobs are being created is an important area for future research.

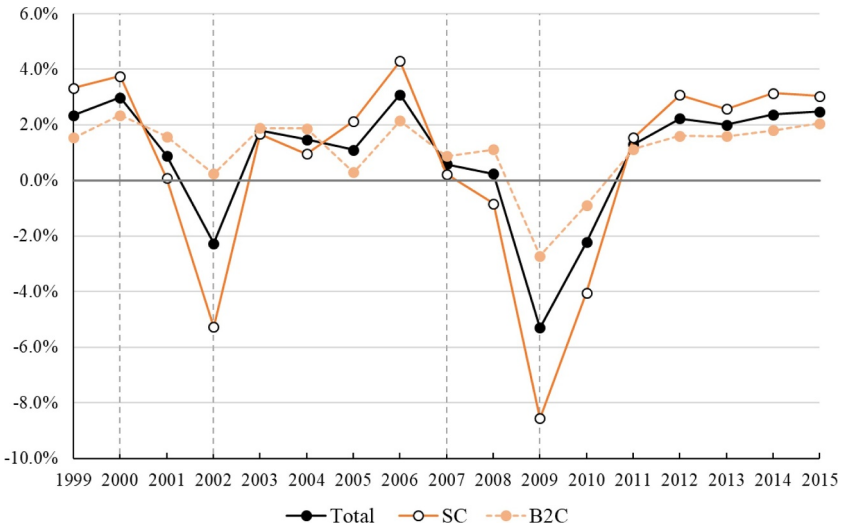
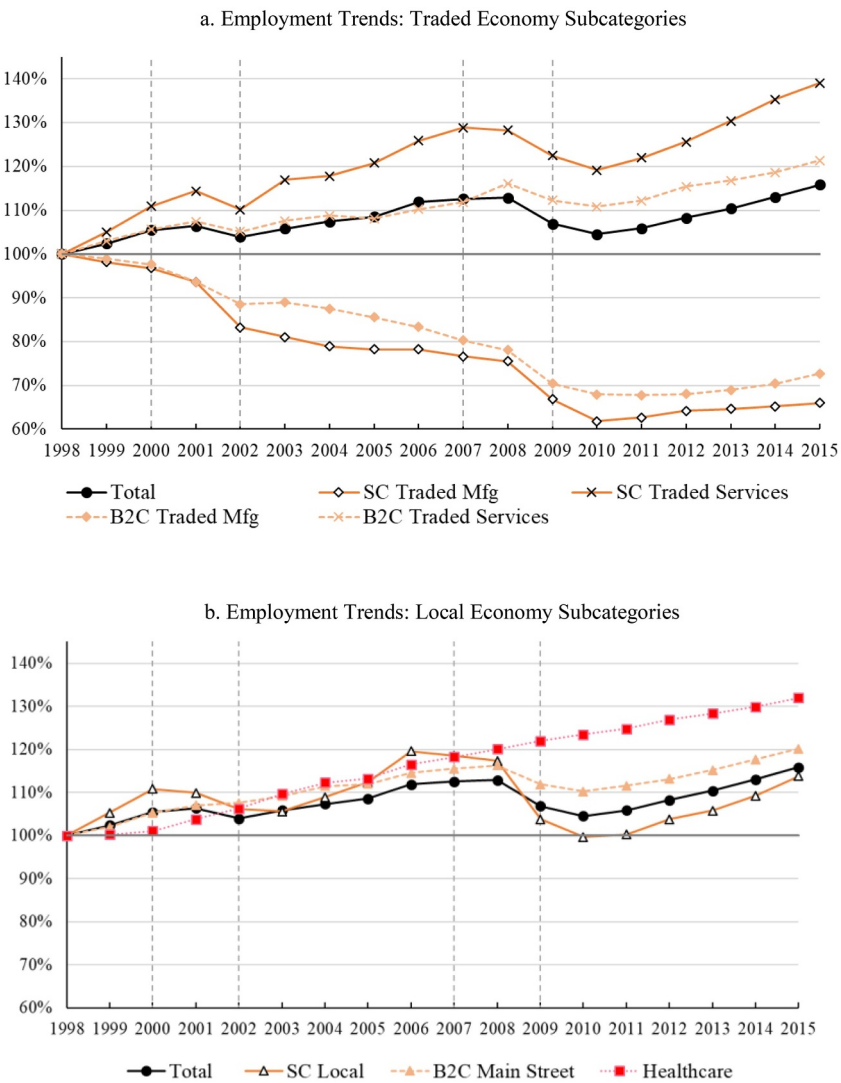
## 7.2. The vulnerability of the SC economy to economic recessions

Do SC and B2C subcategories differ in their vulnerability to economic crises in terms of employment and wage growth? During 1998–2015 there were two economic crises that we study: the dotcom bust of 2000–2002 and the Great Recession of 2007–2009.<sup>31</sup> Fig. 6 illustrates that the supply chain economy is more vulnerable to economic crises in terms of employment growth. During both crises, the SC category experienced a significantly larger contraction in annual employment growth than the B2C category, but in the pre- and post-recession periods, the SC category grew faster than the B2C category. Specifically, during the Great Recession (2007–2009), the average annual employment growth was much lower in the SC category than in

<sup>30</sup> For Main Street industries with PCE score above 65% (versus above 35%), the wage growth rate was lower (2%) and the employment growth was higher (25%). See Table A4 in Appendix A.

<sup>31</sup> The NBER's Business Cycle Dating Committee determined that the 2001 recession took place between March and November; and the Great Recession years were December 2007 through June 2009 (see [www.nber.org/cycles.html](http://www.nber.org/cycles.html)). It is important to note that the CBP annual employment data corresponds to mid-March. The recession period using this data corresponds to 2000–2002 and 2007–2009.





the B2C category (-4.7% versus -0.8%). The higher cyclicalities of the SC category holds for growth in wages as well (see Table A6). The SC Traded subcategory is also more cyclical than the B2C Traded subcategory, in terms of employment and wage growth. Within the Local category, SC is more vulnerable than B2C Main Street in terms of employment growth.

The higher vulnerability of suppliers to economic shocks implied by these findings is consistent with the “bullwhip” or “Forrester” effect identified in the supply chain literature (Forrester, 1961; Lee et al., 2004). Suppliers can experience much larger uncertainty and declines in economic activity as their buyers adjust inventory levels and decrease their purchasing during an economic crisis.

Interestingly, the vulnerability of SC industries to economic crises is mitigated when they are located in a “strong” industry cluster (i.e., one with a high relative presence of employment and businesses in related industries). We noted that one of the attributes of SC industries is that they can benefit more from agglomeration economies. In a recent paper, Delgado and Porter (2017) use our categorization and show that when industries were located in a strong regional cluster, their employment growth was less affected by the Great Recession. These agglomeration benefits were greater for SC industries than B2C industries during the whole business cycle, and especially during the crisis. This suggests that supplier-buyer co-location could be important for SC industries to reduce the uncertainty associated with economic crises.

The particular vulnerability of suppliers calls for targeted policies during economic crises. If supply chain industries perform better in industry clusters, catalyzing and strengthening organizations that support clusters is one way to promote resilience. Another example of such policies in the area of access to capital was the Obama Administration's QuickPay initiative in 2011 that paid the small suppliers to the government faster with the goal of reducing their working capital costs and facilitating firm growth after the Great Recession (Barrot and Nanda, 2016). The QuickPay initiative could be extended to other forms of inter-firm credit from larger customers that could facilitate resilience to shocks.

## 8. Conclusion

We offer a novel innovation framework that focuses on the suppliers of goods and services to businesses and the government. We provide an industry categorization that quantifies the supply chain economy in the United States, and show conceptually and empirically that the supply chain category is important for innovation and distinct from the B2C category. The supply chain economy is large and has significantly higher wages, STEM intensity, and patenting than the B2C economy.

By separating traded suppliers into manufacturing and services, we find that the subcategory of supply chain traded services (e.g., design, engineering, and cloud computing services) is very large and has the highest presence of STEM occupations, but low patenting. This finding calls into question the usefulness of patent-based indicators for examining innovation in the important services sector.

In terms of growth dynamics, we find that employment in the supply chain economy has been evolving away from manufacturing and towards traded services. Our new industry categorization has revealed a distinct and large subcategory, supply chain traded services, which has the highest wages, STEM intensity, industry upstreamness, and fast (but cyclical) growth. These findings challenge the prior innovation narrative that is focused on bringing manufacturing back, and suggest a more optimistic view of the economy centered on supporting the suppliers of services. Our findings offer new insights to recent work on the increasing servicification of manufacturing firms, increasing intangible capital in trade, and the polarization of service jobs (SC Traded Services versus B2C Main Street).

The new categorization of the U.S. economy described in this paper has implications for policy. The supply chain has long been a focus of the federal government, manifested primarily through its procurement

activities (in areas like defense and energy). The ability to define and measure the total category of suppliers in the economy and its subcategories—in particular the suppliers of traded services—can improve the ability of policymakers to create and assess new programs that target the unique challenges that suppliers may face, particularly with regard to accessing three critical resources: skilled labor, buyers, and capital.

Access to skilled labor is relevant because supply chain industries rely on STEM workers. Service suppliers may be especially at risk since their innovations are highly dependent on access to and retention of skilled workers. The growth of supply chain traded services suggests that policy emphasis on STEM training is warranted. With regards to access to buyers, suppliers can particularly benefit from policies that facilitate collaboration with buyers in industry clusters. Finally, access to capital can be difficult for service suppliers because they produce innovations that often cannot be patented. Policy solutions could include loan guarantees, credit support, or research funding that facilitate capital for these suppliers to start and grow. In the private sector, initiatives that encourage large firms to create partnerships with their supply chains also have the potential to bolster growth and resilience in this critical part of the economy (Helper and Henderson, 2014). By supporting the supply chain economy through targeted policies, government and businesses could contribute to creating the innovation and good jobs of the future. Determining the practices that would be most effective in achieving these goals is an important area for future research.

Our analysis offers many directions for future research aimed at informing policies to foster the innovation of a country. First, future work could test how sensitive the quantification of the supply chain economy is to the particular industry classification and input-output accounts used. Specifically, service industries are more aggregated than manufacturing industries, and statistical agencies could improve the input-output accounts with more granular data for services.

Second, our conceptual and empirical framework could be applied to any country (and sub-national regions) to estimate their domestic supply chain economies and assess their innovation capacity.

Third, future research could further describe the SC and B2C industries based on other relevant indicators such as capital intensity, entrepreneurship, productivity, and exports-imports. These analyses could help to identify the underlying causes of the evolution of the economy from manufacturing towards services. Is the high growth in supply chain traded services due to lower import competition and higher exports? Is it driven by startup activity or by the transformation of large incumbent firms from manufacturing into services (Lodefalk, 2017)?

Fourth, building on our analysis of the particular occupations that support the supply chain and B2C economies, one could further investigate the polarization of jobs in services (Autor, 2015). What particular occupations (e.g., computer-related, managerial, and logistics occupations) contribute to explain the growth in high-wage supply chain traded services? Is there a multiplier effect from these high-tech service jobs to the rest of the economy (Moretti, 2010)? This research would have implications for education and labor policies.

At the region level, future research might assess the attributes of locations that foster the supply chain economy, including the role of industry clusters (Delgado and Porter, 2017), the organization of inter-firm networks, and institutions that shape inter-firm collaboration culture (Saxenian, 1994; Storper et al., 2015).

At the firm level, a fruitful area for future research is understanding the implications for strategy and performance of being a supply chain firm. This paper has defined firms whose primary industry was part of the supply chain economy as suppliers. Future work should map the supply chain firms and their supplier-buyer networks (Helper and Kuan, 2018). Then, we could explore how organizational and managerial practices (Gereffi et al., 2005; McElheran, 2015; Flammer and Kacperczyk, 2016), location choices, and innovation practices differ for

SC and B2C firms.

Finally, the high STEM intensity but low patenting of the suppliers of traded services raises an old but relevant question: how can we better measure innovation for all economic activities? Trademarks, surveys and tools that measure or predict firm introductions of new goods and services and map the innovation process would be useful for capturing innovativeness (e.g., von Hippel, 2005; Bitner et al., 2008; Flikkema, De Man and Castaldi, 2014; Guzman and Stern, 2015).

### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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### Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:[10.1016/j.respol.2020.104039](https://doi.org/10.1016/j.respol.2020.104039).

## Appendix A. Defining supply chain vs. business-to-consumer industries

### A1. Classification of industries as supply chain versus B2C

We offer a systematic and comprehensive classification of industries into Supply Chain (SC) and Business-to-Consumer (B2C) categories. Our analysis uses the 2002 Benchmark Input-Output (IO) Accounts of the United States from the Bureau of Economic Analysis.<sup>32</sup> The IO Accounts are based primarily on data from the Economic Census, and are built up with establishment-level data where possible. A detailed explanation on how the accounts are built is provided by Horowitz and Planting (2009) and Stewart et al. (2007).<sup>33</sup>

For each industry, the IO Accounts register two types of transactions: intermediate uses and final uses. The intermediate uses of a given industry is the value of its products sold to industries and the government as intermediate inputs. This value would include any transformation of the original products. The final uses of the industry is the value of the products sold for final demand by households, government, or businesses. Building on prior work, we classify the industries into SC or B2C based on the percent of value sold for final use by households: i.e., sold to Personal Consumption Expenditure (PCE). The PCE is the value of the goods and services that are purchased by households, such as food, cars, and college education. The PCE assumes that there is no further transformation of the good or service by households. Goods and services that are sold to retailers (e.g., Walmart or car dealers) without further transformation are captured in the PCE. For example, in the *Automobile Manufacturing* industry, the cars sold to households are part of PCE (see Stewart et al., 2007).<sup>34</sup>

To compute the PCE score, we match the IO commodity codes into industries (six-digit NAICS codes).<sup>35</sup> Then, for each industry, we compute the percentage of its total value sold to the intermediate and final uses. For example, Table A1 shows that the *Engineering Services* industry sells 0% to PCE, 19% to non-PCE final uses, and 81% to intermediate uses.<sup>36</sup>

#### A1.1. Choice of the PCE cut-off to define SC industries

We identify as SC industries those with less than 35% of their output sold to PCE (see Section A1.3). Thus, in our baseline definition, those industries that sell most of their goods and services to businesses or to the government (i.e., more than 65% sold outside PCE) are classified as SC, and the rest are classified as B2C (i.e., SC if  $PCE < 35\%$  and B2C if  $PCE \geq 35\%$ ). Because we are interested in understanding the attributes and performance of suppliers, we use this conservative PCE cut-off to define SC industries and implement a series of validation tests that we explain below. Our supply chain categorization results in 594 SC industries and 384 B2C industries based on 978 six-digit NAICS-2012 codes. The classification of industries into the SC and B2C subcategories is available in the online Appendix B.<sup>37</sup>

We examined the NAICS definition of the SC industries, and corroborated that their goods and services are primarily oriented to business

<sup>32</sup> In future work, we plan to implement the analysis using the recently released 2007 IO Accounts, and examine the stability of the supply chain categorization. We expect that for most industries, the changes in consumer-orientation will occur slowly over time unless radical innovations transform the industry.

<sup>33</sup> The IO methodology assigns establishments to their primary industries. Then, industries are broken down into commodities. For an establishment that produces multiple commodities, the commodities are divided up into the "primary product" and the "secondary products." In the standard IO Accounts, an establishment's "primary product" determines its commodity designation.

<sup>34</sup> The PCE item defines household consumption as a final use. However, households could transform the products they buy and give away their innovations (von Hippel, 2017). This would imply that some industries may be less consumption-oriented than is suggested by the PCE score.

<sup>35</sup> The 426 IO commodity codes map into 528 NAICS codes that we bridge into 978 six-digit NAICS-2012 industries. For NAICS codes that are aggregated (e.g., 420000 with  $PCE = 34.9\%$ ), the corresponding six-digit industries receive the same PCE score as their aggregated industry (e.g., 423210 with  $PCE = 34.9\%$ ). IO data is more aggregated for services than manufacturing industries, limiting the ability to quantify supply chain versus B2C services.

<sup>36</sup> There are three types of final use items in the IO Accounts. Households' final use item is the Personal Consumption Expenditure (PCE). Government's final use items include Federal Government Investment and State/Local Government Investment. Businesses' final uses are Private Fixed Investment, Change in Private Inventories, Exports, and Imports. A detailed definition of these items is available in Horowitz and Planting (2009).

<sup>37</sup> To build a time series 1998–2015, some industries are consolidated because the NAICS code changed during the period. The result is 972 six-digit industries.

**Table A1**  
Selected industries: percent of value sold across final and intermediate uses

NAICS 2012	Industry name		Subcategory	PCE	% Sold to final uses		% Sold to intermediate uses	
					Government	Other	Industries	Government
325414	Biological Product Mfg	SC	Traded Mfg	0%	0%	17%	80%	3%
541330	Engineering Services	SC	Traded Svc	0%	0%	19%	59%	22%
561320	Temporary Help Services	SC	Local	0%	0%	0%	93%	7%
311230	Breakfast Cereal Mfg	B2C	Traded Mfg	90%	0%	5%	3%	2%
611420	Computer Training	B2C	Traded Svc	86%	0%	0%	9%	5%
722511	Full-Service Restaurants	B2C	Main Street	79%	0%	0%	18%	3%

Note: Percent of industry value sold to Final Uses and Intermediate Uses.

**Table A2**  
Selected largest supply chain traded and local industries

NAICS 2012	Industry Name	Emp (000s) 2015	PCE	Company Example
<b>Supply Chain Traded Manufacturing</b>				
323111	Commercial Printing (exc. Screen/Books)	339	3.2%	CCL Industries
336411	Aircraft Mfg	174	0.7%	Boeing
334511	Search/Detection/Navigation/Instrument Mfg	124	0.1%	Raytheon
339112	Surgical and Medical Instrument Mfg	103	0.6%	Boston Scientific
336611	Ship Building and Repairing	108	0.0%	Huntington Ingalls Ind.
<b>Supply Chain Traded Services</b>				
561330	Professional Employer Organizations	2435	0.5%	StaffScapes
541330	Engineering Services	1029	0.0%	Aecom
541511	Custom Computer Programming Services	785	0.0%	Okta
493110	General Warehousing and Storage	693	0.7%	Verst Group Logistics
541512	Computer Systems Design Services	653	0.0%	Accenture
<b>Supply Chain Local</b>				
561320	Temporary Help Services	3320	0.5%	Roth Staffing
561720	Janitorial Services	1012	7.8%	Blackmon Mooring
238220	Plumbing/Heating/Air-Conditioning Contractors	934	0.0%	Comfort Systems USA
561612	Security Guards and Patrol Services	708	18.7%	Universal Protection GP
524210	Insurance Agencies and Brokerages	685	0.0%	Brown & Brown

Note: Company Example are based on Hoovers data (accessed July 2018). They are companies whose primary NAICS is the one reported in the table, and the secondary NAICS (if any) are in the same subcategory.

customers or to the government. To illustrate our industry categorization, [Table A2](#) shows some of the largest SC industries by employment in 2015. Based on the industry definitions and their low PCE scores, these industries seem to be properly categorized as SC. Similarly, we examined the largest B2C industries and confirmed that their products are primarily sold to consumers (see Appendix B).

#### A1.2. Mapping firms into the SC and B2C categorization

The focus of the paper is categorizing industries, but mapping supply chain firms is an important area for future research. In our categorization, the underlying data is at the establishment level. In the County Business Pattern (CBP) data, establishments are assigned to their primary industry to estimate the employment and payroll of each six-digit NAICS industry. We then aggregate the industries' employment and wages into our SC and B2C subcategories.

Our industry categorization does not map perfectly into firm-level data because some firms have establishments in multiple industries in SC and B2C. To calculate the number of firms in each of our categories and subcategories, we use the 2012 Economic Census, which assigns each firm to a primary six-digit NAICS industry with the largest payroll, and computes the number of firms by industry.

Using D&B Hoovers data,<sup>38</sup> [Table A2](#) offers examples of firms that map clearly in the supply chain economy for each of the selected industries in SC Manufacturing (e.g., Boeing and Raytheon), SC Traded Services (e.g., Aecom and Accenture), and SC Local (e.g., Roth Staffing and Brown & Brown). In contrast, a hybrid firm like General Motors has some establishments that map into SC industries and others that map into B2C industries. According to Hoovers, GM's primary NAICS is *Automobile Manufacturing* (B2C industry with PCE of 47%), but GM has establishments in *Other Motor Vehicle Parts Manufacturing* (SC industry with PCE of 4%). Hence, in the analysis on the number of firms ([Fig. 1](#)), GM would be classified as a B2C firm based on its primary industry. However, in our industry-based analysis, where establishment-level data is used to estimate employment, wages, and innovativeness, the firm would be split between the SC and B2C subcategories.

#### A1.3. Sensitivity analysis: alternative SC and B2C industry definitions

We examined the sensitivity of the size of the SC economy to PCE values around 35%. [Fig. A1](#) shows the percentage of total employment in industries with PCE scores below different cut-off values; and [Table A3](#) reports the size (employment, number of firms, and number of industries) for alternative definitions of SC industries. A total of 209 industries have a PCE score of zero, and they account for 17% of employment and 23% of firms

<sup>38</sup> To illustrate how to map firms into the SC and B2C categorization, we use the Hoovers dataset because it is the most current and publicly available dataset that identifies the main industries of a firm. Hoovers uses revenue size to identify a firm's primary and secondary NAICS codes. However, it has limitations in that it may not include the complete set of industries of a firm. Optimally, we would use detailed establishment-level payroll data to identify the primary and all secondary industries of a firm, which is the criterion used by the Economic Census.



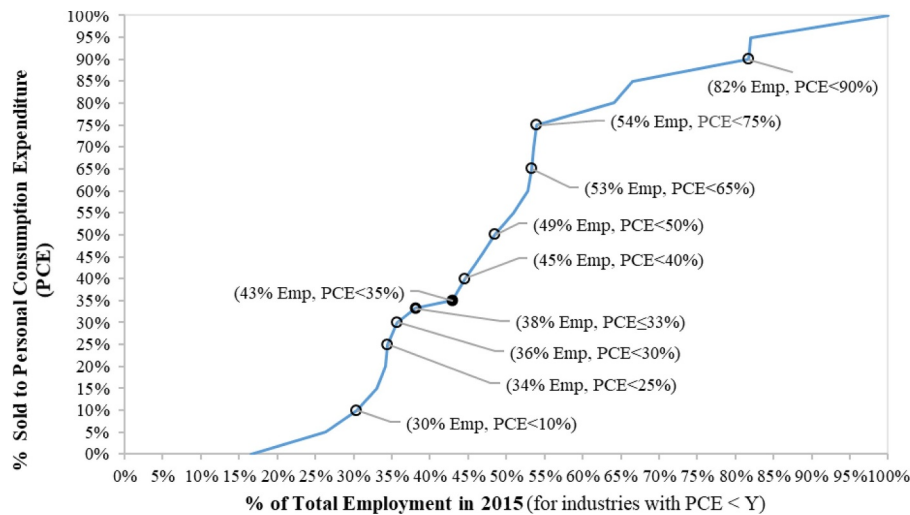


Fig. A1. Distribution of employment by PCE score, 2015

Table A3

Supply chain economy size: alternative SC definitions, 2012

SC definition	Employment 2015 Mill	% Total	Firms 2012 Mill	% Total	Industries NAICS-2012 No.	% Total
SC PCE = 0%	20.5	17%	1.4	23%	209	21%
SC PCE < 35%	53.3	43%	2.8	48%	592	61%
SC Proportional-PCE	60.8	49%	3.1	53%		

Note: Employment (CBP data) and count of firms (2012 Economic Census). There are 978 industries.

(Table A3). The rest of the industries contain a mix of SC and B2C activities, and we categorize them as SC in the baseline categorization if the percentage sold to PCE is below 35%. To choose this cut-off value, we examined the sensitivity of the size of the SC economy to PCE values around one-third (33%). The size of the SC economy is very robust to PCE cut-off values (25%, 33%): accounting for 34% to 38% of employment. For PCE scores (33%, 40%), there is a discontinuity at 35% and the accumulated SC employment increases by 5 percentage points (38% to 43%) due to *Wholesaler* industries (NAICS 42) that have a PCE score of 34.9%. Given the level of aggregation of the IO data, it is not possible to assess which of the 71 six-digit wholesaler industries sell primarily to businesses. These industries could perform packaging, sorting, and other marketing services, and can play an important role in distribution and e-commerce services.<sup>39</sup> Furthermore, wholesaler industries sell to all industries and their *Upstreamness* score is similar to that of the total economy (Section 6.2). Hence, we decided to include wholesalers in our baseline definition of SC versus B2C industries: SC if PCE < 35% and B2C if PCE ≥ 35%.

In the sensitivity analysis, we use two alternative definitions of SC versus B2C industries. First, we re-define B2C industries as those with more than 65% of their output sold to PCE to better contrast SC and B2C industries (SC if PCE < 35% and B2C if PCE > 65%).<sup>40</sup> Second, we develop a proportional definition of SC industry that uses the PCE score (SC Proportional-PCE) to proportionally allocate industry outcomes (e.g., employment) to the SC and B2C categories. For example, in the case of *Breakfast Cereal Manufacturing*, the PCE is 90% (Table A1). Hence, 90% of the industry employment is allocated to the B2C category and 10% to the SC category. This allows us to further test that our results are not driven by the specific PCE cut-off to separate industries into SC.

The core findings on the size, innovation activity, wages, and growth of our baseline SC category and subcategories are robust to using the alternative SC versus B2C definitions. Table A3 shows that the estimates of the size of the SC category increases moderately when using SC Proportional based on the PCE (49% of employment).<sup>41</sup> The STEM intensity of the SC category is slightly smaller (10%) when we use SC Proportional-PCE, and all the SC subcategories have significantly higher STEM intensity than their B2C counterparts (Table A4a). Patenting activity in the SC category is also very robust (87% of patents in all the alternative definitions). Our main conclusions regarding wages and growth of the subcategories are also robust to using the alternative definitions (see Table A4b for employment and Table A4c for wages). By contrasting SC industries (PCE < 35%) with B2C industries with higher consumer orientation (> 65%) our wage findings are amplified. The positive wage gap between the SC and B2C subcategories increases, and the slow wage growth in Main Street services is more apparent.

Two additional sensitivity analyses involve *Finance, Insurance, and Real Estate* (FIRE) services and Non-Manufactured Goods. FIRE services

<sup>39</sup> According to the NAICS description, “the Wholesale Trade sector (NAICS 42) comprises establishments engaged in wholesaling merchandise, generally without transformation, and rendering services incidental to the sale of merchandise.” These industries include *Merchant Wholesalers of Durable Goods* (NAICS 423), of *Nondurable Goods* (NAICS 424), and *Wholesale Electronic Markets and Agents and Brokers* (NAICS 425). For additional description of this sector, see <https://siccode.com/en/naicscodes/42/wholesale-trade>.

<sup>40</sup> We drop industries with PCE scores of 35%–65%, which account for 10% of employment in 2015.

<sup>41</sup> Final uses by government and businesses (Non-PCE Final Use) are allocated to the SC category because we cannot use them to assess the consumer-orientation of an industry (e.g., companies could export to businesses or households). In the IO data, as expected, the PCE and Intermediate Use (IU) scores of industries are highly, negatively correlated. To further assess the robustness of our findings, we compute the SC proportional category based on the IU scores. For example, in the case of *Breakfast Cereal Mfg*, 90% of employment would be allocated to the B2C category and 5% to the SC category (Table A1). Our findings are robust to using the SC Proportional-IU categorization that excludes the Non-PCE Final Uses – the SC economy size decreases slightly to 40% of U.S. employment.

**Table A4a**  
STEM intensity and patenting across subcategories: alternative SC definitions

	STEM Intensity, 2015 (%)				Utility Patents (% Total), 2015			
	SC <sub>PCE &lt; 0.35</sub> B2C <sub>PCE ≥ 0.35</sub>	SC <sub>PCE &lt; 0.35</sub> B2C <sub>PCE &gt; 0.65</sub>	SC <sub>1-PCE</sub> B2C <sub>PCE</sub>	SC <sub>NoFIRE</sub> B2C <sub>NoFIRE</sub>	SC <sub>PCE &lt; 0.35</sub> B2C <sub>PCE ≥ 0.35</sub>	SC <sub>PCE &lt; 0.35</sub> B2C <sub>PCE &gt; 0.65</sub>	SC <sub>1-PCE</sub> B2C <sub>PCE</sub>	SC <sub>NoFIRE</sub> B2C <sub>NoFIRE</sub>
	1	2	3	4	5	6	7	8
SC	11%	11%	10%	11%	87%	87%	87%	87%
B2C	2%	1%	2%	2%	13%	7%	13%	13%
SC Traded Mfg	11%	11%	11%	11%	76%	76%	75%	76%
B2C Traded Mfg	4%	6%	5%	4%	9%	7%	10%	9%
SC Traded Svc	17%	17%	17%	18%	9%	9%	10%	9%
B2C Traded Svc	6%	6%	7%	5%	3%	0%	2%	3%
SC Local	3%	3%	3%	3%	2%	2%	2%	2%
B2C Main Street	1%	0%	1%	1%	1%	0%	1%	1%
B2C Healthcare	1%	1%	1%	1%	0%	0%	0%	0%

Note: *STEM Intensity* is the % of the subcategory jobs that are in STEM. Columns 1 and 5 use the baseline definition of SC and B2C (SC if PCE < 35% and B2C if PCE ≥ 35%). Columns 2 and 6 use a definition of B2C with higher PCE (i.e., excludes industries with PCE scores 35%-to-65%). The SC-Proportional definition based on the PCE score (SC<sub>1-PCE</sub>, B2C<sub>PCE</sub>) is used in columns 3 and 7. Finally, columns 4 and 8 use the baseline definition of SC and B2C, but excludes all FIRE Industries (NAICS 52 and 531).

**Table A4b**  
Employment across subcategories: alternative SC definitions

	Employment, 2015 (% U.S. Total)				Employment growth 1998–2015			
	SC <sub>PCE &lt; 0.35</sub> B2C <sub>PCE ≥ 0.35</sub>	SC <sub>PCE &lt; 0.35</sub> B2C <sub>PCE &gt; 0.65</sub>	SC <sub>1-PCE</sub> B2C <sub>PCE</sub>	SC <sub>NoFIRE</sub> B2C <sub>NoFIRE</sub>	SC <sub>PCE &lt; 0.35</sub> B2C <sub>PCE ≥ 0.35</sub>	SC <sub>PCE &lt; 0.35</sub> B2C <sub>PCE &gt; 0.65</sub>	SC <sub>1-PCE</sub> B2C <sub>PCE</sub>	SC <sub>NoFIRE</sub> B2C <sub>NoFIRE</sub>
	1	2	3	4	5	6	7	8
SC	43%	43%	49%	40%	11%	11%	11%	10%
B2C	57%	47%	51%	54%	20%	25%	21%	21%
SC Traded Mfg	7%	7%	7%	7%	-34%	-34%	-33%	-34%
B2C Traded Mfg	2%	1%	2%	2%	-27%	-40%	-32%	-27%
SC Traded Svc	20%	20%	20%	18%	39%	39%	39%	41%
B2C Traded Svc	8%	3%	7%	6%	21%	41%	20%	31%
SC Local	17%	17%	22%	15%	14%	14%	13%	12%
B2C Main Street	34%	29%	28%	32%	20%	25%	22%	21%
B2C Healthcare	14%	14%	13%	14%	32%	32%	32%	32%

Note: See Note in [Table A4a](#).

**Table A4c**  
Real wages (2015 USD) across subcategories: alternative SC definitions

	Real wage, 2015 (\$000)				Real wage growth, 1998–2015			
	SC <sub>PCE &lt; 0.35</sub> B2C <sub>PCE ≥ 0.35</sub>	SC <sub>PCE &lt; 0.35</sub> B2C <sub>PCE &gt; 0.65</sub>	SC <sub>1-PCE</sub> B2C <sub>PCE</sub>	SC <sub>NoFIRE</sub> B2C <sub>NoFIRE</sub>	SC <sub>PCE &lt; 0.35</sub> B2C <sub>PCE ≥ 0.35</sub>	SC <sub>PCE &lt; 0.35</sub> B2C <sub>PCE &gt; 0.65</sub>	SC <sub>1-PCE</sub> B2C <sub>PCE</sub>	SC <sub>NoFIRE</sub> B2C <sub>NoFIRE</sub>
	1	2	3	4	5	6	7	8
SC	\$65.8	\$65.8	\$61.6	\$63.4	18%	18%	17%	17%
B2C	\$38.8	\$33.0	\$39.4	\$36.7	10%	9%	11%	9%
SC Traded Mfg	\$59.8	\$59.8	\$59.0	\$59.8	9%	9%	9%	9%
B2C Traded Mfg	\$49.9	\$51.2	\$50.8	\$49.9	12%	20%	12%	12%
SC Traded Svc	\$83.5	\$83.5	\$80.3	\$78.6	20%	20%	20%	19%
B2C Traded Svc	\$55.1	\$39.2	\$61.8	\$48.3	19%	12%	19%	18%
SC Local	\$47.2	\$47.2	\$45.1	\$46.0	12%	12%	11%	10%
B2C Main Street	\$29.4	\$23.3	\$27.8	\$27.4	3%	2%	3%	1%
B2C Healthcare	\$51.0	\$51.0	\$51.1	\$51.0	17%	17%	17%	17%

Note: See Note in Table A4a.

correspond to NAICS 52 and 531, and include 33 SC industries and 13 B2C industries (see Appendix B). This set of industries represents about 6% of employment, has a STEM Intensity comparable to that of the U.S. economy (5.8%), and the highest average wage of \$88,000 as of 2015. These well-paying jobs could be attracting skilled talent ([Shu, 2016](#)). To assure that they do not drive our results, we dropped them from the analysis and our findings are robust (see Table A4).

Non-Manufactured Goods include *Agriculture, Forestry, Fishing, and Hunting* (NAICS 11); *Mining* (NAICS 21); and *Construction* (NAICS 23). All of these 75 industries (except one) are part of the SC Services:<sup>42</sup> SC Traded Services (47 industries with 1.2% of U.S. employment) and SC Local (27

<sup>42</sup> The exception is *Hunting and Trapping* (NAICS 114210), which is a B2C industry. Note that our analysis excludes agricultural Non-Manufactured Goods (*Crop Production* (NAICS 111) and *Animal Production & Aquaculture* (NAICS 112)) because they are excluded from the CBP data. Some of these industries are SC (e.g., *Grain Farming* with a PCE of 2%) and others are B2C (e.g., *Fruit Farming* with a PCE of 59%).

**Table A5a**

Top 10 labor occupations in the traded SC vs. B2C subcategories, 2015

Traded subcategories: top 10 occupations by % employment			
<b>SC Traded Manufacturing</b>	<b>28.4</b>	<b>B2C Traded Manufacturing</b>	<b>38.3</b>
Team Assembler	7.1	Team Assembler	7.5
First-Line Supervisor of Production Workers	3.7	Packaging & Filling Machine Operator & Tender*	5.7
Machinist*	2.8	Meat, Poultry, & Fish Cutter & Trimmer*	4.7
Inspector, Tester, Sorter, Sampler, & Weigher	2.8	First-Line Supervisor of Production Workers	3.4
Welder, Cutter, Solderer, & Brazier*	2.3	Laborer & Mover, Hand	3.3
Laborer & Mover, Hand	2.1	Food Batchmaker*	3.1
Helper-Production Worker	2.0	Slaughterer & Meat Packer*	3.0
General & Operations Manager*	1.9	Packer & Packager, Hand*	2.6
Sales Representative, Wholesale & Mfg*	1.9	Helper-Production Worker	2.6
Electrical & Electronic Equip. Assembler*	1.7	Inspector, Tester, Sorter, Sampler, & Weigher	2.4
<b>SC Traded Services</b>	<b>28.6</b>	<b>B2C Traded Services</b>	<b>23.5</b>
Laborer & Mover, Hand*	4.4	Maid & Housekeeping Cleaner*	5.0
Customer Service Representative	3.9	Customer Service Representative	3.8
Sales Representative, Wholesale & Mfg*	3.1	Hotel, Motel, & Resort Desk Clerk*	2.6
Heavy & Tractor-Trailer Truck Driver*	2.9	Office Clerk, General	2.2
Office Clerk, General	2.9	Secretary & Administrative Assistant	1.8
General & Operations Manager*	2.7	Waiter & Waitress*	1.8
Accountant & Auditor*	2.3	Claims Adjuster, Examiner, & Investigator*	1.6
Software Developer, Applications*	2.3	First-Line Supervisor of Office/Adm Worker*	1.6
Secretary & Administrative Assistant	2.1	Insurance Claim & Policy Processing Clerk*	1.6
Bookkeeping, Accounting, & Auditing Clerk*	2.0	Maintenance & Repair Worker, General*	1.5

Note: \*Occupations (6-digit SOC codes from OES Survey by BLS) are unique to the SC versus B2C subcategory.

**Table A5b**

Top 10 labor occupations in the local SC and B2C subcategories, 2015

Local subcategories: top 10 occupations by % employment					
SC Local	32.4	B2C Main Street	43.8	B2C Healthcare	46.3
Janitor & Cleaner*	4.3	Retail Salesperson*	10.0	Registered Nurse*	14.2
Laborer & Mover, Hand*	4.0	Cashier*	7.5	Nursing Assistant*	7.7
Heavy/Tractor Truck Driver*	3.9	Food Preparation & Serving Worker*	7.2	Personal Care Aide*	4.2
Office Clerk, General	3.6	Waiters & Waitress*	5.5	Home Health Aide*	4.0
Security Guard*	3.5	Stock Clerk & Order Filler*	3.2	Licensed Nurse*	3.6
Construction Laborer*	3.1	Supervisor: Retail Sales Worker*	2.6	Medical Assistant*	3.4
Secretary & Adm Assistant*	2.6	Cook, Restaurant*	2.6	Medical Secretary*	2.9
Landscaping Worker*	2.5	Supervisor: Food Prep/Serving Worker*	1.8	Receptionist, Info Clerk*	2.6
Customer Svc Representative*	2.5	Food Preparation Worker*	1.8	Office Clerk, General	2.0
Carpenter*	2.4	Personal Care Aide*	1.6	Dental Assistant*	1.8

Note: \*Occupations (6-digit SOC codes from OES Survey by BLS) are unique to the SC versus B2C subcategory.

industries with 4.4% of U.S. employment). Non-Manufactured Goods include many industries that produce commodities according to the Rauch (1999) classification (see Section 6.2). To examine their impact, we drop the Non-Manufactured Goods from our SC Traded Services subcategory. As expected, this results in a small decline in employment (23 versus 24.5 million in 2015), and a small increase in wages (\$84,200 versus \$83,500), STEM intensity (17.8% versus 17.1%), and employment growth (34% versus 33%).

The rest of this Appendix examines the top labor occupations (Table A5), and the cyclicity during the business cycles (Table A6) of the SC and B2C subcategories.

**Table A6**

Annual Growth during the business cycle: pre-crisis, crisis, and post-crisis

	Average annual growth in employment					Average annual growth in real wages				
	1998–2000	Crisis 2000–2002	2002–2007	Crisis 2007–2009	2009–2015	1998–2000	Crisis 2000–2002	2002–2007	Crisis 2007–2009	2009–2015
<b>Total</b>	<b>2.7%</b>	<b>-0.7%</b>	<b>1.6%</b>	<b>-2.5%</b>	<b>1.4%</b>	<b>2.5%</b>	<b>-0.6%</b>	<b>0.8%</b>	<b>-0.8%</b>	<b>1.1%</b>
SC	3.5%	-2.6%	1.9%	-4.7%	1.6%	2.7%	-0.9%	1.0%	-0.6%	1.6%
B2C	1.9%	0.9%	1.4%	-0.8%	1.2%	1.8%	0.7%	0.4%	0.0%	0.5%
SC Traded	2.5%	-2.9%	1.6%	-3.7%	1.5%	3.8%	-1.9%	1.5%	-1.0%	1.9%
B2C Traded	1.6%	-1.5%	0.4%	-1.3%	1.2%	2.4%	0.6%	0.8%	-0.8%	1.4%
SC Traded Mfg	-1.6%	-7.2%	-1.6%	-6.5%	-0.2%	1.7%	-0.9%	0.3%	-1.2%	1.4%
B2C Traded Mfg	-1.2%	-4.8%	-1.9%	-6.3%	0.6%	1.2%	1.7%	0.4%	-1.7%	1.2%
SC Traded Svc	5.3%	-0.3%	3.2%	-2.5%	2.2%	4.2%	-3.0%	1.5%	-1.3%	1.8%
B2C Traded Svc	2.8%	-0.2%	1.3%	0.2%	1.3%	2.8%	0.2%	0.9%	-0.6%	1.4%
SC Local	5.3%	-2.2%	2.3%	-6.3%	1.6%	0.8%	2.0%	0.2%	-0.6%	1.0%
B2C Main Street	2.6%	1.1%	1.4%	-1.5%	1.2%	2.4%	0.0%	-0.3%	-1.2%	0.4%
B2C Healthcare	0.5%	2.5%	2.2%	1.5%	1.3%	0.9%	2.5%	0.9%	1.6%	0.3%

Note: Real wages in 2015 USD using CPI-U (All Urban Consumers; BLS).

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