Structural Change Within Versus Across Firms: Evidence from the United States

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PRELIMINARY – PLEASE DO NOT CITE OR CIRCULATE

Abstract

Continuing manufacturing firms account for a substantial share of US non-manufacturing employment growth between 1977 and 2017. We investigate the role of intangible knowledge in this within-firm contribution to US structural change. Empirically, we use new information on the auxiliary establishments that primarily serve the other plants of a firm to develop a new measure of inhouse knowledge creation and show that it is associated with faster growth and greater pivoting to new industries. We rationalize this relationship in a model in which a firm's investments in intangible knowledge raise its productivity in all sectors, facilitating within-firm structural change. Consistent with the model, we find that shocks to firms' input prices induce a shift from physical production to services among firms with greater inhouse knowledge.

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1 Introduction

One the most striking features of the U.Ss economy over the last five decades is its transition away from manufacturing and towards services. Indeed, between 1977 and 2016, the share of US employment in manufacturing dropped by 18 percentage points, from 27 to 9 percent. In this paper, we assemble several new Census datasets tracking the universe of U.S. firms' employment and payroll according to the specific industries in which they operate. These data offer a detailed accounting of the U.S. transition towards services over the past 45 years, motivate a theoretical framework that rationalizes the importance of *manufacturing* firms in the rise of *service* employment, and provide econometric evidence in support of the model's main theoretical predictions about structural change.

Existing research on US structural transformation often emphasizes a reallocation of final consumption expenditures away from goods and towards services (Comin, Lashkari, and Mestieri, 2018). Here, we show that by far the largest growth in US employment from 1977 to 2016 occurs in the Business Services sector (NAICS 5). Drilling down into increasingly narrow industries, we find that Business Services account for 37 percent of overall US employment growth, and that the subsector Professional Technical, and Scientific Services (NAICS 54, henceforth PST) and the sub-subsector Computer Systems Design (NAICS 5415) are particularly influential, accounting for 12 and 3 percent of overall US employment growth, respectively. PST, which encompasses design, engineering, research and marketing, stand out for two additional reasons. First, their pay has grown rapidly over this period, compared with other sectors. Second, their output is predominantly used as an intermediate input rather than for final consumption. In particular, they are among the more influential industries spanned by "auxiliaries", defined by the U.S. Census Bureau as establishments that primarily serve their own firm versus outside customers (e.g., an R&D lab).

Surprisingly, we find that surviving manufacturing firms are a major source of the overall growth of US employment outside manufacturing, as they pivot from the physical production of goods towards services, especially PST (e.g., design, engineering, and marketing) and retail. Between 1977 and 2016, manufacturing firms add 10.8 million workers at their non-manufacturing establishments, accounting for 17 to XXX percent of the aggregate increase in non-manufacturing employment, depending on how firms are defined. Moreover, nearly all of this growth occurs within continuing manufacturing firms. Among firms outside manufacturing, by contrast, firm net entry dominates employment growth, comprising 63 to XXX percent of the overall increase in non-manufacturing employment. The relatively greater role of the intensive margin in manufacturing firms' non-manufacturing employment growth is noteworthy, suggesting that structural transformation from manufacturing to services need not lead to the destruction of manufacturing firms' intangible knowledge. Indeed, these firms' intangible knowledge may facilitate pivoting towards services.

We investigate this potential channel of structural change *within* firms by developing a new measure of in-house investment in proprietary, intangible knowledge using heretofore un-examined Census data on firms' auxiliary establishments. We find that firms with auxiliaries are on average larger than other firms, and that auxiliaries pay higher wages than non-auxiliaries within the same industries. These facts are consistent with auxiliaries employing relatively high-skilled workers to help firms adapt and achieve greater scale. In fact, we find that both firm growth and pivoting towards

other sectors are increasing in auxiliary employment.

To rationalize the growth of MPRO service inputs within and across firms, and relate this growth to aggregate shocks that induce structural change, we develop a model of heterogeneous firms in differentiated (physical) product markets following Melitz (2003) and Bernard, Redding, and Schott (2010a). In the model, firms pay an upfront sunk entry cost to obtain a differentiated brand and observe their productivity for each final goods sector. Given fixed production costs, firms choose to participate in just a subset of sectors, and firms with higher productivity across all sectors participate in more of them.

Our approach differs from conventional models of heterogeneous firms in two ways that are important for our setting. First, we assume that firms produce final goods by combining PST services and production workers, and that these two inputs are complements, so that positive shocks to the relative productivity of one pushes firms to reallocate towards the other. Firms decide endogenously whether to pay a fixed cost to supply PST services in-house or procure them without a fixed cost via outsourcing to a third party. Second, conditional on the mode of PST service provision, firms decide endogenously how much to invest in intangible PST knowledge, which lowers their costs in all sectors. If performed in-house, this knowledge is proprietary, else it diffuses to all firms. In equilibrium, more productive firms that choose to vertically integrate PST services make greater investments in intangible knowledge, boosting productivity and thereby their ability to enter new sectors in response to structural transformation, i.e., taste or productivity shocks.

Our model thus allows for both "sectoral" structural change, i.e., reallocation of employment across goods (e.g. from paper to podcasts), and "functional" structural change, i.e., shifting input usage within goods (e.g. from "dumb" to "smart" phones). Furthermore, both forms of structural transformation can occur within and across firms. A shock to consumer tastes, for example, renders previously profitable sectors unprofitable, and *vice versa*. Within-firm sectoral structural change occurs as some continuing firms switch products, while across-firm structural change is manifest in entering firms electing to produce a different mix of goods than those that exit. Productivity shocks, by contrast, cause firms with in-house PST provision to increase the share of PST services in all products (within-firm functional structural change), and some stand-alone PST providers to flourish (across-firm functional structural change). Additional across-firm functional structural change occurs as entering PST outsourcers selecting different shares of MPRO services than exiters.

These comparative statics highlight a role for micro factors like firm productivity to shape aggregate structural transformation. In our model, more productive firms can produce a wider range of goods profitably, and they invest more in the mutable intangible knowledge that facilitates pivoting. As a result, they magnify the response of aggregate shocks relative to a model in which firms are homogeneous.

Our setting generates several additional implications at the micro and macro levels relative to traditional models of structural change. First, because firms are allowed to pivot across sectors in response to shocks, there may be less "creative destruction" of intangible capital as some firms in sunset sectors are able to shift resources to sunrise industries. Second, because the services in our setting are an input rather than a final consumption good, unbalanced growth need not result

in aggregate stagnation, as the overall productivity growth converges to the level of the slowest growing sector (Baumol, 1967). Indeed, our framework extends Oulton (2001)'s insight to a model with heterogeneous firms, and shows that aggregate productivity can continue to grow so long as productivity growth in the service sector is positive. Relatedly, our setting present a challenge to measuring productivity among manufacturing establishment. If PST auxiliaries supply services to multiple production establishments within the same firm, the factor inputs used in the auxiliary establishments should be taken into account in measuring production establishments' productivity.

In the final section of the paper, we provide empirical evidence in support of our assumption that PST services and production are complements, using as a natural experiment China's emergence as a global producer between 1997 and 2007. On the one hand, greater import competition in final goods leads to the conventional contraction of firm employment. On the other hand, greater import competition in inputs reduces firms' production costs, inducing a shift in employment from production to services. We measure firms' output exposure as the weighted-average change in China's penetration of EU markets, using firms sales across their manufactured goods as weights. Input exposure measure is a similar weighted average, using the firm's input purchases as weights.

We focus on reduced-form specifications in which we regress changes in firm sales and employment directly on these instruments, and interact the instruments with the firm's initial period auxiliary status. We find that while increased Chinese competition in a firm's outputs decreases its manufacturing sales and employment, the input shock leads to growth in its non-manufacturing sales and employment, but only for those firms with auxiliaries. Further analysis of firms' non-manufacturing employment growth shows that PST employment changes most. These results support the premise that inhouse knowledge plants facilitate functional structural change, with firms increasingly specializing in PST (i.e., knowledge-related) activities in responses to lower production costs, in this case due to changes in globalization.

Our paper is related to several different strands of research. First, it contributes to the micro literature that studies the reallocation effects of plant and firm entry and exit within industries. There is considerable churn among US establishments, with systematic differences between entering, exiting and continuing firms and plants (Dunne, Roberts, and Samuelson, 1988, 1989), that play a key role in aggregate productivity growth Davis and Haltiwanger (1992) and Foster, Haltiwanger, and Syverson (2008). A further vein of work provides empirical evidence on the set of products multi-product firms supply (Bernard, Redding, and Schott, 2010b; Hottman, Redding, and Weinstein, 2016; Argente, Moreira, Oberfield, and Venkateswaran, 2021). Our contribution is to provide theory and evidence on structural transformation towards services within firms, and the role of intangible knowledge in this reallocation. In this sense, we are closest to Atalay, Hortacsu, and Syverson (2014), who argue that the transfer of intangibles across plants may be an important motive for integration, and Boehm, Dhingra, and Morrow (2021) who show that input proximity is the best predictor of subsequent firm expansion into other manufacturing products. Our results suggest that manufacturers accumulate mutable knowledge that facilitates their transition towards services.

Second, our analysis of the rise of management and professional service employment relates to several recent papers studying how new technologies relate to changes in industry concentration and

the spatial distribution of production. Berlingieri (2014) documents the dramatic rise of Business Services in the US and analyzes the extent to which it may be due to manufacturing firms' outsourcing of these activities.[1] Fort (2017) shows how ICT has facilitated fragmentation of production, especially to higher skill locations. Eckert (2019) and Eckert, Ganapati, and Walsh (2019) find that provision of highly paid, high-skill services has become more spatially concentrated over time and attribute this trend to falling communication costs due to ICT. Bessen (2017), Ganapati (2016), and Hsieh and Rossi-Hansberg (2019) suggest that the rise of high fixed cost capabilities such as information technology and foreign sourcing help rationalize growing concentration among firms. Relative to these studies, we provide theory and evidence on structural transformation within and between firms over our long historical sample period, and examine the role of endogenous investments in intangible capital in enabling firms to pivot away from declining sectors.

Third, our work connects with the literature on the impact of international trade on firms and plants, as surveyed in Tybout (2003). One group of studies examines the impact of low-wage import competition on firms' product mix and (Bernard, Jensen, and Schott, 2006; Bernard, Jensen, Redding, and Schott, 2011) and technological and quality upgrading (Khandelwal, 2010; Bloom, Draca, and Van Reenen, 2016). Another strand of work explores the impact of imported inputs and offshoring on firm productivity, employment levels and composition, and the firm-size distribution, including Amiti and Konings (2007); Goldberg, Khandelwal, Pavcnik, and Topalova (2010); Halpern, Koren, and Szeidl (2015); Antràs, Fort, and Tintelnot (2017); Boehm, Flaaen, and Pandalai-Nayar (2017); Magyari (2017). A further line of research examines the impact of the China shock on aggregate US manufacturing employment and local labor markets within the United States, including Autor, Dorn, and Hanson (2013); Pierce and Schott (2016a); Bloom, Handley, Kurmann, and Luck (2019). Whereas most of this research focuses on traded sectors, we provide theory and evidence on sectoral and functional structural transformation towards services within and between firms. To provide evidence on the complementary between MPRO services and production, we use the China shock as an exogenous source of variation. Although most research on the China shock uses variation across local labor market areas, we exploit variation across individual firms, and distinguish between firm output and input exposure to the shock.

Finally, our research is related to the macroeconomics literature on structural transformation, as reviewed in Herrendorf, Rogerson, and Valentinyi (2014). One strand of this research emphasizes changes in final goods expenditure shares across sectors as a result of rising incomes and non-homothetic preferences, including Matsuyama (2000), Boppart (2014) and Comin, Lashkari, and Mestieri (2018). Another strand of this literature stresses reallocations of economic activity across sectors because of unbalanced productivity growth, including Baumol (1967), Ngai and Pissarides (2007) and Herrendorf, Rogerson, and Valentinyi (2013). Although most research focuses on aggregate reallocations across sectors, some recent studies examine the contribution of differences in firm entry rates across sectors to structural transformation, including Dent, Karahan, Pugsley, and Sahin (2016); Pugsley and Sahin (2019). Other recent research provides evidence on factory-less goods

[1] In related work, Dey, Houseman, and Polivka (2012b) estimate that at their peak, manufacturing firms' outsourcing of ancillary activities, such as janitorial services, constituted 9 percent of US manufacturing employment.

producers that offshore production activities, including (Bernard and Fort, 2015; Bernard, Smeets, and Warzynski, 2017; Bernard, Fort, Smeets, and Warzynski, 2018; Breinlich, Soderbery, and Wright, 2018; Fort, Pierce, and Schott, 2018). Our contribution is to provide the first systematic evidence on structural transformation within and between firms over the last forty years on a consistent industry basis, and to provide theory and evidence on the role of endogenous investments in intangible capital in enabling firms to pivot away from declining sectors.

The remainder of the paper proceeds as follows. Section 2 discusses the construction of our data. Section 3 presents our stylized facts about structural transformation within and between firms, and Section 4 describes auxiliaries and studies their role as inhouse knowledge plants. Section 5 develops our theoretical framework that we use to rationalize these stylized facts. Section 6 uses the China shock as an exogenous source of variation to provide empirical evidence in support of the key mechanism in our theoretical framework. Section 7 concludes.

2 Data

We construct a new dataset that tracks establishments over a forty-year period from 1977 to 2016. We make three contributions in the data construction. First, we improve upon the Census firmid definitions both by fixing clearly spurious breaks and by developing a method to account for merger and acquisition activity in decomposing employment changes across continuers versus net births. Second, we employ the longitudinally consistent industry codes from Fort and Klimek (2018) to address significant changes in the US industry classification schemes over the period. Finally, we exploit four different data sources to identify auxiliary establishments consistently throughout the period and analyze their behavior. To our knowledge, ours is the first study of auxiliaries over such a long period.

2.1 Main Dataset Construction

The frame for our analysis is the U.S. Census Bureau's Longitudinal Business Database (LBD), initially assembled by Jarmin and Miranda (2002) and recently updated by Chow, Fort, Goetz, Goldschlag, Lawrence, Perlman, Stinson, and White (2021) to track the employment, pay, and industry of all private, non-farm U.S. establishments from 1977 to 2016 annually. An establishment is a single physical location where business transactions take place and for which payroll and employment are recorded. The LBD contains a longitudinally consistent establishment identifier ($lbdnum$), a firm identifier ($firmid$) that captures all of the establishments under common ownership or control in a given year, and an LBD-specific firm identifier that corrects for recycled $firmid$s in this long time series ($lbdfid$).

We augment the LBD data with additional information from Economic Censuses (ECs) of Auxiliaries (AUX), Construction (CCN), Finance, Insurance, and Real Estate (CFI), Manufactures (CMF), Mining (CMI), Retail Trade (CRT), Services (CSR), Transportation, Communications, and Utilities (CUT), and Wholesale Trade (CWH). The EC data are collected in years ending in "2" and "7", henceforth referred to as "Census" years, and provide establishment-level measures of sales for all

sectors.

We also use CMF data on manufactures' input purchases and product-level sales by industry to construct shares of manufacturing firms' sales and input purchases by industry, which enable us to identify their differential exposure to changes in Chinese import competition for their outputs and inputs. The trailer data are only available for a subset of manufacturing establishments that includes all large, multi-unit firms with industry-specific thresholds for the number of employees, as well as a random sample of smaller firms.[2]

2.2 New Firm Definitions

A primary goal of this paper is to assess the extent to which firms develop knowledge that may facilitate growth and pivoting across industries. This goal is complicated by the fact that Census' $firmid$s are not longitudinally consistent. By Census convention, $firmid$s break whenever firms transition between single-unit (SU) and multi-unit (MU) status. The Census firm identifier may also change spuriously during reorganizations and mergers and acquisitions (M&A) activity. In this section we provide a brief summary of how we address these limitations, deferring a more complete discussion to Appendix Section B.1.

We correct spurious SU-to-MU breaks by developing a 'fixed' Census firmid based on a simple algorithm that links firms' establishments across transitions between SU and MU status .[3] We use this corrected firmid to identify all the establishments that belong to a firm in a given year, and refer to it as a "Census firm." These "Census firms" are used to compute lower bounds in the quantification of within-firm structural change in Section 3.3, and are the way we identify firms when calculating pivoting and in regressions.

We also develop a broader definition of the firm that accounts for merger and acquisition activity. Inspired by Haltiwanger, Jarmin, and Miranda (2013), this approach captures the idea that (at least some) knowledge may be preserved when plants move across firms, even these transitions lead to firm entry or exit. Specifically, we classify a "Haltiwanger firm" as a continuer from year t to t' if at least one of its establishments exists in t' and t, respectively. Likewise, it is a death if all of its establishments perish before t', and it is a birth if all of its establishments are born after t. This definition thus addresses spurious breaks in firmids over time, and also allows treats a continuation of some part of the firm as a continuation of the firm. As Haltiwanger firms are broader than Census firms, they assign greater activity to continuers.[4] We use this definition to provide an upper bound on the amount of non-manufacturing employment growth accounted for continuing manufacturing firms in Section 3.3.

[2]The Census of Manufactures includes all manufacturing establishments in the United States. For very small establishments, data are based only on administrative records. All establishments that belong to multi-unit firms with at least 250 employees are sent the long census form, which includes questions about input purchases and sales by detailed product categories. A random sample of smaller establishments are also sent the long form. Remaining establishments are sent the short form, which does not include the questions on detailed inputs.

[3]We use Census' *lbdfid* in this corrections so that recycled $firmid$s are not present in our analysis.

[4]To sum the employment (or count) of "Haltiwanger firms" in a given year, we sum the employment (or count) of "Census firms" in that year that contain the antecedent or remnant of the continuing "Haltiwanger" firm. Thus, while the number of continuing "Census firms" in t and t' must be the same in both years, the number of continuing "Haltiwanger" firms can differ in the two years.

To address the second issue, we develop a broader definition of firm that accounts for establishments' movement across firms over time. Inspired by Haltiwanger, Jarmin, and Miranda (2013), this alternate approach captures the idea that, if firms house their knowledge in establishments, at least some of this knowledge may be preserved if the plant subsequently moves to another firm. Specifically, we classify a "Haltiwanger firm" as a continuer from year t to t' if at least one of its establishments exists in t' and t, respectively. Likewise, it is a death if all of its establishments perish before t', and it is a birth if all of its establishments are born after t. As Haltiwanger firms are broader than Census firms, they assign greater activity to continuers.[5] We return to this issue in Section 3.3.

2.3 Consistent Industry Classification

We measure the evolution of the US economy across industries by assigning each establishment to a single, six-digit North American Industry Classification System (NAICS) code. The governing principle under NAICS is to classify establishments based on the activities performed at the establishment, so it is particularly well-suited for studying changes in what firms and workers actually do. As in all establishment-based Census data, all workers in an establishment are classified under the same industry.

To track activity as consistently as possible over time, we employ the new LBD's *bds_vcnaics* variable, which contains the most recent vintage NAICS code for all establishments over the entire time period, along with additional information in accompanying industry files, as detailed in Fort and Klimek (2018).[6] An establishment may change its industry code over time, as its primary activity changes. We allow for these changes, but rely most heavily on codes assigned in EC years, since these contain the most accurate information.

We use the establishment-level codes to identify the mix of industries in which multiple-establishment firms operate, and to assign each firm principal 6-, 3-, and 2-digit NAICS codes according to its largest shares of employment and pay, respectively, at those levels of aggregation.[7]

2.4 Auxiliary Panel

A significant contribution of this paper is to construct and analyze a long time series of auxiliary establishments. Auxiliaries are establishments that primarily serve other establishments of their firm, rather than selling goods or services to other firms, e.g., an R&D lab or a warehouse. Analyzing auxiliaries over our 1977 to 2017 sample period is particularly challenging because, under the Standard Industry Classification (SIC) system used until 1997, they were classified under the industry they

[5] To sum up the employment of (or count) "Haltiwanger firms" in a given year, we sum up the employment of (or count) "Census firms" in that year that contain the antecedent or remnant of the continuing "Haltiwanger" firm. Thus, while the number of continuing "Census firms" in t and t' must be the same in both years, the number of continuing "Haltiwanger" firms can differ in the two years.

[6] NAICS replaced the former Standard Industrial Classification System (SIC) codes in 1997. Even within SIC and NAICS years, there are multiple vintages of these codes that change over time. We follow suggestions in Fort and Klimek (2018) to avoid using codes that have too much noise to provide meaningful information. See Online Appendix Section B.2 for details.

[7] In the cases where there is no variation in n-digit NAICS sectors within $(n-1)$-digit roots, we replace the n-digit codes with $(n+1)$-digit codes. For example, NAICS sector professional services (54) contains no variation at the 3-digit level – they are all 541. In that case, we use the $541x$ codes in place of 3-digit codes.

served rather than the activities they performed. For example, if an R&D lab conducted research for a manufacturing plant, it was assigned the manufacturing industry SIC code of that manufacturing plant.

To identify auxiliary establishments and their activities consistently across our sample period, we combine information from three sources: (1) the FK_NAICS "aux files" included in the LBD; (2) Census' AUX, Business Register (BR) and CBPBR files; and (3) the Censuses of Services (CSR) and Utilities (CUT). We find that there are 92 6-digit NAICS industries that may contain auxiliary establishments. These industries are in Trucking and Warehousing (NAICS 48-9), Information (NAICS 51), Professional, Technical, and Scientific Services (NAICS 54), Administration Services (NAICS 56), and Repair Services (NAICS 81). We provide further details on auxiliary data construction in Online Appendix Section B.3, as well as technical documentation available within the Census RDC network.

2.5 Additional Data Sources

We employ publicly available Comtrade data on Chinese exports by industry to Europe to construct plausibly exogenous measures of Chinese comparative advantage growth in other markets. We also use widely available Compustat data on public firms to compare our auxiliary-based measure of firms' intangible knowledge creation to firms' reported selling, general and administrative (SG&A) expenses, a key input into estimation of intangible capital appearing in the literature (Peters and Taylor, 2017).

3 An Anatomy of US Structural Change from 1977 to 2017

In this section, we introduce a number of new stylized facts about U.S. structural change that motivate our theoretical model below. In Subsection 3.1, we show that a substantial amount of the aggregate increase in non-manufacturing employment and payroll is accounted for Business Services (NAICS 5), which is disproportionately used as an intermediate input rather than in final consumption. In Subsection 3.3, we show that manufacturing firms account for a substantial amount of this aggregate reallocation, and systematically pivot towards services over time. In Subsection 4, we develop a new measure of intangible knowledge within firms, based on auxiliary establishments that primarily serve other establishments of their firm (e.g. a headquarters or a R&D lab). We provide evidence that these auxiliaries facilitate firm growth and pivoting towards services.

3.1 Structural Transformation Towards Services

We begin with the contribution of Business Services (NAICS 5) as a whole to the structural transformation of the U.S. economy. We next examine the constituent parts of Business Services, highlighting the roles of Professional Scientific and Technical Services (NAICS 54) and Management Services (NAICS 55), which we collectively refer to as "MPRO" services. Finally, we look within Professional, Scientific and Technical Services (NAICS 54), and provide further evidence on the role of knowledge services closely related to production, as captured by Computer System Design (NAICS 5415).

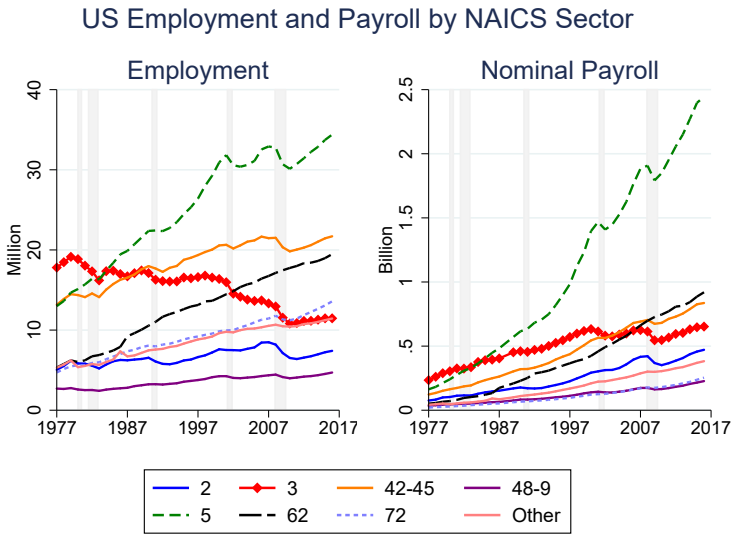
Business Services (NAICS 5) Figure 1 reports US employment (left panel) and payroll (right panel) by one- or two-digit NAICS sectors from 1977 to 2016. The starkest trend in the figure, in red, is the steady movement of U.S. employment away from Manufacturing (NAICS 3) and towards services. Indeed, manufacturing employment falls 35 percent between 1977 and 2016, from 17.8 to 11.5 million. By contrast, the two service sectors with the largest employment growth are Business Services (NAICS 5) in green and Healthcare (NAICS 62) in black. Employment in these two sectors grows by 21.3 and 14.1 million, or 165 and 265 percent, respectively. Overall, the share of US employment devoted to manufacturing declines from 27 percent in 1977 to 9 percent in 2016.

The right panel of Figure 1 provides an analogous decomposition with respect to nominal payroll, i.e., wages times employment.[8] The relative decline in manufacturing is similar: from 31 to 11 percent for payroll versus 27 to 9 percent for employment. The rise of Business Services (NAICS 5) payroll, by contrast, is starker: its share of overall payroll almost doubles, from 22 to 39 percent, versus the increase in its employment share from 19 to 28 percent.

Further comparison of the two panels reveals several interesting *implicit* trends with respect to wages. The relatively high payroll shares for Manufacturing and Business Services compared to their employment shares reveals their relatively high wages (i.e., payroll/employment) compared to other sectors. Wage growth in Business Services has been particularly rapid: over the entire 1977 to 2016 interval, the average annual increase in the Business Services wage is 12 percent, versus an average of 7 percent across all other sectors. After 2000, this relative increase subsides somewhat, as Business Services wage growth averages 3.6 percent versus 2.8 percent for all other sectors.

[8] Sales information is not currently available in the LBD.

Figure 1: US Employment and Payroll by Sector



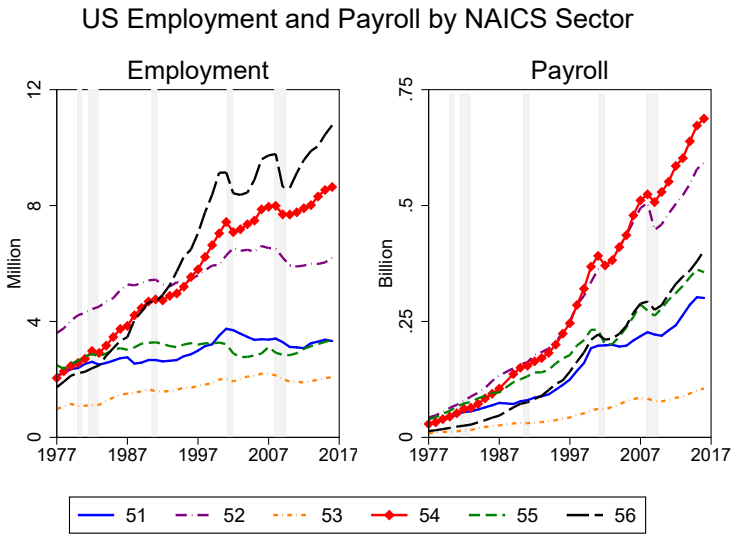
Source: Longitudinal Business Database and authors' calculations. Figure displays US employment (left panel) and wagebill (right panel) by broad NAICS sector from 1977 to 2016. Sector descriptions are as follows: Mining, Utilities and Construction (2), Manufacturing (3), Wholesale and Retail Trade (42-45), Transportation and Warehousing (48-49), Business Services (5), Health Care (62), Accommodation and Food Services (72), and Other, which includes Educational Services, the Arts and Public Administration. Payroll data for 1988 are missing.

Professional, Scientific and Technical Services (NAICS 54 and 55) We now turn to the role of Professional, Scientific and Technical (PST) services within Business Services (NAICS 5). The six 2-digit categories included within this sector are Information (NAICS 51), Finance, Insurance and Real Estate (NAICS 52-3), Professional, Scientific and Technical Services (NAICS 54), Management Services (NAICS 55) and Administration Services (NAICS 56). Employment and payroll across the 2-digit NAICS codes are reported in Figure 2.

As indicated in the figure, Administrative Services (NAICS 56) in black and Professional, Scientific and Technical (PST) Services (NAICS 54) in red account for most of the growth in NAICS 5 overall. In terms of employment, Administrative Services (NAICS 56), which includes temp agencies and janitorial service providers, grows from 1.7 million in 1977 to 10.8 million in 2016, or from 2.6 to 8.7 percent of overall US employment.[9] Employment in NAICS 54, which consists of a host of technical fields ranging from scientific research to computer design to marketing, increases from 2 million in 1977 to 8.7 million in 2016, or from 3 to 7 percent of overall US employment. Its rise in terms of payroll, from 4 to 11 percent of the US total, is even more dramatic, and dominates all other two-digit NAICS sectors.

[9]See Dey, Houseman, and Polivka (2012a) for evidence on the growing use of staffing services by manufacturers.

Figure 2: US Employment and Wagebill Within the Business Services Sector

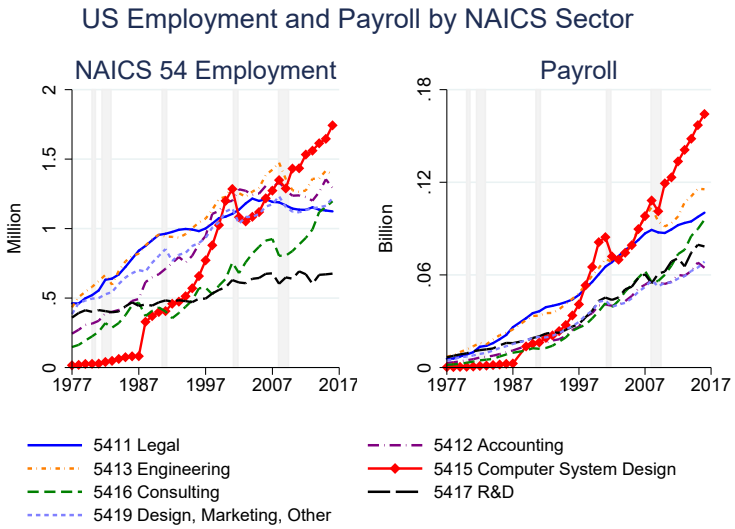


Source: Longitudinal Business Database and authors' calculations. Figure displays US Business Services (NAICS 5X) employment (left panel) and wagebill (right panel) by two-digit NAICS sectors from 1977 to 2016. Sector descriptions are as follows: Information (51), Finance and Insurance (52), Real Estate (53), Professional Services (54), Headquarters Services (55) and Administration Services (56). Payroll data for 1988 are missing.

Management Services (NAICS 55) establishments are more commonly referred to as "headquarters", that is, plants whose primary purpose is to oversee the other establishments of a multi-plant firm (U.S. Census Bureau, 1998). This supervisory role includes a range of core services, including planning, marketing, accounting, legal services, human resources, and financial management. Plants performing at least two of these activities are classified as NAICS 55. If they perform just one, their NAICS code corresponds to that single activity, e.g., Marketing (NAICS 541613). Thus NAICS 55 establishments can loosely be thought of as plants that perform at least two PST activities, a primary reason why we bundle them together under the moniker management and professional services ("MPRO") in our regression analysis below. As indicated in Figure 2, Management Services (NAICS 55) employment and payroll account for approximately 3 and 5 percent of the US totals during the 1977 to 2016 sample period.

Computer Systems Design (NAICS 5415) We next highlight the role of categories of closely related to knowledge services used in production in the growth of MPRO services. Figure 3 decomposes NAICS 54 into its four-digit NAICS components: Legal Services (5411), Accounting (5412), Engineering and Architecture (5413), Computer System Design (5415), Management and Technical Consulting (5416), Research and Development (5417) and Other (5419), within which we include Specialized Design (5414) and Advertising and Marketing (5418).

Figure 3: US Employment and Wagebill Within Professional and Technical Services (NAICS 54)



Source: Longitudinal Business Database and authors' calculations. Figure displays US Professional, Scientific, and Technical Services (NAICS 54X) employment (left panel) and wage bill (right panel) by four-digit NAICS sectors from 1977 to 2016. Sector descriptions are as follows: Legal (5411), Accounting (5412), Engineering (5413), Computer Systems Design (5415), Consulting (5416), R&D (5417) and Design, Marketing and Other (5419). Payroll data for 1988 are missing.

As indicated in the figure, Computer Systems Design (NAICS 5415), in red, exhibits the largest growth over the sample period, with employment well below 100 thousand workers until 1988, at which point it begins rising sharply, presumably in line with the rise of personal computers. Its employment increases to 1.7 million in 2016, or from 0.002 to 1.4 percent of overall US employment, while its share of overall US payroll increases from 0.003 to 2.6 percent.[10]

We summarize the empirical results from this subsection as our first stylized fact below.

Fact 1: US aggregate employment is moving towards services and especially PST services.

3.2 PST Services as Intermediate Inputs

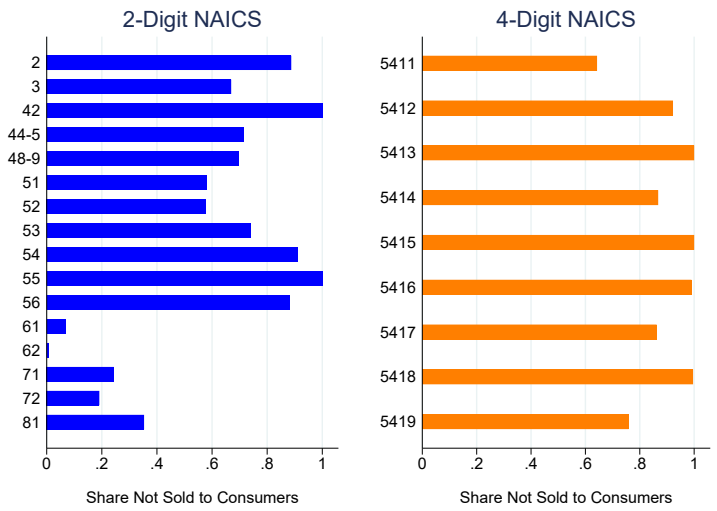
A distinctive feature of PST services (NAICS 54 and 55) is that they are disproportionately used for intermediate inputs rather than for final consumption. In Figure 4, we use data from the 1997 US supply-use input output table to report the share of the value of output "not" sold to final consumers (i.e. used for intermediate inputs) across two-digit NAICS sectors.[11] We use 1997 because it is halfway through our sample period, and the earliest input-output table using NAICS industries, but we note results are similar for subsequent years. We find that Wholesale (NAICS 42), Management

[10] Establishments providing these services are far more difficult to measure and analyze using SIC codes because under that industry classification system they are coded according to the industry they serve. An auto firm's R&D facility, for example, would be classified as an automobile establishment. We are able to track these establishment during both the SIC and NAICS eras here using the Fort and Klimek (2018) NAICS codes discussed above.

[11] Output sold to final consumers is identified via BEA output sector F01000.

Services (NAICS 55) and Professional Services (NAICS 54) have the highest intermediate input shares, while Healthcare (NAICS 62), Education (NAICS 61) and Retail (NAICS 44-45) have the lowest. Therefore, the growth of MPRO services documented above is largely driven by intermediate input demand rather than final consumption demand.

Figure 4: Share of the Value of Output Used for Intermediate Inputs in 1997



Source: Bureau of Economic Analysis and authors' calculations. Figure displays the share of each sector's value not sold to consumers, i.e., share of output sold as intermediates to firms as well as to the government. Data are from the detailed 1997 US Supply-Use Table published on the BEA website. The NAICS 2-digit sectors in the left panel are Mining, Utilities and Construction (2), Manufacturing (3), Wholesale Trade (42), Retail Trade (44-45), Transportation and Warehousing (48-49), Information Services (51), Finance, Insurance, Real Estate Services (52-3), Professional, Scientific and Technical Services (54), Management Services (55), and Administrative Services (5), Education (61), Health Care (62), Arts and Entertainment (61), Accommodation and Food Services (72), and Other (81). The NAICS 4-digit sectors in the right panel are: Legal (5411), Accounting (5412), Engineering (5413), Computer Systems Design (5415), Consulting (5416), R&D (5417) and Design, Marketing and Other (5419)..

We summarize the empirical results from this subsection as our second stylized fact below.

Fact 2: Professional, Scientific and Technical Services (PST) are primarily used as intermediate inputs rather than for final consumption.

3.3 Manufacturing Firms are Pivoting Towards Services

We begin providing evidence on the contribution of manufacturing firms to the aggregate growth in non-manufacturing employment over our sample period. We next show that patterns of non-

manufacturing employment growth differ systematically between manufacturing firms and other firms. Finally, we establish that continuing manufacturing firms are pivoting towards services over time.

Manufacturing Firms' Contribution to Non-manufacturing Employment Growth We provide lower and upper bounds on the employment growth of non-manufacturing (NM) versus manufacturing (M) firms using the two definitions of firms outlined in Section 2. The results in the top panel panel of Table 1 focus on "Census firms", i.e., the standard *lbdfid* firm identifier created by Census, albeit with our correction for spurious breaks. Census firms are labelled continuers between two years if their *lbdfid*s are present in both the begin and end year. The analysis in the bottom panel of Table 1 is based on "Haltiwanger" firms, which are classified as continuers if they contain any plants that are present in both the begin and end years, whether or not they are part of continuing *lbdfid*s. This more liberal definition of a continuer accounts for potential survival of firm knowledge through establishments as they are added and dropped by firms over time.

In both panels, we distinguish between continuing M versus NM firms. We use different rules for classifying Census and Haltiwanger firms as M. We label a Census firm as M if it contains an M establishment in at least one year from 1977 to 2016. Haltiwanger firms, by contrast, are classified as M if they ever contain an establishment that was ever part of a Census firm containing an M plant. Here, too, our looser definition for Haltiwanger firms is meant to capture potential transfers of knowledge across plants as they wind their way through firms.

As indicated in the two panels of the table, we find that M firms account for substantial shares – 17 and XXX percent – of the growth of overall NM employment under the two definitions. For Census firms, in the top panel of the table, we find that NM employment accounts for more than a fifth of total M firm employment in both years, approximately doubling from 12.8 to 23.5 million over the course of our sample period. Perhaps unsurprisingly, NM employment accounts for a larger share of NM firms (more than 70 percent in both years), and increases even more rapidly, from 36.4 to 89.2 million. Nevertheless, the increase in NM employment at M firms accounts for just under one fifth (17 percent) of the aggregate increase in NM employment.

Table 1: Non-Manufacturing Employment and Growth by Firm Definition, Firm Type and Margin

	"Census Firms" (Lower Bound)					
	1977		2016		Change	
	Level	Share	Level	Share	Level	Share
M Firms	12.8	0.26	23.5	0.21	10.7	0.17
Continuers	6.0	0.12	16.0	0.14	10.1	0.16
Net Birth/Death	6.8	0.14	7.5	0.07	0.7	0.01
NM Firms	36.4	0.74	89.2	0.79	52.7	0.83
Continuers	6.9	0.14	19.5	0.17	12.7	0.20
Net Birth/Death	29.6	0.60	69.7	0.62	40.1	0.63
Total	49.3	1.00	112.7	1.00	63.5	1.00

	"Haltiwanger Firms" (Upper Bound)					
	1977		2016		Change	
	Level	Share	Level	Share	Level	Share
M Firms	xxx	xxx	xxx	xxx	xxx	xxx
Continuers	xxx	xxx	xxx	xxx	xxx	xxx
Net Birth/Death	xxx	xxx	xxx	xxx	xxx	xxx
NM Firms	xxx	xxx	xxx	xxx	xxx	xxx
Continuers	xxx	xxx	xxx	xxx	xxx	xxx
Net Birth/Death	xxx	xxx	xxx	xxx	xxx	xxx
Total	xxx	xxx	xxx	xxx	xxx	xxx

Source: Longitudinal Business Database (LBD) and authors' calculations. Total non-manufacturing employment is the sum of the employment of all U.S. establishments in the LBD with a main industry outside manufacturing. Non-manufacturing employment at manufacturing firms (M) is the sum of the employment of all establishments with main industries outside manufacturing for firms that have at least one establishment with a main industry in manufacturing. Non-manufacturing employment a non-manufacturing firms (NM) is the sum of employment of all establishments with main industries outside manufacturing for firms that have no establishments with a main industry in manufacturing.

Using Haltiwanger firms, we find that M firms account for more than XXX percent of NM employment in both years, increasing from XXX to XXX million between 1977 and 2016. Here, too, NM employment accounts for a larger share of NM firms (about XXX percent in both years), and increases more rapidly, from XXX to XXX . Overall, M firms account for XXX percent of the aggregate increase in NM employment.

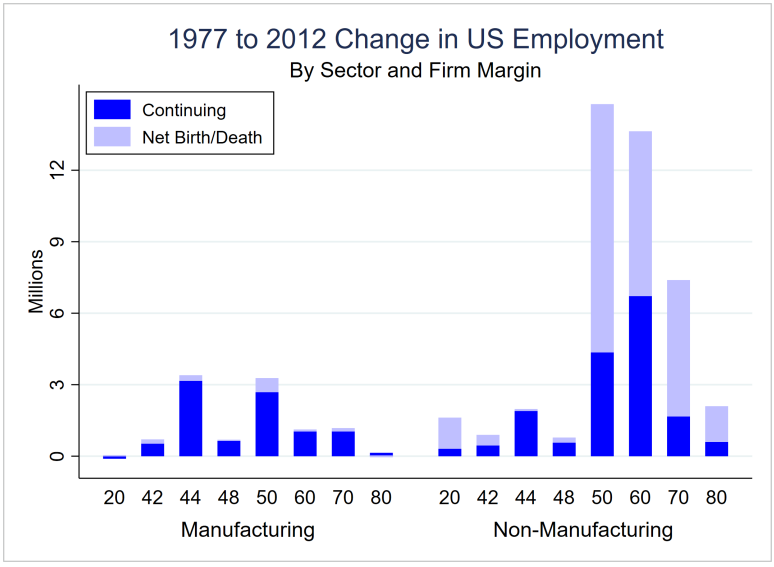
Both panels of Table 1 reveal a striking difference in the pattern of NM employment growth among M and NM firms. For M firms, virtually all of the increase in NM employment occurs among continuing firms, which make up 16 and XXX percent of the aggregate increase in non-manufacturing employment, leaving only 1 and XXX percent from net firm birth, respectively. In contrast, for NM firms, we find a much smaller contribution from continuing firms, which comprise 20 and XXX percent of the aggregate increase in NM, across the two firm types.

Taken together, these results yield the following fact:

> *Fact 3: Continuing manufacturing firms account for a substantial share (17 to xx percent) of aggregate non-manufacturing employment growth.*

Within Versus Between-Firm Non-manufacturing Employment Growth We now examine whether the distribution of NM employment growth among manufacturing firms is systematically different from that of NM firms. In Figure 5, we plot Census firms' 1977 to 2012 NM employment growth by 1-digit NAICS sector for both M firms (left panel) and NM firms (right panel). Contributions from continuing firms are in dark blue, and from net firm birth in light blue. For M firms, we find that NM employment growth is overwhelmingly concentrated in Business Services (NAICS 5) and Retail Trade (NAICS 44). NM firms, by contrast, exhibit substantial NM employment growth in Education (NAICS 6) and Accommodation and Food Services (NAICS 7) as well as in Business Services (NAICS 5).

Figure 5: Continuing M Firms' Grow Differentially Across NM Sectors



Source: Longitudinal Business Database and authors' calculations. Figure displays 1977 to 2012 change in employment (in millions) or manufacturing firms (left panel) and non-manufacturing firms (right panel). Dark blue denotes continuing firms. Light blue indicates net firm birth and death. NAICS industries are Mining (20); Wholesale Trade (42); Retail Trade (44); Transportation and Warehousing (48); Business Services (50); Education (60); Accommodation and Food Services (70); Other Services (80). Note that Manufacturing employment (3) is excluded.

This pattern of results gives rise to the following fact, indicating that NM employment growth at M firms does not simply reflect a broader shift towards non-manufacturing for the economy as a whole, but rather captures a distinctive pattern of pivoting towards services that is specific to manufacturing firms:

> *Fact 4: Manufacturing firms pivot towards a different mix of services than non-manufacturing firms.*

Manufacturing Firms' Pivoting Towards Services In this section we provide a within-firm view of the employment shifts examined above by analyzing changes in firms' principal NAICS codes over time. We use widely available data on publicly traded firms from Compustat rather than Census data as disclosure of individual firm information from the latter is prohibited. Results are reported in Table Table 2, where rows and columns correspond to firms' reported major NAICS sector in 1987 and 2018, respectively.[12] Each cell in the table reports the 1985 global employment (in thousands) across all continuing firms inhabiting that cell. Blank cells indicate zero employment.

Unsurprisingly, we find substantial persistence in major NAICS sectors over time, with the diagonals accounting for approximately 88 percent of all employment. More strikingly, however, we find that off-diagonal cells are generally unpopulated except for initial manufacturing firms, which are relatively likely to transition to Business Services (NAICS 5), specifically Information (NAICS 51), Finance and Insurance (NAICS 52), PST (NAICS 54) and Management Services (NAICS 55). The firms populating these cells are illustrative of US structural change. IBM, for example, transitions from Computer and Electronic Product Manufacturing (NAICS 334) to Information, while National Cash Register Company and Unisys move from the same origin industry to PST (NAICS 54).

Table 2: Firms' Major NAICS Transition Matrix, 1985 to 2018

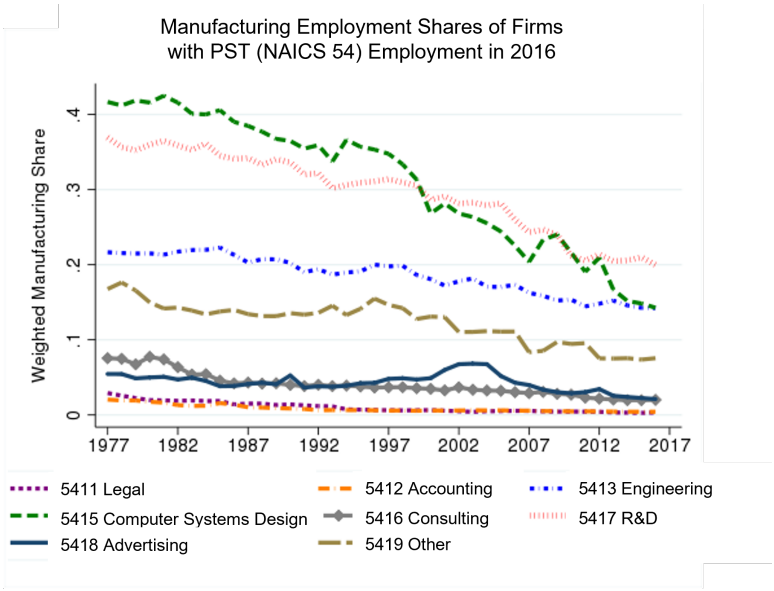
Major NAICS Sector in 1985 \ Major NAICS Sector in 2018	20	30	42	44	48	51	52	53	54	56	60	70	81	Total
20	982	8	1		2		0	1				0		994
30	47	7,659	29			410	70	0	165	0	0	21		8,401
42		9	63	0	6			2			5			85
44	7	2		231			27	11				1		279
48	1	0			780			5		13				800
51		1				388			11	14	6			421
52	3	418				5	703	0						1,129
53								30						30
54		24						0	22		0			46
56		0							1	547				548
60										12	122			135
70						37	0	157				211		405
81		3						1					15	18
Total	1,040	8,124	92	231	788	840	800	207	199	587	134	233	15	13,291

Source: Computstat data and authors' calculations. Sample is continuing firms from 1987-2018. Rows are firms major NAICS sector in 1987. Columns are firms major NAICS sector in 2018. Each cell reports global employment (in thousands) for continuing firms in that cell. NAICS industries are Mining (20); Manufacturing (30); Wholesale Trade (42); Retail Trade (44); Transportation and Warehousing (48); Professional Services (50); Education (60); Accommodation and Food (70); Other Services (80).

[12] Data on firms' major sector in Compustat is not available until 1987.

One limitation of these transition matrices is that they only capture changes in a firm's major industry. Hence, they focus solely on the extensive margin of major sector classification, and abstract from changes in the intensive margin of employment in each sector where the firm operates. In Figure 6, we return to our use of Census data and provide evidence on these intensive margin changes. For each continuing firm with positive employment in PST (NAICS 54) at the end of our sample in 2016, we display the share of manufacturing in total firm employment for each year back to the beginning of our sample in 1977. We show these manufacturing employment shares separately for each 4-digit sub-sector within PST.

Figure 6: Firm Pivoting from Manufacturing into Professional and Technical Services from 1977-2016



Source: Longitudinal Business Database and authors' calculations. Sample is continuing firms with Professional and Technical Services (NAICS 54) employment in 2016. Figure displays the share of manufacturing in the employment of these firms in each year.

Across all four-digit sub-sectors of Professional and Technical Services (NAICS 54), we find that manufacturing employment shares are larger in earlier years than in later years, again consistent with continuing firms pivoting away from manufacturing and towards PST services. We find that this pivot away from manufacturing is largest for firms with positive employment in Computer System Design (NAICS 5415) and Research & Development (NAICS 5417), both of which capture knowledge services complementary to production activity.

4 Auxiliary Establishments as Knowledge Plants

Manufacturing firms' shift towards services presented in the last section suggests the presence of general capabilities or intangible knowledge that firms can redeploy from manufacturing to services. In this section, we propose auxiliaries as establishments in which this knowledge is created and maintained within the firm, such that the knowledge remains proprietary and excludable. We begin

by describing auxiliaries and analyzing how they differ from other establishments in the same detailed industries. We then examine how firms with auxiliaries differ from other firms, and how their auxiliary employment is distributed. Finally, we investigate associations between the presence of auxiliaries and firm growth and pivoting.

4.1 Characteristics of Auxiliary Establishments

Auxiliaries are plants that primarily serve other establishments of their firm, such as an R&D lab or a warehouse. They are present in 92 six-digit NAICS, which belong to the following six two-digit NAICS sectors: Transportation (48), Warehousing (49), Information (51), PST (54), Management of Companies and Enterprises (55), Administrative and Support Services (56), and Repair Services (81). Within these broad sectors, there is considerable variation in terms of the number of 4- and 6-digit NAICS sub-sectors in which they appear. Of note, auxiliaries are present in all 4-digit subsectors of PST (NAICS 54), though their importance varies considerably across them and over time.

We begin by examining differences in performance between auxiliaries and other establishments within the same six-digit industry. To do so, we estimate the following regression specification:

$$\begin{aligned} y_{ift} = \quad & \alpha + \beta_A AUX_{ift} + \Sigma\beta_{AN}(AUX_{ift} \times N2_{ift}) + \\ & \beta_G Age_{ift} + \Sigma\beta_N N6_{ift} + \Sigma\beta_Y Year_t + \epsilon_{ift}, \end{aligned} \tag{1}$$

where AUX_{ift} is an indicator equal to one if establishment i at firm f in year t is an auxiliary, $N2$ is the two-digit NAICS of the establishment interacted with the auxiliary indicator, Age_{ift} includes a set of categorical age controls for the establishment (birth, 1-4 years, 5-9 years, 10 -20 years and 20+), and $N6_{ift}$ and $Year_t$ are fixed effects for the six-digit NAICS of the establishment and year. We consider the log of establishment employment, sales, and wage (payroll/employment) as dependent variables. We limit this sample to the six-digit NAICS sectors that have auxiliary establishments, and to Census years ending in "2" and "7" from 1977 to 2012. Since all establishments within NAICS 551114 are auxiliaries, we exclude NAICS 55 from this analysis.[13]

We present results from estimating equation (1) via OLS in Table 3. Columns 1 and 4 indicate that auxiliary establishments are 76 and 94 log points larger than non-auxiliaries in terms of employment and sales, respectively. Column 7 shows that auxiliaries' wages are 38 log points higher, even within the same detailed industry.

[13] It is unclear whether establishments in 551111 or 51112 are auxiliaries, and in any case these sectors are too small to analyze and disclose.

Table 3: Auxiliary establishment characteristics

	$ln(emp_{ijt})$			$ln(sales_{ijt})$			$ln(wage_{ijt})$		
	(1)	(2)	(3)	(7)	(8)	(9)	(4)	(5)	(6)
$Auxiliary_{ijt}$	0.764***	-0.078***		0.970***	-0.158***		0.383***	0.064***	
	(0.027)	(0.021)		(0.025)	(0.021)		(0.016)	(0.011)	
$Auxiliary_{ijt}$ in:									
Transportation			-0.231**			-0.862***			-0.262
			(0.102)			(0.304)			(0.255)
Warehousing			-0.331***			-0.198***			0.059***
			(0.061)			(0.062)			(0.016)
Information			0.002			-0.2			0.034
			(0.119)			(0.138)			(0.030)
PST			-0.054***			-0.172***			0.075***
			(0.020)			(0.018)			(0.010)
Administrative			-0.110***			-0.112***			0.093***
			(0.032)			(0.031)			(0.012)
Repair			0.097			-0.033			0.036**
			(0.068)			(0.030)			(0.015)
Constant	1.305***	0.060***	0.060***	5.427***	0.345***	0.345***	2.952***	0.033***	0.033***
	(0.006)	(0.004)	(0.004)	(0.006)	(0.020)	(0.020)	(0.003)	(0.003)	(0.003)
Adj. R^2	0.22	0.84	0.84	0.24	0.86	0.86	0.35	0.95	0.95
Plant Age FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Age FEs	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Firm Dep Var	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
$ln(estabs_{ft})$	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes

Source: Table presents results from estimating equation (1) via OLS. Dependent variable is the log of employment, sales, or wage for establishment i, in industry j, and year t, as indicated in columns. $Auxiliary_{ijt}$ is an indicator for whether the establishment primarily serves other establishments in its firm. "$Auxiliary_{ijt}$ in:" denotes the 2-digit NAICS sector of an auxiliary: 48 - Transportation, 49 - Warehousing, 51 - Information, 54 - Professional, Technical, and Scientific Services (PST), 56 - Administrative Services, 81 - Repair Services. Sample limited to 6-digit NAICS industries with auxiliary establishments and covers each Economic Census year (years ending in 2 or 7) from 1977 to 2012. All regressions include 6-digit NAICS, FIPs, and Year fixed effects. "Firm Dep Var" is the firm-level measure of the dependent variable. $ln(estabs_{ft})$ is the log number of establishments at the establishment's firm in year t. Age categories are: births, 1-4, 5-9, 10-19, and 20+. Standard errors clustered by firm.

In columns 2, 5, and 8 we add controls for firm age, the log of firm employment (sales, for column 5, and wage, for column 8), and the log of the total number of establishments at the firm. Once we control for these firm characteristics, auxiliary establishments are actually smaller than non-auxiliaries, and particularly so for sales. Since the sales measure at auxiliaries captures sales to *other* firms, this outcome is consistent with the premise that these establishments are generally focused on providing inputs within their own firm. In contrast to the negative size premia, column 8 indicates that auxiliary establishments pay higher wages, even when controlling for the average firm wage.

Columns 3, 6, and 9 break out the auxiliary indicator by the establishments' 2-digit NAICS sector, e.g., an R&D auxiliary would be interated with a PST (NAICS 54) dummy. These estimates indicate that wages are particularly high at inhouse Warehouses (NAICS 49) and PST establishments, and

absent from Transportation (NAICS 48), in which trucking is the predominant auxiliary industry.[14] The premia documented in this section are consistent with the premise that auxiliary establishments generate knowledge via relatively high-skill workers.[15]

4.2 Characteristics of Firms with Auxiliaries

In this subsection, we examine how firms with auxiliary establishments differ from other firms.

We first estimate

$$y_{ft} = \alpha + \beta_A AUX_{ft} + \beta_{ASh} AUXEmpSh_{ft} + \Sigma\beta_N N4_{ft} + \Sigma\beta_Y Year_t + \Sigma\beta_S NonAuxEmpShN2_{ft} + \epsilon_{ft}, \quad (2)$$

where AUX_{ft} is an indicator equal to one if firm f in year t has one or more auxiliary establishments, $AUXEmpSh_{ft}$ is a measure of the firm's share of employment in auxiliaries in year t, and $N4_{ft}$ and $Year_t$ are fixed effects for the main four-digit NAICS of the firm (based on employment) and year. When including the firm's auxiliary employment share, we also control for its non-auxiliary employment shares across two-digit sectors ($NonAuxEmpShN2_{ft}$) to ensure that our auxiliary measure does not capture activity across potential auxiliary sectors more generally.[16] We estimate equation (2) using the log of firm employment, the log of firm sales, the log number of establishments, and firm age as dependent variables. We use the Economic Census data in each decade from 1977 through 2007 for these regressions.

Table 4 presents the results from estimating equation (2) via OLS. We generally find that firms with auxiliaries are substantially larger, older, and have more establishments. All of these premia are decreasing in a firm's share of auxiliary employment. Since the average firm with an auxiliary has 17 percent of its employment in auxiliaries, the average firm is still about 343 log points larger in employment terms and 360 log points larger in sales.[17]

[14] In additional results not reported here, we investigate the robustness of these results in two ways. First, we confirm that the results in Table 3 are insensitive to controlling for firm employment (rather than the same firm-level measure of the dependent variable for sales and wage), to limiting the sample to multi-unit firms, and to examining the wage premia by four-digit sector of the PST and Information sectors. We do not find a statistically significant estimate for wage premia in Legal Services (NAICS 5411). By contrast, Telecommunications (517) and Data Processing (518) both exhibit positive and significant wage premia. Second, we assess whether inhouse manufacturing establishments display similar characteristics as these inhouse "knowledge" plants. In contrast to the results we document here, manufacturing plants that provide inputs to other establishments of their firm are larger, but do not pay higher wages relative to non-inhouse plants in the same detailed industries.

[15] We estimate similar specifications using 4-digit dummies and find that auxiliary establishments in Telecommunications (NAICS 517) and Data Processing (NAICS 518) also exhibit positive wage premia. In Warehousing, the only six-digit NAICS industry with auxiliary establishments is General Warehousing and Storage (493110). While this may not seem like a knowledge-intensive sector, the EC forms for auxiliaries in that industry ask about supply chain management and other related questions. We are investigating those data to see if we can provide additional evidence on how those types of activities may occur in these establishments.

[16] We also consider specifications in which we decompose the firm's share of auxiliary employment across sectors. Steve: see output/tables_nov21.xls for all the output.

[17] For employment, a firm with an auxiliary and the average auxiliary employment share is 3.840+(-2.377*0.173)=343 log points larger.

Table 4: Auxiliary firm premia

	$ln(emp_{ft})$		$ln(sales_{ft})$		$ln(estabs_{ft})$		Age_{ft}	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$Auxiliary_{ft}$	3.481***	3.840***	3.690***	4.023***	2.186***	2.431***	5.310***	5.557***
	(0.008)	(0.011)	(0.009)	(0.012)	(0.006)	(0.008)	(0.029)	(0.040)
$AuxEmpShare_{ft}$		-2.377***		-2.469***		-1.965***		-2.294***
		(0.056)		(0.063)		(0.033)		(0.217)
Adj. R-Squared	0.20	0.20	0.30	0.30	0.35	0.36	0.24	0.24
N2 Non-Aux Emp Shares	No	Yes	No	Yes	No	Yes	No	Yes

Source: Table presents results from estimating equation (2) via OLS. Dependent variable is the log of employment, sales, number of establishments or age for firm f, in year t, as indicated in columns. $Auxiliary_{ft}$ is an indicator for whether the firm has an auxiliary establishment. $AuxEmpShare_{ft}$ is the firm's share of employment in auxiliary establishments. For firms with an auxiliary, the mean and standard deviation of their auxiliary employment share are 0.17 and 0.19, respectively. All regressions include fixed effects for the firm's main 4-digit NAICS (by employment) and year. Standard errors clustered by firm. N2 Non-Aux Emp Shares are the share of non-auxiliary employment by 2-digit NAICS. Sample consists of 14.2 million observations of firms in each decade from 1977 to 2007.

Auxiliaries, Firm Growth and Pivoting We now examine the association between the presence of auxiliaries and firm growth and pivoting. We estimate the following regression:

$$\begin{aligned}\Delta y_{ft,t+10} = \quad & \alpha + \beta_A AUX_{ft} + \beta_{ASh} AUXEmpSh_{ft} + \Sigma\beta_F X_{ft} \\ & \Sigma\beta_N N4_{ft} + \Sigma\beta_Y Year_t + \Sigma\beta_S NonAuxEmpShN2_{ft} + \epsilon_{ft},\end{aligned} \tag{3}$$

where $\Delta y_{ft,t+10}$ is the change in a firm outcome over decades defined by Census years from 1977 to 2007. In light of the significant size and age premia of firms with auxiliaries documented in Table 4, we control for the log of firm employment, firm age categories, and the log of the number establishments at the firm. As before, we include fixed effects for the firm's main four-digit NAICS and for each year.

We consider the log change in firm employment and sales, as well as a pivot measure that calculates the amount of overlap between a firm's employment in year t compared to $t+10$,

$$Pivot_{ft} = \quad -\sum_j \min\{Share_{fj,t}, Share_{fj,t+10}\}, \tag{4}$$

where $Share_{fj,t}$ represents firms the employment share of firm f in 6-digit NAICS industry j in year t. We pre-multiply this overlap measure by -1 so that less overlap translates into higher values of $Pivot_{ft}$.

The top panel of Table 5 presents the results from estimating equation (3) via OLS. As indicated in the table, while firms with auxiliaries do not seem to grow differentially on average, their growth rate is strongly increasing in their share of auxiliary employment. Firms with the average share of auxiliary employment grow approximately 3.4 percentage points more relative to firms without auxiliaries $(-0.048 + (0.472 \times 0.173))$. This differential growth rate is even more pronounced for sales,

where firms with the average auxiliary employment share grow about 4.2 percentage points more than firms without auxiliaries.

Columns 5 and 6 in the top panel of Table 5 document the relationship between auxiliary employment and pivoting. Firms with an auxiliary and the average share of auxiliary employment pivot relatively more than firms without an auxiliary. A firm with the average auxiliary employment share pivots 1.28 $(-.013 + (-0.149 \times 0.173))$ percentage points more relative to firms without an auxiliary.

Table 5: Auxiliaries and Firm Outcomes

	$\Delta ln(emp_{ft})$		$\Delta ln(sales_{ft})$		$Pivot_{ft}$	
Panel A: Any Auxiliary	(1)	(2)	(3)	(4)	(5)	(6)
$Auxiliary_{ft}$	0.00	-0.048***	-0.011	-0.086***	0.002	-0.013***
	(0.007)	(0.009)	(0.009)	(0.010)	(0.003)	(0.003)
$AuxEmpShare_{ft}$		0.472***		0.738***		0.149***
		(0.045)		(0.059)		(0.016)
Adj. R-Squared	0.09	0.09	0.06	0.06	0.11	0.11
Panel B: Auxiliary by N2						
$Auxiliary_{ft}$		-0.049***		-0.096***		-0.017***
		(0.009)		(0.011)		(0.003)
Transportation		0.315*		0.002		-0.156***
		(0.167)		(0.251)		(0.057)
Warehousing		0.458***		0.693***		0.227***
		(0.107)		(0.131)		(0.038)
Information		0.478		1.227**		0.048
		(0.382)		(0.580)		(0.112)
PST (NAICS 54)		0.446***		0.566***		0.156***
		(0.086)		(0.102)		(0.036)
Management		0.475***		0.926***		0.218***
		(0.059)		(0.076)		(0.019)
Administrative		0.666***		0.627***		0.047
		(0.106)		(0.110)		(0.043)
Repair		0.338***		0.503***		0.002
		(0.107)		(0.120)		(0.047)
Adj. R-Squared		0.09		0.06		0.11
Observations (M)	3.9	3.9	3.9	3.9	3.9	3.9

Source: Table presents results from estimating equation (3) via OLS. Dependent variables in columns (1) to (4) are the log change of firm employment or sales by decade. $Pivot_{ft}$ measures the share of employment in $t+1$ in the same industries as the firm's employment in t. $Auxiliary_{ft}$ is an indicator for whether the firm has an auxiliary establishment. $AuxEmpShare_{ft}$ is the firm's share of employment in auxiliary establishments. For firms with an auxiliary, the mean and standard deviation of their auxiliary employment share are 0.17 and 0.19, respectively. All regressions include fixed effects for the firm's main 4-digit NAICS (by employment) and year, and control for the log of firm employment, firm age categories, and the log number of establishments, and the firm's share of non-auxiliary employment across 2-digit NAICS sectors. Standard errors clustered by firm. Sample consists of 3.9 million observations of continuing firms in each decade from 1977 to 2007.

In the bottom panel of Table 5, we interact the auxiliary dummy variable with the firms' employment shares in each of the six sectors in which these establishments appear. As indicated in the table, the increased pivoting associated with auxiliary employment is driven by auxiliary employment in Warehousing, PST, and Management Services. The industry descriptions for PST and Management both suggest that these are particularly high-skill sectors. While canonical views on warehouses suggest low-skill labor, the higher wage premia for warehouse auxiliaries, along with questions on the EC warehouse forms, suggest that some warehouses are involved with technology-intensive supply chain management activities.

We summarize the empirical findings of this subsection in our third stylized fact.

> *FACT 5: Auxiliary establishments have higher average wages than non-auxiliary establishments within the same detailed industry, even when controlling for their firms' size and age. Firms with auxiliary establishments are older, employ more workers, and have more establishments than firms without auxiliaries. Firms with greater employment in auxiliary establishments exhibit greater firm growth and pivoting.*

5 Theoretical Framework

We rationalize the empirical patterns of U.S. structural change presented above in a model in which firm operations involve both management and professional (MPRO) services and production activities, which are complementary to one another. MPRO services involve investments in intangible knowledge that are specific to the firm but general across sectors. If structural transformation occurs within firms, this intangible knowledge can be redeployed from one sector to another. In contrast, if reallocation occurs through the entry and exit of firms, this firm-specific intangible knowledge is destroyed. Firms that undertake MPRO services within firm boundaries have greater incentives to invest in intangible knowledge, because it is easier to exclude other firms from these investments when they are undertaken in-house. Therefore, firms that vertically integrate MPRO services make greater investments in intangible knowledge, and hence have greater ability to pivot across sectors.

This theoretical framework features structural transformation within and between firms. We distinguish between "sectoral" structural change, in which the reallocation of economic activity towards services occurs across final consumption expenditure categories (e.g. from agriculture to manufacturing) and "functional" structural change, in which this reallocation towards services occurs through intermediate input expenditure categories (e.g. from production to MPRO services). This functional structural change can occur within firms, if MPRO services and production are vertically integrated within the boundaries of the same firm, and otherwise occurs between firms. Firms make endogenous investments in intangible knowledge that facilitate pivoting across final goods sectors. More productive firms choose to vertically integrate MPRO services, and hence make greater investments in intangible knowledge, which allows them to more easily pivot across sectors.

5.1 Preferences

We consider a world of N countries indexed by $n, i \in N$.[18] Consumer's preferences in country n are defined over consumption indexes (C_{nj}) of a set of final demand sectors indexed by $j \in J$:

$$U_n = \left[\sum_{j \in J} \left(\frac{C_{nj}}{\eta_{nj}^U} \right)^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}}, \tag{5}$$

where ν is the elasticity of substitution across sectors; η_{nj}^U captures the representative consumer's relative preferences across sectors; to streamline notation, we suppress the implicit dependence on time, but take it as understood that we allow all variables to vary over time.

The consumption index for each sector j in destination country n (C_{nj}) is defined over consumption (c_{njf}) of horizontally-differentiated varieties supplied by firms $f \in F_{ij}$ from each origin country i:

$$C_{nj} = \left[\sum_{i \in N} \sum_{f \in F_{ij}} c_{nijf}^{\frac{\sigma_j - 1}{\sigma_j}} \right]^{\frac{\sigma_j}{\sigma_j - 1}}, \tag{6}$$

where σ_j is the elasticity of substitution across varieties within sectors. Given this nested constant elasticity of substitution (CES) demand structure, sales for firm f from origin country i in destination country n and in sector j (x_{nijf}) are:

$$x_{nijf} = p_{nijf}^{1-\sigma_j} X_{nj} P_{nj}^{\sigma_j - 1}, \tag{7}$$

where X_{nj} is expenditure on sector j in destination country n and P_{nj} is the price index for sector j in destination country n (dual to equation (6)). Total firm sales (x_{if}) are the sum of sales across all sectors within each destination country and across all destination countries served by the firm:

$$x_{if} = \sum_{n \in N_{if}} \sum_{j \in J_{nif}} x_{nijf} = \sum_{n \in N_{if}} \sum_{j \in J_{nif}} p_{nijf}^{1-\sigma_j} X_{nj} P_{nj}^{\sigma_j - 1}, \tag{8}$$

where N_{if} is the set of destination countries served by firm f from origin country i and J_{nif} denotes the set of sectors in which firm f from origin country i serves destination country n.

5.2 Final Goods Production

Each country i is endowed with inelastic supplies of unskilled workers ($\bar{L}_i^P$), who undertake production tasks (as indicated by the superscript P), and skilled workers ($\bar{L}_i^S$), who perform MPRO services (as indicated by the superscript S). Our specification of production and entry extends Melitz (2003) to incorporate multiple sectors and factors of production, with a complementary between MPRO services and production activities. In order to enter, a final goods firm must incur an upfront entry cost of f_e units of skilled workers. Incurring this sunk entry cost creates a horizontally-differentiated

[18] Unless otherwise noted, we use n to indicate countries of consumption (destinations) and i to denote countries of production (origins).

brand, which can be used to supply one variety in each sector j, and reveals the firm's productivities in each sector (φ_{fj}). If the firm chooses to serve a country n in sector j, it must incur an additional fixed market entry cost of F_{nj}^N units of skilled workers for that country and sector. After incurring this market entry cost, the firm can supply its variety in sector j to country n at a constant unit cost that depends on its productivity in that sector (φ_{fj}). Additionally, the firm faces iceberg variable trade costs, such that $\tau_{nij} \geq 1$ units of a variety must be shipped from origin country i in sector j in order for one unit to arrive in destination country n, where $\tau_{nij} > 1$ for $n \neq i$ and $\tau_{nnj} = 1$. Finally, after entering, each entering firm faces a constant probability of death (δ), which induces ongoing entry and exit of firms in the steady-state equilibrium of the model.

Unit costs for firm f in sector j in origin country i depend on the cost of performing MPRO services (e.g. managing, marketing, advertising, accounting) and production activities (e.g. assembling, machining, stamping). We assume that MPRO services and production activities are combined according to the following CES unit cost function:

$$\frac{1}{\theta_f}\gamma_{ifj} = \frac{1}{\theta_f}\left[\left(q_{if}^S\right)^{1-\mu_j} + \left(\frac{\left(w_i^P\right)^{\beta_j}\left(Q_{ij}\right)^{1-\beta_j}}{\varphi_{fj}}\right)^{1-\mu_j}\right]^{\frac{1}{1-\mu_j}}, \qquad \begin{matrix} 0 < \mu_j < 1 \\ 0 < \beta_j < 1 \end{matrix}, \tag{9}$$

where $\theta_f \geq 1$ is a Hicks-neutral productivity shifter that depends on firm investments in intangible knowledge; q_{if}^S is the cost of MPRO services; w_i^P is the wage of unskilled workers used in production, which can differ from the wage of skilled workers (w_i^S) used for MPRO services; Q_{ij} is the cost of intermediate inputs in sector j in country i; μ_j is the elasticity of substitution between MPRO services and production activities in sector j; and β_j controls the intensity with which production in sector j involves the use of unskilled workers and intermediate inputs.

We model intermediate inputs using roundabout production, in which each sector uses all sectors as intermediate inputs with the same elasticity of substitution between sectors as for final demand. The cost of intermediate inputs for each sector (Q_{ij}) takes the same form as the price index dual to the utility function (5):

$$Q_{ij} = \left[\sum_{k \in J}\left(\frac{P_{ik}}{\eta_{ijk}^P}\right)^{1-\nu}\right]^{\frac{1}{1-\nu}}, \tag{10}$$

where η_{ijk}^P controls the relative intensity with which each sector k is used as an input for sector j, which can differ from the relative preferences for each sector k in consumption ($\eta_{nk}^U \neq \eta_{ijk}^P$).

Two aspects of this production technology are noteworthy. First, we assume that MPRO services and production activities are complements ($0 < \mu_j < 1$), which is in line with the assumption in the macroeconomics literature of that services and goods are complements, although here we make the assumption about the production technology rather than final demand. Second, we assume that the same MPRO services are used across sectors within firms, which implies that the cost of MPRO services is the same across all sectors within firms ($q_{ifj}^S = q_{if}^S$ for all j), although we show below that the relative shares of MPRO services and production activities in unit costs vary across sectors with the firm's productivity in each sector (φ_{fj}). We now turn to examine the determination of this cost

of MPRO services (q_{if}^S).

5.3 Management and Professional (MPRO) Services

Each final goods firm faces the choice between outsourcing MPRO services to a standalone supplier or incurring a fixed cost of F^S units of skilled workers to undertake them in-house. Each firm also chooses how much to invest in intangible knowledge to reduce unit costs. We assume that a firm can obtain a stock of $\theta_f > 1$ of intangible knowledge by employing $\psi\left(\theta_f^\zeta - 1\right)$ skilled workers in research.[19] The parameter ψ governs the productivity of these investments, while the parameter ζ controls the convexity of research costs with respect to these investments. We assume that investments in intangible knowledge are only excludable if MPRO services are undertaken within the boundaries of the firm.[20] Therefore, if a final goods firm incurs the fixed cost of vertically integrating MPRO services, only it retains access to its intangible knowledge. In contrast, if the final goods firm outsources MPRO services, its intangible knowledge diffuses freely to all firms in the economy.

Under these assumptions, the vertical integration and intangible investment decisions become closely connected to one another. If a firm incurs the fixed cost of vertically integrating MPRO services and invests in intangible knowledge, its exclusive access to this intangible knowledge raises its share of revenue within each sector. In contrast, if a firm outsources MPRO services, any investment in intangible knowledge diffuses freely to all firms, and leaves the firm's share of revenue within each sector unchanged. Assuming that each firm is sufficiently small that its investments in intangible knowledge have a negligible effect on the sector price index and total sector expenditure, it follows that no firm that outsources MPRO services has any incentive to undertake costly investments in intangible knowledge ($\theta_f = 1$). In contrast, firms that vertically integrate MPRO services in general undertake positive investments in intangible knowledge ($\theta_f > 1$), as determined further below.

We assume that MPRO services are produced using skilled workers according to the following unit cost function:

$$\delta_{if}^S = w_i^S, \tag{11}$$

where δ_{if}^S denotes the unit cost of MPRO services for firm f in origin country i.

We assume that this production technology for MPRO services is freely available to all firms. If MPRO services are outsourced, they are produced by a standalone supplier using this technology under conditions of perfect competition. Therefore, zero profits implies that the price of MPRO services equals unit cost, which is equal to the wage of skilled workers (w_i^S). If MPRO services are vertically integrated in-house, they are produced by the final goods firm using this same technology, which implies that unit cost is again equal to the wage of skilled workers (w_i^S). Therefore, in either case, the final goods firm's unit cost function (9) can be re-written as follows:

$$\frac{1}{\theta_f}\gamma_{ifj} = \frac{1}{\theta_f}\left[\left(w_i^S\right)^{1-\mu_j} + \left(\frac{\left(w_i^P\right)^{\beta_j}\left(Q_{ij}\right)^{1-\beta_j}}{\varphi_{fj}}\right)^{1-\mu_j}\right]^{\frac{1}{1-\mu_j}}. \tag{12}$$

[19] This formulation of research costs ensures that a firm that makes no investment in intangible knowledge ($\theta_f = 1$) incurs zero costs, since $\psi\left(1^\zeta - 1\right) = 0$.

[20] For a broader discussion of knowledge-based approaches to the boundaries of the firm, see Demsetz (1988).

Under our assumptions, there are only two differences between vertical integration and outsourcing. First, vertical integration requires an additional fixed cost (F^S) to be incurred. Second, only final goods firms that vertically integrate MPRO services have an incentive to invest in intangible knowledge ($\theta_f > 1$). In contrast, final goods firms that outsource MPRO services make zero investments in intangible knowledge ($\theta_f = 1$).

5.4 Firm Problem

We assume that final goods firms compete under conditions of monopolistic competition within each sector. Each firm chooses the number of countries to serve, the number of sectors in which to serve each country, whether to outsource MPRO services or undertake them in-house, its investment in intangible knowledge, the price to charge for each variety, and inputs of MPRO services, unskilled workers and intermediate inputs to maximize its profits. Using the unit cost function (12), the firm problem can be written as follows:

$$\max_{\{\{p_{nijf}\},N_{if},J_{nif},\mathbb{I}_{if}^S,\theta_f\}} \left\{ \begin{array}{l} \sum\limits_{n\in N_{if}} \sum\limits_{j\in J_{nif}} p_{nifj} y_{nifj}\left(p_{nifj}\right) - \frac{1}{\theta_f}\gamma_{ifj} y_{nifj}\left(p_{nijf}\right) \\ - \sum\limits_{n\in N_{if}} \sum\limits_{j\in J_{nif}} w_i^S F_{nj}^N - \mathbb{I}_{if}^S w_i^S F^S - w_i^S \psi\left(\theta_f^\zeta - 1\right) \end{array} \right\}, \tag{13}$$

where $y_{nifj}\left(p_{nijf}\right)$ is output of firm f from origin country i in each sector j and destination country n, which is a function of the price chosen for its variety (p_{nijf}; and $\mathbb{I}_{if}^S$ is an indicator variable that equals one if firm f in origin country i chooses to undertake MPRO services in-house and zero otherwise.

We characterize the solution to the firm's problem as follows. First, we solve for the equilibrium price for the firm's variety in each country and sector conditional on its choice of the sets of countries and sectors to serve, its decision whether to organize MPRO services in-house, and its investment in intangible knowledge. Second, we determine a firm's usage of factor inputs conditional on its market entry, vertical integration and intangible investment decisions. Third, we characterize the firm's choice of the set of countries and sectors to serve conditional on its vertical integration and intangible investment decisions. Fourth, we analyze the firm's vertical integration and intangible investment decisions.

5.5 Equilibrium Prices

Beginning with the equilibrium pricing rule, profit maximization under CES demand and monopolistic competition implies that the equilibrium price for each firm variety is a markup over marginal cost:

$$p_{nijf} = \frac{\sigma_j}{\sigma_j - 1}\tau_{nij}\frac{1}{\theta_f}\gamma_{ifj}, \tag{14}$$

where the markup depends on the constant elasticity of substitution (σ_j); and marginal costs include both the unit production cost (γ_{ifj}/θ_f) and the iceberg variable trade cost (τ_{nij}).

Using this equilibrium pricing rule in the revenue function (7), firm revenue in a given sector and

market is a power function of firm unit costs:

$$x_{nijf} = \left(\frac{\sigma_j}{\sigma_j - 1}\tau_{nij}\frac{1}{\theta_f}\gamma_{ifj}\right)^{1-\sigma_j} X_{nj}P_{nj}^{\sigma_j - 1}. \tag{15}$$

Therefore, the relative revenues of any two firms within the same sector and destination market depend solely on their relative unit costs:

$$\frac{x_{nfj}}{x_{n\ell j}} = \left(\frac{\gamma_{ifj}/\theta_f}{\gamma_{i\ell j}/\theta_\ell}\right)^{1-\sigma_j}. \tag{16}$$

From equation (15), although we have interpreted intangible knowledge investments as reducing unit costs, an isomorphic interpretation for equilibrium firm revenue is that they increase product quality.

5.6 Final Goods Costs

Turning now to the firm's optimal choice of factor inputs, we establish a number of predictions that we provide empirical evidence on below. Using cost minimization, the share of MPRO services in the unit costs of final goods firm f in origin country i in sector j (ξ_{ifj}^S) depends on the prices of skilled and unskilled workers in that country (w_i^S, w_i^P), the cost of intermediate inputs in that sector and country (Q_{ij}), and firm productivity (φ_{fj}):

$$\xi_{ifj}^S = \frac{\left(w_i^S\right)^{1-\mu_j}}{\left(w_i^S\right)^{1-\mu_j} + \left(\frac{\left(w_i^P\right)^{\beta_j}\left(Q_{ij}\right)^{1-\beta_j}}{\varphi_{fj}}\right)^{1-\mu_j}}. \tag{17}$$

We now establish some properties of this final goods cost share with respect to shocks to technology and international trade. Totally differentiating this cost share (17), the log change in the share of MPRO services in firm costs can be linearly decomposed into log changes in factor prices and log changes in productivity:

$$\mathrm{d}\ln\xi_{ifj}^S = (1-\mu_j)\left(1-\xi_{ifj}^S\right)\left[\ \mathrm{d}\ln w_i^S - \beta_j \mathrm{d}\ln w_i^P - (1-\beta_j)\,\mathrm{d}\ln Q_{ij} + \mathrm{d}\ln\varphi_{fj}\ \right]. \tag{18}$$

Using our assumption that MPRO services and production activities are complements ($0 < \mu_j < 1$), and holding constant factor prices ($\mathrm{d}\ln w_i^S = 0$ and $\mathrm{d}\ln w_i^P = 0$), equation (18) implies that both productivity growth ($\mathrm{d}\ln\varphi_{fj} > 0$) and lower prices of intermediate inputs as a result of lower trade costs ($\mathrm{d}\ln Q_{ij} < 0$) induce structural transformation in the form of a higher share of MPRO services in unit costs ($\mathrm{d}\ln\xi_{ifj}^S > 0$).[21] The mechanism underlying this structural transformation is the same as that in the macroeconomics literature on unbalanced productivity growth following Baumol (1967). Whereas this macroeconomics literature focuses on structural transformation between final goods sectors, our framework features both this sectoral structural transformation and func-

[21] Although we hold factor prices constant here, wages of skilled workers rise faster than those of unskilled workers during our sample period, which raises the share of MPRO services in unit costs under our assumption that MPRO services and production activities are complements.

tional structural transformation between intermediate activities (MPRO services versus production activities), consistent with our stylized facts above.

We now connect this result for the share of MPRO services in overall firm unit costs to the share of MPRO services in labor costs and employment, which are directly observable in the data. We start with the share of MPRO services in labor costs:

$$\vartheta_{ifj}^S = \frac{w_i^S L_{ifj}^S}{w_i^S L_{ifj}^S + w_i^P L_{ifj}^P}. \tag{19}$$

Totally differentiating this share of MPRO services in labor costs, we have:

$$\mathrm{d}\ln \vartheta_{ifj}^S = \left(1 - \vartheta_{ifj}^S\right)\left[\mathrm{d}\ln w_i^S - \mathrm{d}\ln w_i^P + \mathrm{d}\ln L_{ifj}^S - \mathrm{d}\ln L_{ifj}^P\right]. \tag{20}$$

Therefore, holding constant factor prices ($\mathrm{d}\ln w_i^S = 0$ and $\mathrm{d}\ln w_i^P = 0$), a rise in the share of MPRO services in labor costs ($\mathrm{d}\log \vartheta_{ifj}^S > 0$) implies a rise in MPRO services employment relative to production employment ($\mathrm{d}\log L_{ifj}^S > \mathrm{d}\log L_{ifj}^P$), and hence an increase in the share of MPRO services in total employment.

To link these changes in labor cost and employment shares to the changes in unit cost shares examined above, we use the implication of the Cobb-Douglas production technology that expenditures on intermediate inputs are a constant multiple of the wage bill for production workers:

$$Q_{ij} M_{ifj} = \frac{1-\beta_j}{\beta_j} w_i^P L_{ifj}^P, \tag{21}$$

where M_{ifj} is the quantity of intermediate inputs used by firm f from origin country i in sector j.

Using this linear relationship between intermediate input costs and production worker costs, we can rewrite the share of MPRO services in overall unit costs in equation (17) as:

$$\xi_{ifj}^S = \frac{w_i^S L_{ifj}^S}{w_i^S L_{ifj}^S + w_i^P L_{ifj}^P + Q_{ij} M_{ifj}} = \frac{w_i^S L_{ifj}^S}{w_i^S L_{ifj}^S + \left[1 + \frac{1-\beta_j}{\beta_j}\right] w_i^P L_{ifj}^P}. \tag{22}$$

Totally differentiating this relationship and using our earlier expressions for the total derivatives of unit costs (18) and labor costs (20), we find that the share of MPRO services in labor costs is linearly related to the share of MPRO services in unit costs as follows:

$$d\ln \vartheta_{ifj}^S = \left(\frac{1 - \vartheta_{ifj}^S}{1 - \xi_{ifj}^S}\right) \mathrm{d}\ln \xi_{ifj}^S, \tag{23}$$

where the shares of unit costs (ξ_{ifj}^S) and labor costs (ϑ_{ifj}^S) both lie strictly in between zero and one for $0 < \mu_j < 1$, thereby ensuring that the term in parentheses in equation (23) is strictly positive.

Combining the total derivative of the share of professional services in unit costs (18) with this linear relationship between unit cost and labor cost shares in equation (23), we can now characterize the effects of technology and trade shocks on the shares of MPRO services in labor costs and employment. Under our assumption that MPRO services and production activities are complements ($0 < \mu_j < 1$)

and holding constant factor prices ($\mathrm{d}\ln w_i^S = 0$ and $\mathrm{d}\ln w_i^P = 0$), equations (18) and (23) imply that productivity growth ($\mathrm{d}\ln \varphi_{fj} > 0$) and lower prices of intermediate inputs due to lower trade costs ($\mathrm{d}\ln Q_{ij} < 0$) raise the share of MPRO services in unit costs ($\mathrm{d}\ln \xi_{ifj}^S > 0$) and hence the share of MPRO services in labor costs ($d\ln \vartheta_{ifj}^S > 0$). From the relationship between the share of MPRO services in labor costs and employment levels in equation (20), and holding constant factor prices ($\mathrm{d}\ln w_i^S = 0$ and $\mathrm{d}\ln w_i^P = 0$), this higher share of MPRO services in labor costs also translates into a higher share of MPRO services in employment.

Therefore, using only properties of the firm cost minimization problem, we obtain sharp empirical predictions for the effect of technology and input price shocks on structural transformation towards MPRO services. In contrast to the macroeconomic literature on sectoral structural transformation, these predictions are for functional structural transformation between intermediate activities (MPRO services versus production activities). For firms that vertically-integrate MPRO services in-house, these reallocations occur within firms. For firms that outsource MPRO services, these reallocations occur between firms, namely between each final goods firm and its standalone supplier.

5.7 Market Entry

We have thus completed our characterization of the final goods firm's equilibrium price and factor input choices. We now turn its choice of the sets of the countries and sectors to serve conditional on its vertical integration and intangible investment decisions. Using the firm's equilibrium pricing rule (14) in the definition of firm variable profits for a given sector and market, we obtain the standard result under CES demand and monopolistic competition that variable profits are a constant multiple of revenue in that sector and market:

$$\pi_{nifj} = \frac{1}{\sigma_j} x_{nifj}. \tag{24}$$

Given this solution for equilibrium variable profits, firm f from origin country i chooses to serve a given sector j and destination country n if these variable profits exceed the fixed market entry costs for that sector and country (F_{nj}^N). Therefore, the set of sectors J_{nif} served by the firm within a given destination country is simply the set of sectors for which these variable profits exceed the fixed market entry costs:

$$J_{nif} = \left\{ j : \frac{1}{\sigma_j} x_{nijf} - w_i^S F_{nj}^N \geq 0 \right\}. \tag{25}$$

Similarly, the set of countries N_{if} served by the firm is simply the set of countries for which there is at least one sector for which these variable profits exceed the fixed market entry costs:

$$N_{if} = \left\{ n : \max_j \left\{ \frac{1}{\sigma_j} x_{nijf} - w_i^S F_{nj}^N \right\} \geq 0 \right\}. \tag{26}$$

Conditional on the firm's vertical integration and intangible investment decisions, its choice whether to enter one sector and country is independent of its choice whether to enter any other sector and country, because of the property of equation (12) that variable costs are constant. Substituting the equilibrium revenue function (15) into equation (25), the zero-profit condition to enter a

given country and sector can be re-written as:

$$J_{nif} = \left\{ j : \frac{1}{\sigma_j} \left(\frac{\sigma_j}{\sigma_j - 1} \tau_{nij} \frac{1}{\theta_f} \gamma_{ifj} \right)^{1-\sigma_j} X_{nj} P_{nj}^{\sigma_j - 1} - w_i^S F_{nj}^N \geq 0 \right\}. \tag{27}$$

This zero-profit condition highlights that the model also features conventional structural transformation between sectors in response to shocks to technology and trade costs that affect final demand within each sector (through sectoral expenditure (X_{nj}) or the sectoral price index (P_{nj})). While the conventional macroeconomics literature is typically silent as to whether these reallocations occur through the entry and exit of firms or through reallocations of resources within firms, our model features both of these margins of adjustment. As shocks to technology and trade costs increase variable profits in some sectors and reduce them in others, the set of sectors chosen by entering firms will change (between-firm reallocations) and incumbent. firms will choose to drop some sectors and add other sectors (within-firm reallocations).

From this zero-profit condition (27), a lower unit cost ($\frac{1}{\theta_f}\gamma_{ifj}$) increases a firm's variable profits and expands the set of countries and sectors that it finds it profitable to enter. As discussed in the previous section, firms that vertically integrate and invest in intangibles have lower unit costs ($\theta_f > 1$) than firms that outsource professional services and make no investment in intangibles ($\theta_f = 1$). Therefore, by reducing unit costs and increasing variable profits, these investments in intangibles increase the set of countries and sectors in which a firm operates.

5.8 Investments in Intangible Knowledge Capital

Finally, we turn to the final goods firm's vertical integration and intangible investment decisions. We already established that firms that outsource MPRO services make no investments in intangibles. Therefore, we first solve for a firm's optimal investment in intangibles conditional on vertically integrating MPRO services. Taking into account this optimal investment decision, we next determine whether the firm outsources or vertically integrates MPRO services by comparing the firm's total profits under these two alternatives.

Using the equilibrium revenue function (15), the total profits of a firm across all countries and sectors can be written as follows:

$$\begin{aligned} \Pi_{if}(\boldsymbol{\varphi}) = \sum_{n \in N_{if}} \sum_{j \in J_{nif}} \tfrac{1}{\sigma_j} \left(\tfrac{\sigma_j}{\sigma_j - 1} \tau_{nij} \tfrac{1}{\theta_f} \gamma_{ifj} \right)^{1-\sigma_j} X_{nj} P_{nj}^{\sigma_j - 1} - \sum_{n \in N_{if}} \sum_{j \in J_{nif}} w_i^S F_{nj}^N \\ - \mathbb{I}_{if}^S w_i^S F^S - w_i^S \psi \left(\theta_f^{\zeta} - 1 \right) \end{aligned}, \tag{28}$$

which depends on the firm's vector of productivity draws across sectors $\{\varphi_{fj}\}$ through its vector of unit costs across sectors $\{\gamma_{ifj}\}$.

Conditional on incurring the fixed cost of vertically integrating professional services inhouse, the

first-order condition for the firm's investment in intangibles yields the following optimal investment:

$$\theta_{if}^{*} = \left[\frac{\sum_{n \in N_{if}} \sum_{j \in J_{nif}} \frac{\sigma_j - 1}{\sigma_j} \left(\frac{\sigma_j}{\sigma_j - 1} \tau_{nij} \gamma_{ifj} \right)^{1-\sigma_j} X_{nj} P_{nj}^{\sigma_j - 1}}{\zeta \psi w_i^S} \right]^{\frac{1}{\zeta - (\sigma_j - 1)}}, \tag{29}$$

which depends on the firm's vector of productivity draws across sectors $\{\varphi_{fj}\}$ through its vector of unit costs across sectors $\{\gamma_{ifj}\}$. As a firm that makes no investment in intangibles has a unit productivity ($\theta_f = 1$), only firms for which there is an interior solution in which $\theta_f^* > 1$ make positive investments in intangibles. For sufficiently convex research costs ($\zeta > (\sigma_j - 1)$), this optimal positive investment in intangibles is finite ($1 < \theta_f^* < \infty$).

From this solution for equilibrium investment in intangibles and the unit cost function (12), higher firm productivity across all sectors $\{\varphi_{fj}\}$ lowers unit costs (through lower $\{\gamma_{ifj}\}$), which increases total firm profits in equation (28) on both the intensive margin (higher profits within each sector and country) and the extensive margin (entry into more sectors and countries). These higher total profits in turn raise the return to intangible investments and increase the equilibrium level of these intangible investments. This role for the extensive margin of the range of sectors and countries served in influencing equilibrium intangible investment implies that there is an interdependence between a firm's decisions to serve each sector and country and its level of intangible investment. On the one hand, serving an additional sector and country raises the return to intangible investment. On the other hand, an increased investment in intangibles raises the variable profits from entering each sector and country.

Substituting this solution for optimal investment in intangibles (29) into equation (28), we obtain a firm's total profits from vertically integrating MPRO services. A firm chooses to vertically integrate MPRO services if the total profits from doing so exceed those from outsourcing MPRO services to a standalone supplier. As vertical integration involves incurring an additional fixed cost F^S, only the most productive firms find it profitable to perform MPRO services in-house. Through this selection mechanism, the model rationalizes our empirical findings above that firms that vertically integrate MPRO services (as measured by auxiliary establishments in the data) are more productive than those that do not. Furthermore, as these firms that vertically integrate MPRO services make greater investments in intangible knowledge in equilibrium, they have lower unit costs across all sectors, and hence are more likely to be able to pivot to other sectors.

5.9 General Equilibrium

All of the empirical predictions that we examine in the next section were derived above from the properties of the firm optimization problem for given sectoral expenditures (X_{nj}), sectoral price indexes (P_{nj}), skilled wages (w_i^S) and unskilled wages (w_i^P). In this section, we briefly discuss closing the model to determine these variables in general equilibrium.

The general equilibrium of the model is referenced by the following variables: (i) the set of sectors served for each country ($J_{ni}(\boldsymbol{\varphi})$) and the set of countries served ($N_i(\boldsymbol{\varphi})$) as a function of a firm's

productivity vector across sectors ($\boldsymbol{\varphi}$); (ii) an indicator variable for whether a firm vertically integrates MPRO services ($\mathbb{I}_i^S(\boldsymbol{\varphi})$) as a function of its productivity vector; (iii) investment in intangibles as a function of a firm's productivity vector ($\theta(\boldsymbol{\varphi})$); (iv) the wage for skilled workers (w_i^S), (v) the wage for unskilled workers (w_i^P); (vi) the price index for each sector and country (P_{nj}); and (vii) aggregate expenditure for each country (X_n). All other endogenous variables can be determined as functions of these elements of the equilibrium vector.

General equilibrium is determined by the following equilibrium conditions: (i) a firm with each productivity vector makes non-negative profits from all sectors and countries that it enters; (ii) a firm with each productivity vector incurs the fixed cost to vertically integrate MPRO services if this yields higher total profits than outsourcing MPRO services and vice versa; (iii) investment in intangibles equals zero for productivities for which firm's outsource MPRO services and is chosen to maximize profits for productivities for which firms vertically integrate; (iv) the labor market for skilled workers clears; (v) the labor market for unskilled workers clears; (vi) revenue in each sector and country equals expenditure on goods produced in that sector and country; (vii) free entry ensures that the expected value of entry is equal to the sunk entry cost.

5.10 Sectoral and Functional Structural Transformation Within and Between Firms

Our theoretical framework thus rationalizes both sectoral and functional structural transformation and allows these two forms of structural transformation to occur either within or between firms. "Sectoral" structural change occurs through changes in tastes or average firm productivity across final goods sectors. As these parameters change across final goods sectors, some previously profitable sectors become unprofitable, and some previously unprofitable sectors become profitable. Therefore, continuing firms drop some existing sectors and add other new sectors, thereby inducing sectoral structural change within firms. Additionally, entering firms choose to participate in a different set of sectors from exiting firms, which generates sectoral structural change between firms.

"Functional" structural change occurs through changes in the relative productivity of MPRO services and production activities. As MPRO services and production are complements, reductions in production costs lead to increases in the share of MPRO services in total firm costs. For firms that have chosen to vertically integrate MPRO services, this reallocation occurs within firms. In contrast, for firms that have chosen to outsource MPRO services, this reallocation occurs between firms. Additionally, entering firms choose different shares of MPRO services in total firm costs from exiting firms, again inducing reallocation from production to MPRO services.

Our theoretical framework also highlights the role of firm productivity in shaping sectoral and functional structural change. More productive firms can profitably produce in a wider range of sectors, which increases their ability to pivot away from declining to expanding sectors. More productive firms are also more likely to vertically integrate MPRO services, such that functional structural change occurs within firms. Additionally, more productive firms make greater investments in intangible knowledge, which further expands the range of sectors in which they can profitably produce, and hence further enhances their ability to pivot away from declining to expanding sectors.

6 Reduced-Form Evidence on With-Firm Structural Change

In this section we demonstrate that inhouse management and production employment are complementary inputs among U.S. manufacturing firms, and that possession of inhouse management services mediates firms' responses to price shocks.

6.1 Estimating Structural Change Within Firms

The descriptive evidence in Section 3 shows that U.S. structural change is driven by growth in Business Services, the majority of which are sold to other firms rather than consumers. The model in Section 5 rationalizes this trend through the lens of a production function in which knowledge and manufacturing activities are complementary. Here, we test for this complementarity, i..e, that a reduction in the cost of manufactured inputs increases the level and share of firms' inhouse knowledge inputs.[22]

Results in Section 3 also indicate that a substantial share – 17 to XXX percent – of the growth of U.S. non-manufacturing employment occurs within manufacturing firms, and that firms with auxiliaries are more likely to change their product mix. Our theoretical framework posits auxiliaries as sources of excludable knowledge that facilitates within-firm structural change in response to shocks. Here, we investigate whether firms with auxiliaries shift from manufacturing to services in response to increased import competition.

Our baseline empirical specification examines changes in firm outcomes between 1997 and 2007, the Census years spanning China's accession to the WTO:

$$\begin{aligned}\Delta Outcome_{fj} = \quad & \beta_O \Delta Output_f + \beta_{OA} \Delta Output_f \times AUX_f^{1997} + \beta_{OE} \Delta Output_f \times ln(Emp_f^{1997}) \\ & \beta_I \Delta Input_f + \beta_{IA} \Delta Input_f \times AUX_f^{1997} + \beta_{IE} \Delta Input_f \times ln(Emp_f^{1997}) \\ & \beta_A AUX_f^{1997} + \beta_E ln(Emp_f^{1997}) + \Sigma \beta_X X_f^{1997} + \delta_j + \alpha + \epsilon_{fj},\end{aligned} \tag{30}$$

$\Delta Outcome_{fj}$ is the change in sales or employment of firm f with major 4-digit manufacturing industry j, measured by 1997 employment. $\Delta Output_f$ and $\Delta Input_f$, defined below, capture weighted-average shocks to firms' output and input prices. AUX_f^{1997} is an indicator for whether the firm has an auxiliary in 1997, $ln(Emp_f^{1997})$ is firms' overall employment in 1997, and X_f^{1997} is a vector of other firm attributes in 1997. These include the number of establishments, age quintiles, the share of sales in manufacturing, and the share of materials in manufacturing costs. δ_j is a fixed effect for the firm's major industry. Standard errors are clustered at the same 4- to 6-digit level at which the shocks are constructed.

For outcomes, we consider changes in firms' total, manufacturing, and non-manufacturing sales and employment. We also consider changes in firms auxiliary employment, as well as changes in firms' auxiliary and non-auxiliary employment in MPRO services, which we define here as Professional,

[22] While the model allows firms to produce MPRO services inhouse or secure them at arm's length, we are at present unable to test for a similar complementarity among firms choosing the latter due to lack of data on purchaes of external services.

Scientific, and Technical Services (NAICS 54), Management Services (NAICS 55) and Information Services (NAICS 51). Our parameters of interest are β_{OA} and β_{IA}, since they capture the differential effects of the output and input shocks for firms that have auxiliary employment at the start of the period. We estimate specifications with and without the interactions of the shocks with firm employment to account for the possibility that having an auxiliary is a proxy for firm size.

Although our analysis is based on a reduced-form specification in which we regress the outcome variables directly on our measures of exogenous variation in input and output competition, we also present the first-stage results from regressing endogenous measures of US import penetration from China on the shocks. We use these first-stage estimates to show that Chinese market share gains in Europe are indeed good predictors of changes of Chinese competition in the United States, and that we can credibly distinguish between output and input shocks.

6.2 New Measures of Output versus Input Shocks

We exploit China's 2001 WTO accession and subsequent dramatic growth in exports to construct plausibly exogenous changes in Chinese import competition across products. Specifically, we use Comtrade data to compute 1997 to 2007 changes in China's EU import market shares across 6-digit Harmonized Trade System product codes (HS6). Use of Chinese export growth outside the United States is similar to prior work (Autor, Dorn, and Hanson, 2013; Bloom, Handley, Kurmann, and Luck, 2019), though we follow Antràs, Fort, and Tintelnot (2017) by using market share gains rather than level growth in exports to minimize the possibility that correlated demand shocks drive our results.

A novel contribution we make with respect to analyzing firms' exposure to import competition is to use detailed product and material trailer data from the CMF to measure the range of goods a firm produces and sells, versus the inputs that it purchases.[23] We use the product-level trailer data to construct each firm's output shock as the sales-weighted average Chinese market share gains (or losses) in Europe across the manufacturing products sold by the firm in 1997. We map HS6 products to six-digit NAICS using the concordance from Pierce and Schott (2012) and define the output shock as:

$$\Delta Output_f = \sum_{j \in Output_{1997}} \frac{Sales_{j1997}}{Sales_{1997}} \Delta MarketSh_j, \tag{31}$$

where $Sales_{j1997}$ is the firm's sales in the six-digit NAICS industry j in 1997 and $\Delta MarketSh_j$ is the change in China's market share in that six-digit NAICS industry j from 1997-2007.

Similarly, we measure each firm's input shock as the firm's expenditure-weighted average change in Chinese market share in the six-digit goods it uses as inputs:

$$\Delta Input_f = \sum_{j \in Input_{1997}} \frac{Inputs_{j1997}}{Inputs_{1997}} \Delta MarketSh_j, \tag{32}$$

where $Inputs_{j1997}$ is the firm's purchases of material inputs in the six-digit NAICS industry j.

[23] Pierce and Schott (2016b) exploit industry-level input-output tables to distinguish U.S. manufacturing establishments' own, upstream and downstream exposure to Chinese import competition. Mion and Zhu (2013) estimate differential effects of firm-level imports of final goods versus inputs, but define inputs as any imports of goods outside the firm's main three-digit industry.

When constructing these measures, we use all available information for every manufacturing establishment of the firm. For multi-unit firms, we use the product and material trailer data for all of their establishments. For firms without product-trailer data, we assign an output shock based on the six-digit NAICS of their establishments. For firms without material trailer data, we follow Pierce and Schott (2016b) in imputing input usage across industries based on their establishments' output industry and the 1997 US input-output tables produced by the US Bureau of Economic Analysis (BEA).

The latest research on shift-share analyses emphasizes the importance of adjusting the standard errors to address the mismatch between the levels at which the shocks are observed versus applied. In this case, our shock is industry-level shock, whereas our observations are firm-level. However, because our analysis features multiple shift-share shocks – one for inputs and one for outputs – we cannot adopt the methods proposed in Adão, Morales, and Kolesár (2019) or Borusyak, Hull, and Jaravel (2021). We therefore cluster our standard errors at the level of the firm's primary NAICS industry, and perform various Monte Carlo simulations to assess the potential concerns on inference described in those papers. While our standard errors mildly over reject placebo tests at the five percent significance level, we find that they are conservative compared to alternative choices of standard errors.[24] Online Appendix Section XXX discusses these exercises in detail.

Borusyak, Hull, and Jaravel (2021) also emphasize the importance of controlling for missing shares in Bartik shift-share analyses. We follow their recommendation by including the firm's share of sales in manufacturing and share of materials in manufacturing costs as controls in equation (30). These shares account for the possibility that our output and input shocks may merely capture a firm's manufacturing intensity rather than differential exposure to increased competition in its output and input markets. We also interact these controls with the auxiliary indicators to ensure that the differential effects we estimate for firms' with auxiliaries are not similarly biased.

6.3 Results

We present the results from estimating equation (30) via OLS in Table 6. Columns 1 and 3 in the top panel show that total and manufacturing sales decrease in response to the output shock, but only for firms with auxiliaries. While the coefficient on the output shock interacted with auxiliary status is also negative for non-manufacturing sales (column 5), it is not statistically significant. The bottom panel of Table 6 presents comparable estimates for firm employment, except that firms with auxiliaries also experience a statistically significant decline in their non-manufacturing employment in response to increased product-market competition. This asymmetry between sales and employment is consistent with non-manufacturing workers being an input into firms' manufacturing outputs.

A potential concern with the coefficient on the interaction between a firm's initial auxiliary status and the output shock is that it may capture the differential effect of firm size, rather than inhouse knowledge. To assess this concern, the second column for each outcome variable presents a spec-

[24] In our simulations, one percent significant level tests reject the (true) null that $\beta = 0$ for approximately five percent of the samples simulated. Therefore, for our results with p-values < 0.01, a conservative adjustment would put their simulated p-value at 0.05.

ification in which we also interact the log of firm employment with the shocks (and with firm's manufacturing sales and cost shares). This specification shows that firms with auxiliary establishments do not experience statistically significant relative declines in their aggregate sales, and only marginally significant declines in their manufacturing sales. Instead it is the large firms that are hit by Chinese competition, with significant declines in their total and manufacturing sales. By contrast, the bottom panel shows that firms with auxiliaries continue to decrease employment in response to an output shock. This result is consistent with manufacturing and non-manufacturing employment being complementary inputs, and particularly so for firms with inhouse knowledge.

Turning to the input shock, there is no statistically significant relationship between the shock and aggregate sales or employment. While this pattern is also true for manufacturing sales and employment, it is remarkably different for non-manufacturing activity. Column 5 indicates that firms with increased competition in their input markets grew their non-manufacturing employment considerably, but only if they had an inhouse knowledge plant at the start of the period. In addition, unlike for the output shock, Column 6 indicates that the differential impact of the input shock is driven by inhouse knowledge plants, rather than firm size. The coefficient on the interaction between the input shock and auxiliary status remains positive, significant, and of a similar magnitude, while the interaction between the input shock and firm size is insignificant. The results in Table 6 thus do not show that inhouse knowledge plants facilitate firm-level pivoting towards services in response to negative demand shocks, but provide evidence consistent with this transformation in response to input shocks.

We analyze firms' employment responses in more detail by examining employment growth in industries particularly related to knowledge, namely Information (NAICS 51), Professional, Scientific, and Technical Services (NAICS 54), and Management (NAICS 55) (MPRO) establishments. Table 7 presents the results. As before, and consistent with these non-manufacturing activities being complementary to the firm's manufacturing, the output shock leads to declines in all three categories for firms that are large or have an auxiliary at the start of the period. By contrast, firms with auxiliaries grow their MPRO employment significantly in response to an input shock. Moreover, this MPRO employment growth seems concentrated in auxiliaries (column 5), while it is not evident for MPRO establishments that sell to other firms (column 6). Firms with inhouse knowledge plants thus pivot towards knowledge-related activities in response to plausibly exogenous increases in competition for producing their inputs, and this pivoting is driven by growth in inhouse-knowledge plants. This supports the notion that knowledge and manufacturing activities are complementary, and that firms with inhouse knowledge are particularly well-positioned to exploit lower input costs. It points to 'functional' structural change occurring within firms in response to shocks, and suggests that at least some of the US reorientation towards services may be due to knowledge specialization by firms exploiting lower-cost production opportunities for their goods.

Table 6: Effects of Output and Input Shocks on Firm Sales and Employment

Dependent variable is the DHS growth rate from 1997 to 2007 of firm-level outcome indicated in column header

Panel A: Sales	Total Sales		Manuf Sales		Non-Manuf Sales	
	(1)	(2)	(3)	(4)	(5)	(6)
Output Shock	-0.036	0.616***	-0.046	0.873***	0.107	0.078
	0.110	0.209	0.137	0.276	0.072	0.155
Output Shock $\times Aux_f^{1997}$	-0.687***	-0.188	-1.300***	-0.585*	-0.235	-0.250
	0.266	0.273	0.266	0.303	0.411	0.414
Output Shock $\times ln(emp_f^{1997})$		-0.201***		-0.283***		0.009
		0.055		0.071		0.042
Input Shock	-0.127	-0.162	-0.219	-0.325	0.146	0.231
	0.179	0.507	0.172	0.537	0.160	0.408
Input Shock $\times Aux_f^{1997}$	0.012	0.031	-0.127	-0.125	1.563**	1.612**
	0.555	0.482	0.463	0.464	0.716	0.663
Input Shock $\times ln(emp_f^{1997})$		0.020		0.044		-0.025
		0.132		0.153		0.098
AUX_f^{1997}	0.113***	-0.010	0.212***	0.151*	-0.107*	-0.076
	0.043	0.046	0.068	0.082	0.055	0.059
$ln(emp_f^{1997})$	-0.047***	0.036**	-0.003	0.051**	-0.006	-0.026
	0.006	0.016	0.007	0.022	0.004	0.020
R^2	0.075	0.077	0.067	0.069	0.068	0.068
Panel B: Employment	Total Emp		Manuf Emp		Non-Manuf Emp	
	(1)	(2)	(3)	(4)	(5)	(6)
Output Shock	-0.046	0.325*	-0.064	0.464**	0.069	0.135
	0.082	0.169	0.104	0.234	0.068	0.161
Output Shock $\times Aux_f^{1997}$	-0.703***	-0.432*	-1.106***	-0.706**	-0.635**	-0.577*
	0.235	0.247	0.241	0.279	0.317	0.325
Output Shock $\times ln(emp_f^{1997})$		-0.115**		-0.163***		-0.019
		0.047		0.061		0.044
Input Shock	-0.025	-0.069	-0.152	-0.240	0.098	-0.223
	0.195	0.410	0.173	0.433	0.155	0.452
Input Shock $\times Aux_f^{1997}$	0.463	0.454	0.147	0.134	1.723***	1.534***
	0.491	0.446	0.464	0.494	0.555	0.511
Input Shock $\times ln(emp_f^{1997})$		0.018		0.034		0.091
		0.105		0.123		0.117
AUX_f^{1997}	0.176***	0.014	0.205***	0.101	0.078	0.234***
	0.041	0.042	0.058	0.068	0.052	0.052
$ln(emp_f^{1997})$	-0.116***	-0.015	-0.072***	0.001	0.005	-0.087***
	0.005	0.015	0.006	0.020	0.005	0.019
R^2	0.115	0.116	0.082	0.084	0.058	0.059
Observations	73,500	73,500	73,500	73,500	73,500	73,500
Manuf Sales and Input Shares $\times ln(emp_{ft})$	No	Yes	No	Yes	No	Yes

Notes: Table presents results from estimating equation (30) via OLS. Aux_f^{1997} is an indicator for whether the firm has one or more auxiliary establishments in 1997. Davis-Haltiwanger-Schuh (DHS) growth rate is $DHS_f = (x_f^{2007} - x_f^{1997})/((x_f^{2007} + x_f^{1997})/2)$. All regressions include firm-level controls for age, the log number of establishments, the share of sales in manufacturing and its interaction with Aux_f^{1997}, the share of materials in manufacturing costs and its interaction with Aux_f^{1997}, and 4-digit NAICS fixed effects. Columns 2, 4, and 6 include the manufacturing sales and cost shares interacted with $ln(emp_f^{1997})$ Standard errors clustered by firm's primary NAICS.

Table 7: Effects of Output and Input Shocks on Non-Manufacturing Employment

Dependent variable is the DHS growth from 1997 to 2007 of firm-level employment indicated in column headers

	MPRO		MPRO in Auxes		MPRO in non-Auxes	
	(1)	(2)	(3)	(4)	(5)	(6)
Output Shock	-0.008	0.272***	0.001	0.212***	0.017	0.096
	0.027	0.093	0.019	0.074	0.025	0.071
Output Shock $\times Aux_f^{1997}$	-0.774***	-0.553*	-0.889***	-0.725**	0.184	0.238
	0.292	0.292	0.329	0.332	0.184	0.183
Output Shock $\times ln(emp_f^{1997})$		-0.086***		-0.064***		-0.025
		0.028		0.023		0.020
Input Shock	0.003	-0.101	-0.029	-0.264	0.050	0.049
	0.064	0.222	0.053	0.208	0.051	0.185
Input Shock $\times Aux_f^{1997}$	1.423***	1.385***	1.286**	1.161*	0.162	0.169
	0.453	0.452	0.558	0.594	0.304	0.298
Input Shock $\times ln(emp_f^{1997})$		0.034		0.070		0.002
		0.067		0.063		0.053
AUX_f^{1997}	-0.611***	-0.585***	-0.888***	-0.826***	0.101**	0.042
	0.049	0.057	0.059	0.067	0.042	0.047
$ln(emp_f^{1997})$	0.019***	0.010	0.020***	-0.013	0.004**	0.041**
	0.003	0.017	0.002	0.017	0.002	0.016
R^2	0.090	0.092	0.146	0.148	0.029	0.030
Observations	73,500	73,500	73,500	73,500	73,500	73,500

Notes: Table presents results from estimating equation (30) via OLS. MPRO is employment in establishments in NAICS 51, 54, and 55. 'MPRO in Auxes' is employment in MPRO establishments that primarily serve their firm, while 'MPRO in non-Auxes' corresponds to MPRO in establishments that primarily sell to other firms. Aux_f^{1997} is an indicator for whether the firm has one or more auxiliary establishments in 1997. Davis-Haltiwanger-Schuh (DHS) growth rate is $DHS_f = (x_f^{2007} - x_f^{1997})/((x_f^{2007} + x_f^{1997})/2)$. All regressions include firm-level controls for age, the log number of establishments, the share of sales in manufacturing and its interaction with Aux_f^{1997}, the share of materials in manufacturing costs and its interaction with Aux_f^{1997}, and 4-digit NAICS fixed effects. Columns 2, 4, and 6 include the manufacturing sales and cost shares interacted with $ln(emp_f^{1997})$ Standard errors clustered by firm's primary NAICS.

7 Conclusion

We provide new theory and evidence on the large-scale structural transformation that occurred in the United States over the last forty years. We use a newly-constructed dataset that allows us for the first time to track firms and establishments and the sectors in which they operate on a consistent industry basis over this long time horizon.

We use these new data to highlight three key stylized facts about structural transformation. First, while most existing research emphasizes the reallocation of final consumption, we find that a substantial proportion of the observed reallocation occurs towards business services that are largely used as intermediate inputs rather than for final consumption. Second, we show that a major component of this reallocation. occurs within surviving manufacturing firms, as they pivot away from production and towards MPRO services and retail. Third, we develop a new measure of in-house investments in intangible knowledge, based on auxiliary establishments that primarily serve other establishments of their firm (e.g. a headquarters or a R&D lab). We show that this measure of investment in intangible knowledge is correlated with higher growth and pivoting to new industries.

To rationalize these features of the data, we develop a theoretical model, in which firm operations involve both knowledge services and production activities, which are complementary to one another. Knowledge services involve investments in intangible capital that are specific to the firm but general across sectors. If structural transformation occurs within firms, this intangible knowledge can be redeployed from one sector to another. In contrast, if reallocation occurs through the entry and exit of firms, this firm-specific intangible capital is destroyed. Firms that undertake knowledge services within firm boundaries have greater incentives to invest in intangible knowledge, because it is easier to exclude other firms from these investments when they are undertaken in-house. Therefore, firms that vertically integrate knowledge services have greater investments in intangible capital, and hence greater ability to pivot across sectors.

Our empirical findings and theoretical framework have a number of implications at the micro and macro levels. First, in existing research on structural transformation through unbalanced productivity growth, reallocation of final consumption expenditure and employment across sectors is captured through the change in a common technology parameter across all firms. In contrast, when structural transformation occurs within firms, the magnitude of the resulting employment reallocation across sectors depends on endogenous within-industry reallocations across production establishments and within-firm reallocations between production and knowledge services. Second, the extent to which economic growth involves creative destruction depends on whether structural transformation occurs within versus between firms. To the extent that intangible knowledge is firm-specific but general across sectors, intangible knowledge can be preserved within firm boundaries, but is created and destroyed when firms enter and exit, respectively.

Third, the complementary between knowledge services and production activities shapes the response to the economy to shocks, such as increases in import competition. We provide empirical evidence in support of these theoretical predictions using the natural experiment on China's emergence into the global economy. Whereas most prior research on the China shock has exploited variation across sectors or local labor markets, we construct new measures of input and output exposure to the

China shock at the level of individual firms. Consistent with the predictions of our model, we find that greater import competition in final output markets leads to the conventional contraction of firm employment, whereas greater import competition in intermediate input markets induces structural transformation within firms from production to knowledge services, though this effect is only evident for firms with in-house knowledge plants.

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Online Appendix for "Structural Change Within Versus Across Firms: Evidence from the United States" (Not for Publication)

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A Introduction

This online appendix contains additional empirical results as well as more detailed explanations of data used in the main text.

B Data Appendix

B.1 Defining Firms

The longitudinal firmids created by Census for the LBD may be too restrictive for answering some research questions. As noted in the main text, they break by construction when firms grow and shrink in a particular way. That is, if a newly born single-unit (SU) firm adds another establishment in a following year, it receives a new firmid by construction because Census firmids take a different form for SU and multiple-unit (MU) firms. Likewise, if an existing MU firm sheds all but one establishment, it's firmid also will break as its firmid is changed to fit the SU pattern. A second issue with Census firmids is that they may ignore information useful for some research questions. For example, changes in legal ownership status or mergers and acquisitions activity can lead to breaks in Census firmids even when the firm's name and main activities are unchanged.

For this reason, studies of firm dynamics typically identify firm entry and exit using a broader conceptualization of a firm. In decomposing employment growth between begin year b and end year e, Haltiwanger, Jarmin, and Miranda (2013), for example, defines entrants as Census firmids in year e consisting of plants that were not in the LBD in year b, and exiters as Census firmids in year

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b whose plants all exit the LBD before year e. Employment at all other plants in years b and e are categorized as being part of continuing firms. Note that this approach *does not* create alternate firmids to replace the Census firmids, as they are not needed to answer the research question addressed in that paper. Indeed, this approach just identifies the sets of establishments in each year that are "from exiting firms", "from entering firms" and "from continuing firms". Moreover, note that an attempt to create such firmids in the spirit of Haltiwanger, Jarmin, and Miranda (2013) likely would be unsatisfactory, particularly for research questions examining how outcomes (e.g., productivity) change within firms over time. That is because the alternate firmids to which this approach would give rise might encompass an uncomfortably large number of establishments.

Assume, for example, that 10 Census firmids encompassing 10 plants each are present in year b. Between year b and year e, assume that one plant from each of these firms splits off to join the other splitters, and that these 10 splitters constitute a new 10-plant firm that is given its own firmid by Census in year e. Finally, assume that each of the now 9-plant firms in year e retain their 10 original Census firmids, so that there are 11 Census firmids in total in year e. Using the approach taken in Haltiwanger, Jarmin, and Miranda (2013), all of the Census firmids in year b and year e would be classified as continuers, so all of their employment growth – including the growth among the plants of the new firmid in year e – would be counted toward the intensive margin. With respect to Census firmids, however, there would be 10 incumbents in year e and one entrant. If one wanted to create a new firmid in the spirit of Haltiwanger, Jarmin, and Miranda (2013), one would have to include all of the establishments at all of these firms in one new (continuing) firmid. It is not clear that estimating productivity growth across this firm would be meaningful.

In our examination of the share of employment accounted for by "legacy" firms in Section **??**, we make use of the conceptualization of a firm introduced by Haltiwanger, Jarmin, and Miranda (2013), which we label DL, as well as an even broader definition that accounts for all mergers and acquisition activity, which we label IL. In both cases, like Haltiwanger, Jarmin, and Miranda (2013), we *do not* create alternate firmids using these approaches, for the reason just explained. Rather, like Haltiwanger, Jarmin, and Miranda (2013), we use these conceptualizations of a firm to identify plants that match a certain criteria, i.e., whether they can be thought of as "legacy" firms given their association with long-lived plants.

Let a "long-lived" establishment be a plant that survives from year b to year e, e.g., 1977 to 2016. A collection of plants in a Census firmid in year t, $b \leq t \leq e$, is "directly" linked (DL) to a long-lived establishment in that year if it includes such an establishment. As described above the number of DL firms in a particular year can exceed the number of Census firmids in that year that actually survive from year b to year e for several reasons. For example, if a single long-lived establishment changes formal ownership over the period, such that its Census firmid breaks before year t, we classify it as DL.

A collection of plants in a Census firmid in t, $b \leq t \leq e$, is "indirectly" linked (IL) to a long-lived establishment in that year if it includes a plant that has ever (from b to e) been associated with a plant or plants that were alive in b and will be alive in e, up to any degree of separation.[¶] All DL

[¶]We identify IL plants in four steps. First, within each firm-year, we identify the minimum birth year and maximum

firms are IL firms, by definition.

B.2 Consistent Industry Codes

We assign establishments to a consistent, six-digit NAICS industry code using the following steps:

1. For analyses that span the latest years, we use the *bds_vcnaics* variable that contains the latest vintage of NAICS (NAICS 2017 in the 2019 LBD) codes for every establishment.

2. Following the directions from Fort and Klimek (2018), we merge to the $naics_flagsYYYY$ files to pull in the number of splits for records that were randomly assigned NAICS codes. Since some establishments never contain any industry information in the data, those records are randomly assigned any industry code based solely on the distribution of codes across all industries in the aggregate economy. In other words, these codes are pure guesses. We drop these industry codes so that our analysis is contaminated by what is essentially pure noise. To do so, we sum across all the 'splits' variables in the $naics_flagsYYYY$ files and drop industry codes for which the number of splits is greater than xxx.

3. For our regression analysis in Section **??** that spans 1997 to 2007, we use the $naicsYYYY$ files to pull the $fk_naics2002$ variable. This provides NAICS 2002 codes for all establishments, which avoids use of any random assignments that may have been needed to map the 2002 vintage codes to NAICS 2012, which were then mapped to NAICS 2017 for the *bds_vcnaics* variable.

These steps are the most logical for most research projects using the Fort-Klimek vintage-consistent codes, and we recommend that users follow them rather than relying solely on the new LBD's *bds_vcnaics* variable.

B.3 Auxiliary Establishments

Auxiliary establishments are ones that primarily serve other establishments within the firm.

B.3.1 Identifying Auxiliaries

We use four sources of information that vary over time to identify auxiliary establishments and construct a longitudinally consistent panel.

SIC Years: During the SIC years (1977 to 2001), we use the following two sources of data to identify auxiliaries:

death year of all plants. Second, within plants, we identify the minimums and maximums just computed across the firms with which the plant is associated from year b to year e. Third, for each firm-year, we compute the minimum and maximum of the just-computed plant information. Finally, we repeat these three steps until no more changes are made, with each step representing a degree of separation, e.g., associated with a plant, associated with a plant that was associated with a plant, and so on. This iteration captures all shuffling of plants across firmids that takes place between years b and e, and can account for firms that completely change their mix of plants over time, as long as there is some overlap. While this algorithm allows for any number of degrees of separation, in practice we find the largest to be 7 (one more than John Guare!). The number of IL firms in a typical year does not change substantially as one allows for from 1 to 7 degrees of separation.

1. The fk_naics_aux datasets available from Census identify auxiliary establishments using the Census of Auxiliaries, the BR 'type of operation' (TOC) code, and other information. For further details, see Fort and Klimek (2018) and Chow, Fort, Goetz, Goldschlag, Lawrence, Perlman, Stinson, and White (2021).

2. The Census of Auxiliaries (AUX), that are collected in years that end in 2 and 7, through 1997. Except for in 1992 (when the AUX seems to include an implausibly large number of plants), the vast majority of establishments in the AUX are also flagged by FK as auxiliaries.

   The FK codes also flag a large number and portion of auxiliary establishments (equal to about 1/3 of the plants in the -AUX and the FK set) that are not in the AUX. While the majority is driven by LBD-only plants in the early years (i.e., plants that are not in the EC data at all and thus cannot be identified by the AUX), the FK auxes are increasingly present in the CSR data in later years. This suggests possibility that the AUX may be missing new auxiliary establishments increasingly over time. The three or four-digit NAICS of the FK-only sectors also line up closely with those of auxiliaries identified in the AUX, suggesting they are accurately flagging aux estabs.

NAICS Years: During the NAICS years, we use the following two sources to identify auxiliaries:

1. The NAICS_AUX variable in the Business Register (BR) for years xx to xx, and then from the CBPBR starting in XX.

2. The inhouse indicator available in certain Economic Censuses (and then only for establishments that belong to multi-unit firms). The inhouse indicator in the EC data starts in 1997 in the Censuses of Services (CSR), and Transportation, Communications, and Utilities (CUT).

   - Note that CSR records where we calculate that MU=0 and they still have populated information for the inhouse flag, including some 1s.
   - For CRT and CWH, there are instances of the inhouse variable populated when MU=1. We are investigating whether these were transferred estabs from the CSR or CUT.

B.3.2 Identifying the Industries Served by Auxiliaries

Information about the industries served by auxiliary establishments is collected at an aggregate level (e.g., not at the plant or firm level). Here, too, our procedure varies by year. During the SIC years, the data are collected at the two-digit SIC level. During the NAICS era, we observe three- and four-digit NAICS codes depending on the sector (e.g., three digits for manufacturing but four digits for wholesale).

1. *SIC Years*: During the SIC years, we use the fk_naics_aux files to identify these codes. Note that it is important to use only the first three digits of these codes. Note that these codes are only on a NAICS 2002 basis.

2. *SIC Years*: During the NAICS years, we use the NAICS_AUX variable from the BR. These are raw, native codes, so again the NAICS vintage varies by year.

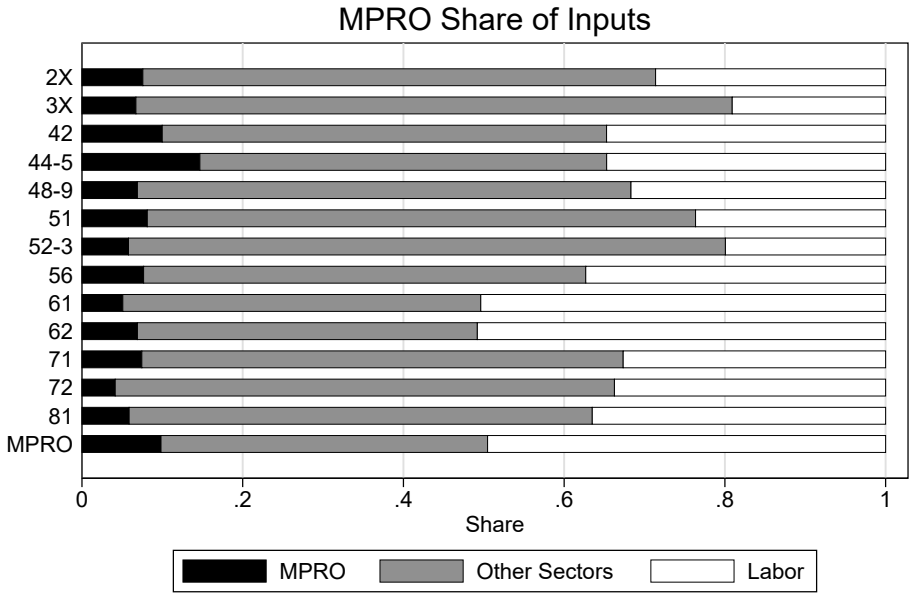
We use all the sources of information to flag auxiliary establishments. We use the plant-level information to determine which sectors contain auxiliary establishments. Specifically, we label a six-digit industry-year as one with auxiliary establishments if at least one percent of establishments and either five percent of employment or payroll is associated with auxiliary establishments within that industry and year, and if there are at least 10 auxiliary establishments. We perform the same classification at the NAICS3 level. For each aggregation level, we then count the number of auxiliary years for that industry.

We define six-digit NAICS as an auxiliary sector (i.e., a sector in which auxiliary establishments are possible) when the sector has at least two years in which it is classified as an AUX sector at the NAICS6 level, or if it is classified as an AUX sector at both the NAICS3 and the NAICS6 level in at least one year. We also use a liberal AUX sector definition, in which a sector is defined as an AUX sector if it is defined as an AUX sector at the NAICS6 level in at least one year. We define 92 AUX sectors and 101 liberal AUX sectors using this method.

B.4 MPRO as a Share of Sector Inputs

Figure A.1 reports the share of each two-digit NAICS sector's inputs represented by Management (NAICS 55) and Professional Services (NAICS 54) versus labor (BEA code V00100) and other sectors.

Figure A.1: MPRO Share of Sector Inputs, 1997



Source: Bureau of Economic Analysis and authors' calculations. Figure displays the share of each sector's inputs accounted for by Management (NAICS 55) and Professional Services (NAICS 54). Data are from the detailed 1997 US Supply-Use Table published on the BEA website. The activities encompassed by the various two-digit NAICS sectors are listed in Figures ?? and ?? of the main text.

Table A.1: Employment Growth Among Continuing Manufacturers

Continuing M Firms
M Employment Change

	$\Delta Emp^{NM} < 0$	$\Delta Emp^{NM} = 0$	$\Delta Emp^{NM} > 0$	**Total**
$\Delta Emp^{M} < 0$	-2.7	-0.2	-1.4	-4.3
$\Delta Emp^{M} = 0$	0.0	0.0	0.0	0.0
$\Delta Emp^{M} > 0$	0.3	0.4	1.6	2.3
Total	-2.4	0.2	0.2	-2.0

Continuing M Firms
NM Employment Change

	$\Delta Emp^{NM} < 0$	$\Delta Emp^{NM} = 0$	$\Delta Emp^{NM} > 0$	**Total**
$\Delta Emp^{M} < 0$	-1.7	0.0	3.3	1.6
$\Delta Emp^{M} = 0$	-0.3	0.0	3.4	3.1
$\Delta Emp^{M} > 0$	-0.3	0.0	5.7	5.4
Total	-2.3	0.0	12.4	10.1

Source: Longitudinal Business Database and authors' calculations. Table reports the change in manufacturing (M) and non-manufacturing (NM) employment, in millions of workers, across manufacturing firms that survive (i.e., continue) from 1977 to 2016 and engage in one of nine mutually exclusive activities: dropping, maintaining or increasing their M employment (i.e., $\Delta Emp^{M} < 0$, $\Delta Emp^{M} = 0$, and $\Delta Emp^{M} > 0$), and dropping, maintaining and increasing their NM employment (i.e., $\Delta Emp^{NM} < 0$, $\Delta Emp^{NM} = 0$, and $\Delta Emp^{NM} > 0$). Top panel reports changes in M employment while bottom panel reports changes in NM employment. Firms are defined according to Census firmids, as outlined in Section **??**. Manufacturing firms are defined as firms that have manufacturing employment in at least one year of the 1977 to 2016 sample period.

C Additional Within-Firm Employment and Payroll Change Results

The nine cells in each panel of Table A.1 report changes across firms taking one of three actions each with respect to their manufacturing (M) and non-manufacturing (NM) employment between 1977 and 2016: decrease it, leave it unchanged, or increase it. The top panel reports changes in M employment, while the bottom panel focuses on changes in NM employment.

As indicated in the top panel, continuing M firms drop 2 million manufacturing workers between 1977 and 2016, which is 30 percent of the aggregate decline in M over that period.[‖] The subset of

[‖] Fort, Pierce, and Schott (2018) find that 75 percent of the net decline in US manufacturing employment from 1977 to 2012 occurs within continuing firms, as they shed 6 million manufacturing workers while adding 10 million non-manufacturing workers, with one-third of the latter in Business Services (NAICS 5). Although the time period examined here is longer, the main reason for the difference in the intensive margin share of the manufacturing worker decline (75 versus 30 percent) is our use of a far more restrictive definition of a firm, i.e., Census' longitudinal firmids versus their DL firms. As discussed in the previous paragraph and in more detail in Section **??**, Census's longitudinal firmids break for a number of reasons orthogonal to our research interest, thereby understating the extent of within-firm structural change to a substantial degree. We use them here, however, because the broader DL and IL definitions of a

continuing M firms that shrink their M employment (top panel, first row), however, lose 4.3 million manufacturing workers, representing 80 percent of their initial, 1977 M employment of 5.6 million (not shown in table). This large decline is offset by the 2.3 million increase in M employment among continuing M firms that add M employment.

The bottom panel of Table **??** reveals that although continuing M firms experience significant M employment declines, they add 10 million NM workers, or 16 percent of the aggregate growth in US NM employment over this period. This panel highlights two forms of M firms pivoting towards services. First, there is the "extreme" pivoting by the subset of continuing M firms that drop M workers while adding NM employment. These firms increase NM employment by 1.6 million. Second, there is the milder pivoting of continuing M firms that weakly increase both forms of employment, but add considerably more NM workers than M workers, 8.5 million versus 2.3 million.**

Tables A.2 and A.3 display similar information for M firm births and deaths, and for NM firms. M firm births and deaths account for the loss of more than twice as many M workers as continuing M firms, -4.5 million versus -2 million, and far less growth among NM workers, 0.7 versus 10.1 million. The message of Table A.1 is that adding NM workers by M firms is primarily accomplished by continuing M firms rather than net M firm birth. Continuing NM firms (Table A.3) grow their NM employment by 12 million, surprisingly similar in levels to the overall NM employment growth observed for continuing M firms. The bulk of NM employment growth, 76 percent, however, is due to net NM firm birth.

firm are not as amenable to examining outcomes within firms over time.

Row 2 of the bottom panel of Table **?? includes firms that have no M employment in either 1977 or 2016, but do have M employment for at least one year in between.

Table A.2: Employment Growth Among Manufacturer Births and Deats

M Firm Birth/Death
M Employment Change

	$\Delta Emp^{NM} < 0$	$\Delta Emp^{NM} = 0$	$\Delta Emp^{NM} > 0$	**Total**
$\Delta Emp^{M} < 0$	-6.3	-5.1	0.0	-11.4
$\Delta Emp^{M} = 0$	0.0	0.0	0.0	0.0
$\Delta Emp^{M} > 0$	0.0	4.1	2.8	6.9
Total	-6.3	-1.0	2.8	-4.5

M Firm Birth/Death
NM Employment Change

	$\Delta Emp^{NM} < 0$	$\Delta Emp^{NM} = 0$	$\Delta Emp^{NM} > 0$	**Total**
$\Delta Emp^{M} < 0$	-5.6	0.0	0.0	-5.6
$\Delta Emp^{M} = 0$	-1.2	0.0	3.9	2.7
$\Delta Emp^{M} > 0$	0.0	0.0	3.6	3.6
Total	-6.8	0.0	7.5	0.7

Source: Longitudinal Business Database and authors' calculations. Table reports the change in manufacturing (M) and non-manufacturing (NM) employment, in millions of workers, across manufacturing firms that are born or die between 1977 and 2016 engaged in one of nine mutually exclusive activities: dropping, maintaining or increasing their M employment (i.e., $\Delta Emp^{M} < 0$, $\Delta Emp^{M} = 0$, and $\Delta Emp^{M} > 0$), and dropping, maintaining and increasing their NM employment (i.e., $\Delta Emp^{NM} < 0$, $\Delta Emp^{NM} = 0$, and $\Delta Emp^{NM} > 0$). Panels 1 and 2 report changes in M and NM employment, respectively. Firms are defined according to Census firmids, as outlined in Section **??**. Manufacturing firms are defined as firms that have manufacturing employment in at least one year of the 1977 to 2016 sample period.

Table A.3: 1977 to 2016 NM Employment Growth Among NM Firms

Continuing NM Firms

	$\Delta Emp^{NM} < 0$	$\Delta Emp^{NM} = 0$	$\Delta Emp^{NM} > 0$	**Total**
$\Delta Emp^{M} < 0$	na	na	na	na
$\Delta Emp^{M} = 0$	-1.8	0.0	14.5	12.7
$\Delta Emp^{M} > 0$	na	na	na	na
Total	-1.8	0.0	14.5	12.7

NM Firm Birth/Death

	$\Delta Emp^{NM} < 0$	$\Delta Emp^{NM} = 0$	$\Delta Emp^{NM} > 0$	**Total**
$\Delta Emp^{M} < 0$	na	na	na	na
$\Delta Emp^{M} = 0$	-29.6	0.0	69.7	40.1
$\Delta Emp^{M} > 0$	na	na	na	na
Total	-29.6	0.0	69.7	40.1

Source: Longitudinal Business Database and authors' calculations. Table reports the change in non-manufacturing (NM) employment, in millions of workers, across non-manufacturing firms engaged in one of nine activities between 1977 and 2016: dropping, maintaining or increasing their M employment (i.e., $\Delta Emp^{M} < 0$, $\Delta Emp^{M} = 0$, and $\Delta Emp^{M} > 0$), and dropping, maintaining and increasing their NM employment (i.e., $\Delta Emp^{NM} < 0$, $\Delta Emp^{NM} = 0$, and $\Delta Emp^{NM} > 0$). Panel 1 reports changes for firms that survive the 1977 to 2016 sample period, while panel 2 reports results across firms that enter or exit over this period. Firms are defined according to Census firmids, as outlined in Section **??**. Non-manufacturing firms are defined as firms that do no have manufacturing employment in any year of the sample period.

Table A.4: Payroll Growth Among Continuing Manufacturers

Continuing M Firms
M Payroll Change

	$\Delta Emp^{NM} < 0$	$\Delta Emp^{NM} = 0$	$\Delta Emp^{NM} > 0$	**Total**
$\Delta Emp^{M} < 0$	-11.6	3.1	20.3	11.8
$\Delta Emp^{M} = 0$	0.0	0.3	0.0	0.3
$\Delta Emp^{M} > 0$	23.7	27.9	126.6	178.2
Total	12.1	31.3	146.9	190.3

Continuing M Firms
NM Payroll Change

	$\Delta Emp^{NM} < 0$	$\Delta Emp^{NM} = 0$	$\Delta Emp^{NM} > 0$	**Total**
$\Delta Emp^{M} < 0$	28.7	0.0	263.4	292.1
$\Delta Emp^{M} = 0$	11.7	0.0	259.4	271.1
$\Delta Emp^{M} > 0$	6.5	0.0	310.2	316.7
Total	49.6	0.0	833.0	879.9

Source: Longitudinal Business Database and authors' calculations. Table reports the change in manufacturing (M) and non-manufacturing (NM) payroll, in trillions of workers, across manufacturing firms that survive (i.e., continue) from 1977 to 2016 and engage in one of nine mutually exclusive activities: dropping, maintaining or increasing their M employment (i.e., $\Delta Emp^{M} < 0$, $\Delta Emp^{M} = 0$, and $\Delta Emp^{M} > 0$), and dropping, maintaining and increasing their NM employment (i.e., $\Delta Emp^{NM} < 0$, $\Delta Emp^{NM} = 0$, and $\Delta Emp^{NM} > 0$). Top panel reports changes in M payroll while bottom panel reports changes in NM payroll. Firms are defined according to Census firmids, as outlined in Section **??**. Manufacturing firms are defined as firms that have manufacturing employment in at least one year of the 1977 to 2016 sample period.