New Perspectives on the Decline of U.S. Manufacturing Employment*

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Abstract

We use proprietary and public data from the U.S. Census Bureau to provide new perspectives on the decline of U.S. manufacturing employment since the late 1970s. We document where U.S. manufacturing employment losses are concentrated along firm, region and industry margins of adjustment; quantify U.S. manufacturing firms' diversification into industries outside manufacturing; and assess how manufacturing firms that adopt several specific technological innovations and trade practices compare in terms of attributes and outcomes.

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1 Introduction

Public debate continues over the appropriate policy response – if any – to the decline in U.S. manufacturing employment. Some argue that increasing tariffs is warranted to cut off foreign import competition and encourage firms to locate production in the United States. Others, persuaded by research that the overall gains from trade outweigh the costs, or that technology, rather than import competition, is behind the drop in manufacturing employment, advocate human capital deepening to facilitate the reallocation of displaced workers to other sectors. Hovering over this discussion is a broader question of how the scope of U.S. manufacturing firms might be changing in response to trade and technology.

We contribute to these discussions by using proprietary and public data from the U.S. Census Bureau to provide new perspectives on the decline of U.S. manufacturing employment since the late 1970s. First, we show where U.S. manufacturing employment losses are concentrated along firm, region and industry margins of adjustment. Second, we examine U.S. manufacturing firms' diversification into industries outside manufacturing, and provide a breakdown of these activities by sector. Finally, we assess how adopters of several specific technological innovations and trade practices compare in terms of attributes and outcomes.

One of our more surprising findings is that three quarters of the decline in U.S. manufacturing employment between 1977 and 2012 occurs within firms present in 1977, primarily due to net plant closure. Why is the primary adjustment *within* firms? What barriers to entry – regulatory or otherwise – might have dampened firm creation or suppressed firm creation? One potential explanation is that manufacturing firms' ability to adapt to changing conditions requires absorbing large fixed costs. Evidence consistent with this hypothesis comes from another of our findings, which is that firms adopting new technologies such as computers and industrial robots exhibit the same size and productivity premia that are well-known among trading firms.

A second perspective on incumbent manufacturing firms' persistence comes from their substantial activity in areas outside manufacturing. Indeed, we find that non-manufacturing employment at manufacturing firms increases markedly between 1977 and 2012, enough to cause an increase in their *overall* employment. About a third of this increase is driven by workers in high-skill service professions such as design and engineering. This expansion may signal a transition from "manu"facturing to "neuro"facturing (Leamer (2009)), where former manufacturing firms increasingly design and take products to market but leave the physical manipulation and transformation of material inputs to outside contractors largely located in lower-wage countries. It may also reveal greater use of marketing and other management services directed towards product differentiation. Are incumbents better suited for such transitions? What are the implications for markups, future innovation and growth? These findings also raise questions about the role of the boundary of the firm. Does the transition from manufacturing to services within firms mimic that which takes place across non-manufacturing firms, or does it point to an important role for the firm in building up capabilities that persist over time?

Analysis of the distribution of manufacturing employment within the United States provides a third perspective on the roles of trade and technology. We find substantial reallocation of manufacturing employment across U.S. Census regions between 1977 and 2000, from north and east to west and south. This "domestic offshoring," i.e., redistribution of activity from higher- to lower-wage areas, may have allowed some firms to remain internationally competitive before the trade policies or technologies needed to manage global value chains were a viable option.

Discussions about the influence of trade and technology on U.S. manufacturing employment often culminate in a request to decompose any given change into the part that is due to each force. For reasons we elaborate on below, we think providing answers to that question is nearly impossible.[1] Instead, our goal in this paper is to highlight largely unexplored dimensions of U.S. manufacturing activity as motivation for further research into the many complex ways trade and technology may interact to affect firms and workers.

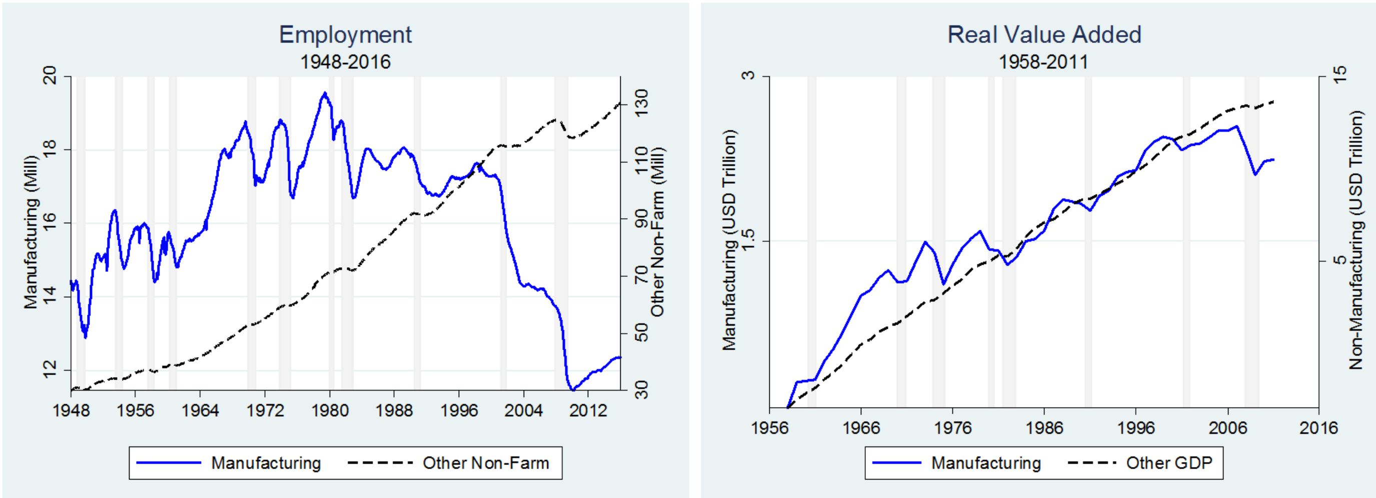
The remainder of this paper proceeds as follows. Section 2 sets the stage for our analysis by summarizing post WWII trends in U.S.manufacturing employment and value added. Sections 3 and 4 present our empirical analyses. Section 5 concludes.

2 Background

The trajectories of U.S. manufacturing and non-manufacturing employment after World War II – displayed in the left panel of Figure 1 – exhibit several notable features. First, manufacturing employment, which is pro-cyclical, stops recovering to its pre-recession level after reaching a peak of 19.5 million workers in 1979. Second, the 17 and 18 percent declines experienced from 2000 to 2003 and during the Great Recession are especially steep. While both of these decreases coincide with cyclical contractions, the first drop stands out given the relative mildness of the 2001 recession and the lack of any recovery before the Great Recession. The early 2000s decline also contrasts with the more moderate cumulative reduction in manufacturing employment that occurs during the 1980s and 1990s. Indeed, U.S. manufacturing employment fell just 12 percent over the 21 years between the post-war peak in 1979 and 2000.

Comparison of U.S. manufacturing employment in Figure 1 with non-farm employment (left panel) and real value added (right panel) highlights two other striking features. The first is an almost continual decline in manufacturing employment's share of total U.S. non-farm employment, which drops from 32 percent in 1948 to 8 percent in 2016. The second is a steady rise in manufacturing real value added, which grows at more or less the same rate as real GDP over the last few decades, at least until the Great Recession. As noted in Houseman et al. (2011) and Baily and Bosworth (2014) and discussed further in Section 3.3, this increase is driven by the computer and electronics

[1] Disagree? Here's a quiz based on a recent Wall Street Journal article (Michaels (2017)). "When Drew Greenblatt bought Marlin Steel Wire Products LLC, a small Baltimore maker of wire baskets for bagel shops, he knew nothing about robotics. That was 1998, and workers made products manually using 1950s equipment....Pushed near insolvency by Chinese competition in 2001, he started investment in automation. Since then, Marlin has spent $5.5 million on modern equipment. Its revenue, staff and wages have surged and it now exports to China and Mexico." Is that a trade or a technology anecdote?



Source: Monthly employment data are from U.S. Bureau of Labor Statistics. Annual manufacturing real value added data are from NBER-CES Manufacturing Industry Database. Annual real GDP data are from U.S. Bureau of Economic Analysis. Non-manufacturing value added is real GDP less manufacturing real value added. Shading corresponds to NBER-dated recessions.

Figure 1: U.S. Manufacturing Employment

industry, and semiconductors in particular. Combined, the drop in employment and increase in value added reveal a substantial increase in labor productivity. They also indicate that that any explanation for the decline in U.S. manufacturing employment be consistent with rising aggregate output and substantial variation in industry-level value-added growth.

Noting these trends, a growing empirical literature uses trade liberalizations as "natural experiments" to show that U.S. manufacturing employment drops disproportionately in industries with greater exposure to reductions in trade barriers. Hakobyan and McLaren (2016), for example, use tariff variation across industries to document a small effect of NAFTA among workers without a college degree. Autor et al. (2013) demonstrate that regions with higher initial shares of employment in industries with relatively greater exposure to Chinese imports experience relatively larger declines in employment and labor force participation. Pierce and Schott (2016a) show that the post-2000 increase in U.S. imports from China and concomitant decline in U.S. manufacturing employment are disproportionately concentrated in industries exposed to a discrete change in U.S. trade policy that occurred in October, 2000. This trade liberalization eliminated the possibility of sudden, substantial spikes in U.S. tariffs on many Chinese imports, thereby removing a significant deterrent to greater integration of the two economies that had been in place since the 1980s.

Further context for the current political backlash against trade comes from related research highlighting a wide range of distributional losses associated with this change in policy. Workers in more-exposed industries experienced relative declines in earnings and increased unemployment (Autor et al. (2014); Acemoglu et al. (2016)), and regions with higher initial shares of employment in those industries also exhibit relative declines in worker earnings (Pierce and Schott (2016b)), the provision of public goods (Feler and Senses (2015)), and marriage rates (Autor et al. (2017)), as well as relative increases in household debt (Barrot et al. (2017)) and crime (Che et al. (2016)). These consequences carry over to health: Pierce and Schott (2016b) show that more-exposed regions exhibit relative increases in "deaths of despair," including suicides and drug overdoses, a connection that is eerily reminiscent of the spike in mortality rates among high-tenure workers laid off from the steel industry in Pennsylvania during the 1980s (Sullivan and Wachter (2009)).

One drawback of the above studies is the inability of difference-in-differences analyses to provide estimates about level changes in employment. A number of calibrated theoretical models offer such estimates. Antràs et al. (2017), for example, find that increases in U.S. firms' foreign sourcing between 1997 and 2007 account for approximately 4 percent of the decline in manufacturing employment over that period. Boehm et al. (2017) calculate that multinationals in the United States account for 41 percent of the decline in manufacturing employment between 1993 to 2011; their calibration estimates that one third of their contribution is due to increases in foreign sourcing. Finally, Caliendo et al. (2015) estimate that increased trade with China explains approximately one quarter of the decline in US manufacturing employment from 2000 to 2007. Despite these negative employment effects, several papers show that changes in U.S. trade policy toward China have led to lower prices for consumers as a result of lower priced imported inputs (Antràs et al. (2017); Amiti et al. (2017), and increased imported product variety (Handley and Limao (2017)).

An interesting question emerging from the empirical literature is why the response to the change in U.S. trade policy with China appears to have been larger and more wide-reaching than prior liberalizations. One possibility is that the magnitude of the shock was simply larger. Another is that the removal of import tariff uncertainty associated with the U.S. granting of Permanent Normal Trade Relations to China in 2000 led to an abrupt shift in firm behavior, complicating workers' transition to new sectors, occupations or regions. Would outcomes during the 2000s have been different had trade with China not been distorted until 2000? Should we expect similarly difficult adjustments in response to abrupt technological changes?

While trade policy changes have received considerable attention, other researchers interpret the long-running decline in the manufacturing employment share, "irrespective of the changing developments in international trade flows, the size of the trade deficit, and other factors" as evidence that the dominant force affecting U.S. manufacturing employment is technological change (Edwards and Lawrence (2013)). This view is also common among policy makers: asked to explain the decline in manufacturing employment, Former Secretary of Commerce Carlos Gutierrez, for example, noted that U.S. "manufacturing output is pretty stable, pretty flat. If you go back 10, 15 years, it's between 12 and 14 percent. But our manufacturing workforce has been declining steadily. So we're producing the same output with fewer people. What that tells me is that technology is more of a threat to American jobs than trade."

Event-study research into the relationship between manufacturing employment and technology is hampered by researchers' inability to observe firms' adoption of specific innovations, as well as the factors which might instigate them (including trade!). Despite these complications, several papers assess the role of particular technologies on labor market changes. Acemoglu and Restrepo (2017) find that U.S. regions that adopt more industrial robots have also experienced relatively larger employment declines, at a rate of approximately 5 workers per robot. Goos et al. (2014) and Autor et al. (2015) attempt to decompose the respective roles of trade and technology on employment and wages. Both argue that technological change has decreased the relative demand for routine tasks; the latter compares the results for computerization of routine tasks to increased Chinese import penetration in the United States and conclude that Chinese imports play a larger role, especially after 2000.

While these papers use careful measures to attempt to address the challenges listed above, they are susceptible to the possibility that trade and technology are jointly determined. Bernard et al. (2006a), Khandelwal (2010) and Bernard et al. (2011) for example, find that U.S. firms facing greater competition from low-wage countries are more likely to change or upgrade their product mix. Fort (2017) and Steinwender (ming) demonstrate that innovations in communications technologies induce trade. Bloom et al. (2016) show that firms (in the U.K.) subject to greater competition from China are more likely to innovate along various dimensions, and that this competition also induces a reallocation towards more technologically advanced firms. We hope the data summarized in the remainder of the paper can help shed additional light on these reactions.

3 Employment Loss by Margin of Adjustment

In this section we use a variety of proprietary and public datasets from the U.S. Census Bureau to dissect the aggregate outcomes reported in Figure 1 along three dimensions: firms, regions and industries.

3.1 Firm Margins of Adjustment

The manner by which firms add or shed workers offers clues about their structure and transition costs as well as the nature of the shocks they face. If automating existing plants is relatively cheap, for example, employment declines may be concentrated along the "intensive" margin, i.e., within continuing firms' continuing establishments. If technology upgrades are more efficiently accomplished by shuttering outmoded plants in favor of new facilities, employment declines may occur via the net death of establishments within continuing firms. Finally, if entrepreneurs at entering firms have an edge in creating or implementing new technologies, reductions in employment may be driven by firm death, as outdated incumbents are pushed from the market.

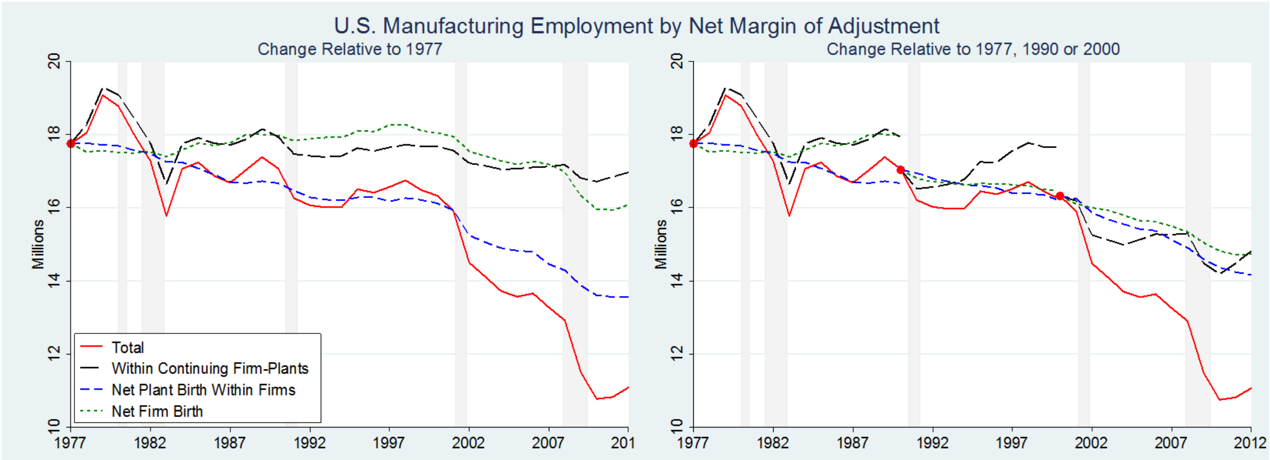
Responses to globalization can, of course, operate along the same margins of adjustment. Trade liberalization with low-wage countries might render a U.S. firm's most labor-intensive products unprofitable. To the extent that firms are able to reallocate production away from these goods within existing facilities, globalization may manifest as declines in employment along the intensive margin. But if plants are wedded to particular products, employment loss may be driven by net plant death within continuing firms. For firms specializing in import-competing products, trade liberalization may lead to firm death.

We assess the importance of these margins in the overall trajectory of U.S. manufacturing employment using data from the U.S. Census Bureau's Longitudinal Business Database (LBD). These data, assembled by Jarmin and Miranda (2002), link all private, non-farm employer establishments and firms over time from 1977 to 2012. Each U.S. establishment in the LBD is assigned a single industry code in each year based upon its predominant activity.[2] Firms with more than one establishment may have employment both inside and outside of manufacturing. We follow Haltiwanger et al. (2013) and define a firm death as occurring when all establishments within a firm exit. Firm birth only occurs when all the establishments in a firm are new. This avoids spurious firm birth and death due to merger and acquisition activity, though future research into the extent to which these types of ownership changes are important factors in understanding manufacturing employment's decline might be useful.

We define a "manufacturing firm" to include all firms ever observed to have a manufacturing establishment during the 1977 to 2012 sample period. We choose this *broad* definition for two reasons. First, and most simply, these firms encompass all U.S. manufacturing employment during our period of interest, which would not be the case if we excluded firms below some threshold level of manufacturing activity. Second, defining firms in this way allows us to analyze manufacturing firms' presence in non-manufacturing industries, including the employment associated with establishments that switch into and out of manufacturing over time. One potential drawback of our definition is that it may capture firms not traditionally thought of as manufacturers, e.g., big box retailers that have relatively small food preparation facilities. We assess the potential importance of such firms by examining the sectoral composition of manufacturing firms' non-manufacturing employment. One interesting issue our current analysis does not address, but which might be useful to pursue in future research, is whether such movements represent manufacturing firm diversifying into non-manufacturing, or *vice versa*.

We begin with two decompositions of manufacturing firms' manufacturing employment, displayed in the left and right panels of Figure 2. Solid lines display overall employment while the dashed lines trace out employment along three net margins: (1) net expansion among continuing firms' continuing establishments (also referred to as the "intensive" margin); (2) net establishment birth within continuing firms; and (3) net firm birth. In the *left* panel, a margin's employment is computed relative to the firms and plants present in 1977. In the *right* panel, margins are computed with re-

[2] An establishment denotes a single physical location where business transactions take place and for which payroll and employment records are kept. In the LBD as in other official employment statistics, workers are grouped into industries based on the classification of the establishment in which they work. As a result, all workers in a manufacturing plant are classified as manufacturing workers, regardless of their occupation. We identify manufacturing plants based on an assignment of time-consistent NAICS codes developed by Fort and Klimek (2016) that ensure that the transition from SIC to NAICS does not result in spurious changes in the number of manufacturing workers based on changes in the set of activities considered "manufacturing". While the resulting manufacturing employment totals from the LBD do not perfectly match the totals from the Bureau of Labor Statistics displayed in Figure 1, they are highly correlated over time. Our analysis drops records that are outside the scope of the County Business Patterns data, such as agriculture, and observations that are clearly erroneous, for example because of implausible payroll and employment numbers.



Source: Longitudinal Business Database and authors' calculations. Left panel reports the cumulative change in employment along the noted net margins of firm adjustment relative to the firms and plants in existence in 1977, the "base" year. Net margins in the right panel report cumulative changes relative to the firms and plants in existence in base years 1977, 1990 and 2000, respectively. In both panels, dots along the solid line indicates base years.

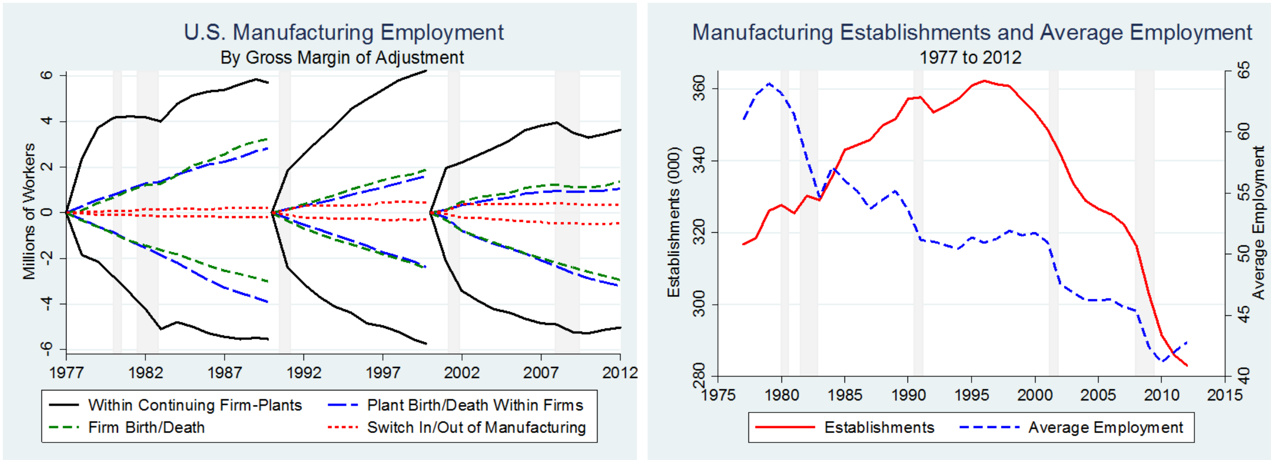
Figure 2: U.S. Manufacturing Employment by Net Margin of Adjustment, 1977 to 2012

spect to the firms and plants that exist as of 1977, 1990 and 2012, respectively. As a result, data from 1977 to 1990 are the same in both panels. We include both views to facilitate comparison of the behavior of firms born before and after 1977.

"Legacy" firms account for most of the loss of U.S. manufacturing employment: The left panel of Figure 2 reveals that most of the change in U.S. manufacturing employment – 75 percent – takes place within firms that already existed in 1977, which we refer to as "legacy" firms. Most striking is the steady decline of employment associated with net plant birth within these firms, which by itself accounts for 63 percent of the overall decline in U.S. manufacturing employment between 1977 and 2012. The loss of employment along these margins is noteworthy given anecdotal evidence often offered in support of an "innovator's dilemma." Christensen (1997), for example, argues that incumbents are at a disadvantage relative to new entrants in terms of coping with new conditions during times of change. The results here may be an indication that legacy manufacturing firms have an edge in terms of human capital or intangibles that facilitates adaptation and survival.

A different sort of incumbent persistence is demonstrated by the intensive margin. As illustrated in the *left* panel of Figure 2, the set of firm-plants that survive between 1977 and 2012 are responsible for relatively little – 12 percent – of the overall decline in employment during the sample period, with most of this decline occurring during the early 2000s. Comparison of this trend with the *right* panel of Figure 2 reveals that the employment of "legacy" firm-plants along the intensive margin is steadier than the intensive-margin employment of firms entering after 1977: it rises less substantially during the 1990s and falls less dramatically during the 2000s. What drives these differences? Are legacy firm-plants the most consistently productive? If so, does trade or technology play a role? We return to this issue in Section 4.

Additional insight into the importance of continuing firms in U.S. manufacturing employment is provided by the left panel of Figure 3. This figure further decom-



Source: Left panel is from Longitudinal Business Database and authors' calculations. Lines above zero are gross job creation margins and lines below zero are gross job destruction margins. For example, solid line above zero displays employment growth associated with expanding plants among continuing firms, while solid line below zero displays employment decline associated with shrinking plants at continuing firms. Employment changes along each margin are relative to the firms and establishments present in 1977, 1990 and 2000, respectively. Right panel is from publicly available Business Dynamics Database and authors calculations.

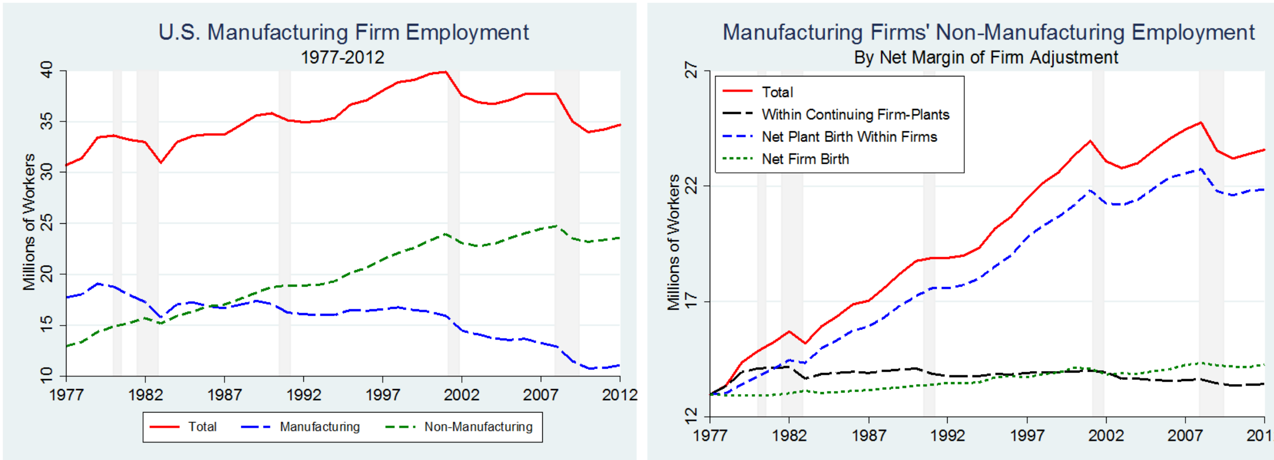
Figure 3: U.S. Manufacturing Employment by Gross Margin of Adjustment, 1977 to 2012

poses the three net margins of firm adjustment used above into their constituent gross job creation and destruction margins. The four job creation margins – expanding firm-plants, plant birth within continuing firms, firm birth, and the switching of non-manufacturing establishments into manufacturing – are displayed in lines above zero. Their corresponding job destruction margins are displayed in similarly patterned lines below zero. As in the *right* panel of Figure 2, cumulative contributions are computed with respect to the firms and establishments present at the beginning of 1977, 1990 and 2012.

The gross margins in Figure 3 reveal a clear decline in job creation. Employment growth due to plant births at continuing firms falls steadily over time. A similar dynamic is at work in firm births, as job creation along this margin also drops across the sample period. Together, these trends in the two birth margins indicates either that fewer new establishments are being opened, or that new establishments have relatively fewer workers, or both. Job creation within continuing firm-plants, shown in the black line, has similarly-sized contributions in the 1980s and 1990s, but this contribution steps down in the 2000s.

An additional notable feature of the left panel of Figure 3 is the increase in manufacturing job creation and destruction associated with establishments that switch into and out of manufacturing. While the level of employment associated with these transitions is relatively small, on the order of hundreds of thousands of workers rather than millions, they hint at potential transitions among some firms to a "post-manufacturing" future, a topic to which we return below.

While we do not report establishment counts along margins of adjustment here, publicly available data from the Census Bureau's Business Dynamics Database, plotted in the right panel of Figure 3, suggests both that plant births are becoming rarer and that new plants employ less labor. As indicated in the figure, growth in the number of



Source: Longitudinal Business Database and authors' calculations. Left panel decomposes U.S. manufacturing firms' total employment into manufacturing versus non-manufacturing sub-totals. Right panel reports the cumulative change in employment along the noted net margins of firm adjustment relative to the firms and plants in existence in 1977, the "base" year.

Figure 4: U.S. Manufacturers' Non-Manufacturing Employment, 1977 to 2012

U.S. manufacturing establishments slows after the 1980s before turning negative in the late 1990s. At the same time, the average number of workers per establishment drops steadily across recessions. While the cyclicality of these drops begs further analysis, the overall downward trend is consistent with a shift in U.S. production towards more capital- and skill-intensive goods or the adoption of more capital- and skill-intensive techniques.

The decline in gross job creation illustrated in Figure 3 is part of a more general decline in business dynamism that has been documented in various ways across all sectors of the U.S. economy by Decker et al. (2014) and others. An interesting question is the extent to which the slowdown in other sectors might be related to the actions of manufacturing firms, or *vice versa* via various channels such as local labor markets or relationships between manufacturing and non-manufacturing industries. To provide further evidence that might be useful in thinking about these links, as well as to provide a deeper understanding of the adjustments made by manufacturing firms highlighted thus far, we next examine the extent of their activity in other sectors.

Manufacturing firms' total employment rises from 1977 to 2012: The left panel of Figure 4 displays manufacturing firms' total employment between 1977 and 2012, as well as a breakdown of this employment by their manufacturing versus non-manufacturing establishments. Somewhat unexpectedly, we find that manufacturing firms employ a substantial number of workers outside of manufacturing. Moreover, their *total* employment rises over the sample period due to a steady increase in non-manufacturing employment up to 2000. After 2000, non-manufacturing employment growth hits a wall, rising and falling during that period's ups and downs, and ending with the 2012 level of non-manufacturing employment essentially unchanged from that in 2000. Given the substantial decline in manufacturing employment during this latter period, total employment at manufacturing firms declines from 2000 to 2012. Between 1977 and 2012 manufacturing firm's total employment increases 13 percent, from 30.7 to 34.7 million, and the share of non-manufacturing employment in this total rises from 42 to

68 percent.

In general, the growing share of non-manufacturing activities within manufacturing firms revealed in Figure 4 is noteworthy in light of recent research suggesting that U.S. manufacturers increasingly outsource ancillary services such as cleaning to domestic contractors (Dey et al. (2012); Berlingieri (2014); Katz and Krueger (2016)). The results here suggest that this separation of production and non-production tasks may also be occurring within firms, i.e., through the addition of establishments whose principal activity lies outside manufacturing.

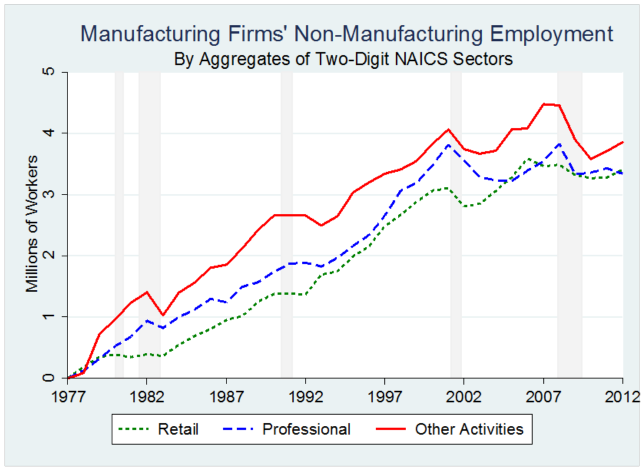
We note that the extent to which non-manufacturing employment rises over this period depends upon how one defines a manufacturing firm. For example, if one defines a manufacturing firm as one with at least a quarter of its employment in manufacturing in at least one year of the sample, the growth in non-manufacturing employment before 2000 is somewhat flatter. Growth in the non-manufacturing employment of manufacturing firms is also slower than overall non-manufacturing employment. This difference may reflect compositional effects of the non-manufacturing industries in which manufacturing firms are active or spillover effects related to employment declines at the firms' manufacturing establishments.

A decomposition of manufacturing firms' non-manufacturing employment by net margins of adjustment, reported in the right panel of Figure 4, reveals that here, too, continuing firms dominate. In this case, net establishment birth within continuing firms accounts for a very high share – 84 percent – of the overall growth in manufacturing firms' non-manufacturing employment between 1977 and 2012, just as net plant death accounts for a large share of the manufacturing employment decline. Margins of adjustments for these multi-sector firms contrast starkly with an analogous decomposition of the employment of non-manufacturing firms (available, but not displayed here), where net firm birth accounts for 62 percent of overall growth. Combined, Figures 2 and 4 may be an indication that the "legacy" firms shedding manufacturing workers via plant closures are adding non-manufacturing workers via plant openings.

Figure 5 reports the particular activities in which these added plants are engaged. It decomposes U.S. manufacturing firms' non-manufacturing employment into three groups of two-digit NAICS sectors: retail (NAICS 44 to 45), professional services (NAICS 51 to 56) and all other non-manufacturing sectors. In contrast to the the growth of non-manufacturing employment, we find that the composition of non-manufacturing employment is not sensitive to defining manufacturing firms according to the kinds of thresholds described above.

Perhaps unsurprisingly, given our broad definition of manufacturing firms, we find that 32 percent of the overall growth in manufacturing firms' non manufacturing employment over the sample period is due to retail establishments.

Thirty-two percent of the increase, however, is driven by professional services, our label for a set of NAICS codes that capture a wide range of often skill-intensive activities: information technology (NAICS 51); finance, insurance, real estate and leasing (NAICS 52-3); engineering and other technical services (NAICS 54); headquarters services (NAICS 55); and administrative support and waste management (NAICS 56). The increase in employment related to these services may reflect changes in production techniques, e.g., increasing use of professional management or IT services. Bloom and



Source: Longitudinal Business Database and authors' calculations. Retail is NAICS sectors 44 to 45. Professional Services are: information technology (NAICS 51); finance, insurance, real estate and leasing (NAICS 52-4); engineering and other technical services (NAICS 55); headquarters services (NAICS 56); and administrative support and waste management (NAICS 56). Other Activities are all other NAICS sectors.

Figure 5: U.S. Manufacturers' Non-Manufacturing Employment by Sector, 1977 to 2012

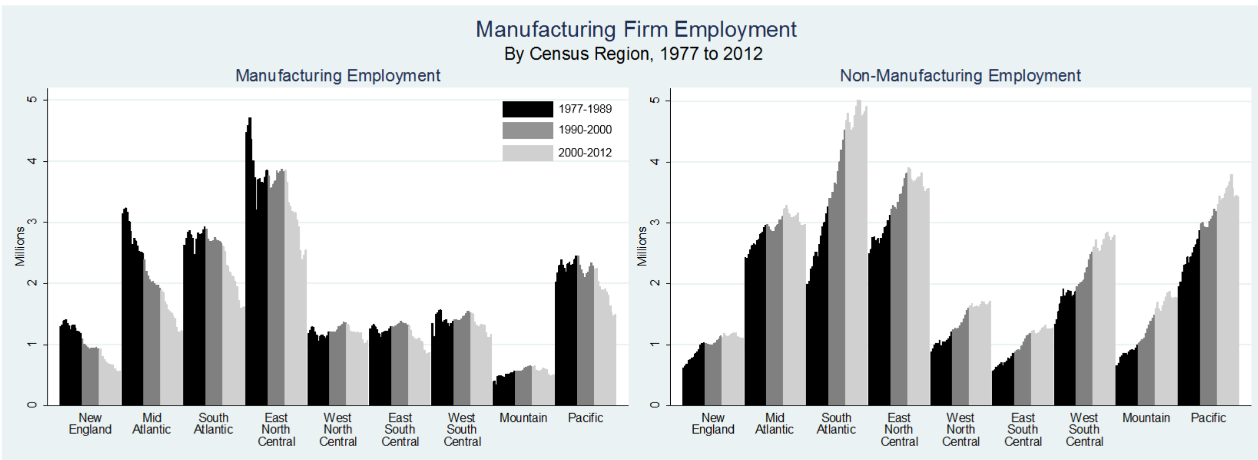
Van Reenen (2007) and Bloom et al. (2012), for example, highlight U.S. firms' relatively greater use of high-quality management practices, and their relative advantage in reaping productivity gains from information technology. It may also reveal greater use of marketing and other management services directed towards product differentiation, a practice which may help explain the rise of market power among U.S. firms starting in the 1980s (Loecker and Eeckhout (2017)). Finally, greater reliance on professional services may also signal a shift towards the kind of factory-less goods production described in Bernard and Fort (2015), in which traditional manufacturing firms shed their production facilities in favor of offshore contract manufacturers to focus on the technology and design of their products (think Apple).

The final 36 percent of the employment growth displayed in Figure 5 encompasses all other NAICS sectors. This broad range of activities includes those which typically complement manufacturing facilities, such as transportation and warehousing (NAICS 48 to 49), but also encompasses healthcare (NAICS 62) and accommodation and food services (NAICS 72). Interestingly, employment in both other services and retail continues to rise through the sharp drop in manufacturing employment between 2000 and 2004. Professional services employment, by contrast, appears more sensitive to the manufacturing employment decline during that period, but experiences a period of recovery prior to the Great Recession that manufacturing employment does not.

3.2 Reallocation Across Regions

Reallocation of manufacturing activity within the United States also sheds light on the potential influence of trade and technology. Toward that end, we use information about plants' locations contained in the LBD to examine changes in the distribution of manufacturing firms' employment across regions and time.

Figure 6 summarizes U.S. manufacturing firms' manufacturing (left panel) and non-manufacturing (right panel) employment across the nine U.S. census regions that encompass the United States. The thirty-six bars for each region plot employment from 1977 to 2012, and bars are shaded to correspond to the time intervals used above: years before 1990 are black; years from 1990 to 1999 are dark gray; and bars after 1999 are light gray.



Source: Longitudinal Business Database and authors' calculations. Panels report manufacturing firms' manufacturing and non-manufacturing employment across years and census regions. Years from 1977 to 1989, 1990 to 1999 and 2000 to 2012 are shaded black, dark grey and light grey, respectively. Census regions are defined as follows. New Enlgand: CT, MN, MA, NH, RI, VT. Middle Atlantic: NJ, NY, PA. East North Central: IN, IL, MI, OH, WI. West North Central: IA, KS, MN, MO, NE, ND, SD. South Atlantic: DE, DC, FL, GA, MD, NC, SC VA, WV. East South Central: AL, KY, MS, TN. West South Central: AR, LA, OK, TX. Mountain: AZ, CO, ID, MT, UT, NV, WY. Pacific: AK, CA, HI, OR, WA.

Figure 6: U.S. Manufacturing Employment and Establishments by Census Region

As indicated in the left panel of the figure, the New England, Mid-Atlantic and East North Central regions exhibit a more-or-less steady decline in manufacturing employment during the 1980s and 1990s. This reduction contrasts starkly with the stable or increasing manufacturing employment in the remaining regions over this interval. Indeed, between 1977 and 2000, manufacturing employment in the former three regions falls by -2.3 million while among the latter regions it rises by 0.8 million. After 2000, manufacturing employment declines in all census regions.

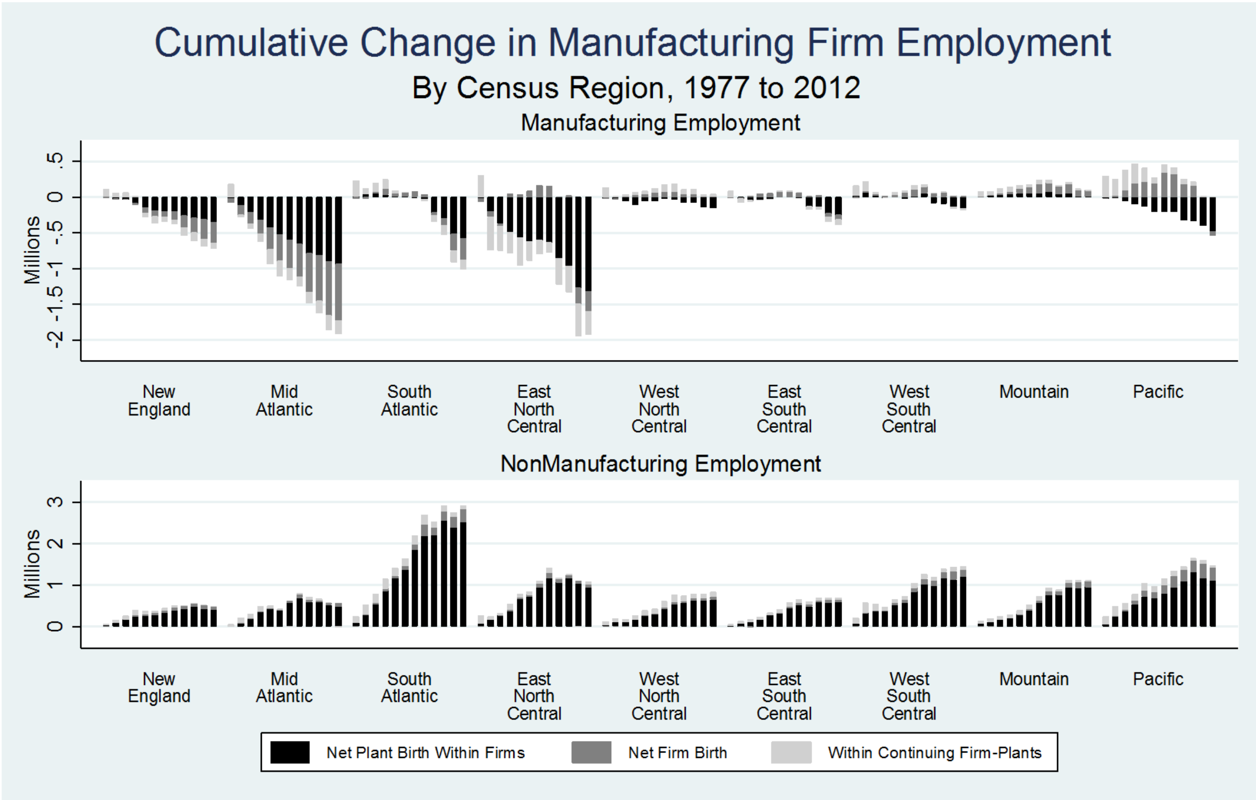
Manufacturing firms' non-manufacturing employment, displayed in the right panel of Figure 6, increases in all regions during the 1980s and 1990s, though it grows most sharply in the South Atlantic, Mountain, and Pacific regions. Together, these three regions account for more than half of the overall increase, at 27, 14 and 14 percent, respectively.

The movement of manufacturing employment within the United States from north and east to south and west likely reflects some of the same forces governing its movement of offshore. Cowie (2001) for example, documents a similar pattern in the continual re-location of RCA's most labor-intensive operations around the United States in their search for lower wages and more flexible labor laws. Holmes (1998) shows that manufacturing employment in more union-friendly states is relatively low compared to neighboring right-to-work states, which are concentrated in the South Atlantic, West

Central, and Mountain regions. More broadly, Bernard et al. (2013) find that wide variation in U.S. labor markets' relative skilled wages and skilled labor abundance is correlated with their industry mix, and that the overlap of industries in regions with low versus high skilled wages is pulling apart over time. Technology likely also plays a role, as advances in communications, transportation and other technologies (e.g., air conditioning) facilitate the ability of firms to take advantage of production in a wide range of areas, either to relocate or to fragment the production process and establish more elaborate domestic value chains. Fort (2017) shows that communication disproportionately facilitates domestic fragmentation over offshoring, and Atalay et al. (2017), find that shipments within U.S. firms are substantially less sensitive to distance than shipments across firms.

The data in Figure 6 beg the question of how much of the geographic reallocation of manufacturing employment occurs within firms. Toward that end, Figure 7 decomposes the cumulative changes in manufacturing (top panel) and non-manufacturing (bottom panel) employment reported above by net margin of adjustment. As in the left panel of Figure 2, all net margins in Figure 7 are computed with respect to the set of firms and plants already present in 1977.

Figure 7 displays three noteworthy trends. First, the regions hit hardest in terms of employment loss due to net plant closure are New England, Mid-Atlantic, East North Central and Pacific. Further research into the extent to which the *same firms* are closing plants in these locations while opening plants in others, and the firm, industry and region characteristics most closely associated with such movement, would provide useful insight into the boundaries of the firm and "domestic offshoring," in which firms shift production from high-wage to relatively low-wage regions within the United States. Second, comparison of the top and bottom panels of the figure shows that legacy manufacturing firms shedding manufacturing employment via plant closures in these four regions are simultaneously adding non-manufacturing employment via net plant openings in those regions. Here, too, further research into the potential spatial complementarities of these additional facilities might be fruitful. Finally, Figure 7 reveals that manufacturing employment losses due to net firm death are not evenly distributed across the United States. Indeed, they are heavily concentrated in the New England and Mid-Atlantic regions, which account for 17 and 46 percent of the overall drop in manufacturing employment along this margin. Those regions in which employment declines due to net firm death may experience more labor market disruption from their manufacturing employment decline, if their exit from manufacturing is not offset with entry into non-manufacturing.

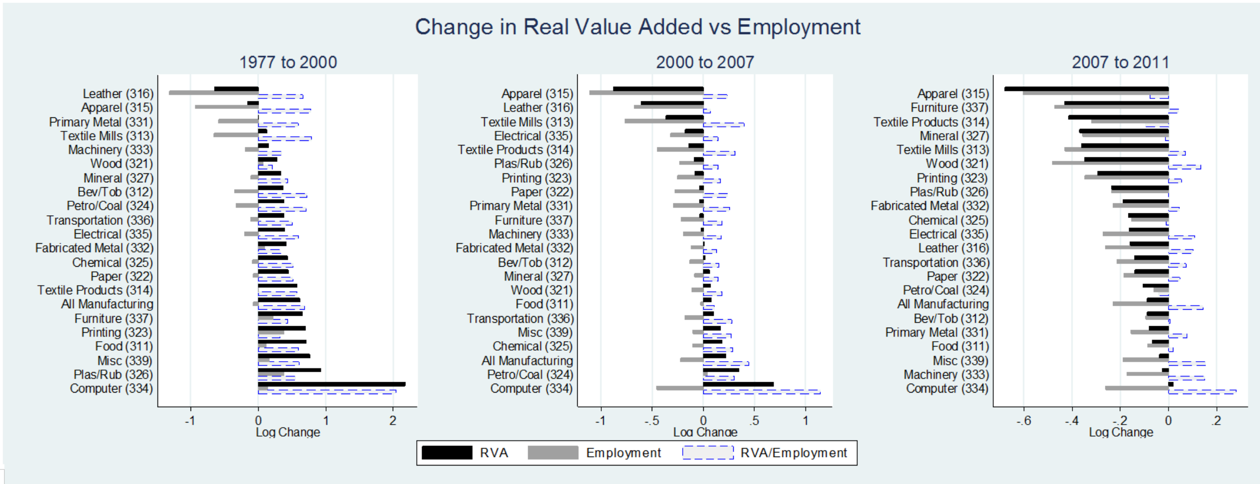


Source: Longitudinal Business Database and authors' calculations. Panels report cumulative change in manufacturing firms' manufacturing and non-manufacturing employment from 1977 to 2012 by net firm margin of adjustment and region. Bars report cumulative changes at three-year intervals, starting with 1979. Census regions are defined as follows. New Enlgand: CT, MN, MA, NH, RI, VT. Middle Atlantic: NJ, NY, PA. East North Central: IN, IL, MI, OH, WI. West North Central: IA, KS, MN, MO, NE, ND, SD. South Atlantic: DE, DC, FL, GA, MD, NC, SC VA, WV. East South Central: AL, KY, MS, TN. West South Central: AR, LA, OK, TX. Mountain: AZ, CO, ID, MT, UT, NV, WY. Pacific: AK, CA, HI, OR, WA.

Figure 7: Cumulative Change in U.S. Manufacturers' Employment by Census Region

3.3 Reallocation Across Industries

The rise in U.S. manufacturing value added and concomitant decline in U.S. manufacturing employment displayed in Figure 1 combine for a substantial increase in U.S. manufacturing labor productivity between 1977 and 2012. In this section we decompose these changes along industry lines. Simultaneous declines in value added and employment, for example, likely identify "sunset" sectors encompassing the production of goods no longer consistent with U.S. comparative advantage. Falling employment coupled with rising or steady value added, on the other hand, may indicate industries benefiting from labor-saving innovations or productivity improvements from increased fragmentation of production (domestically or internationally), or industries where the underlying product mix is changing towards less labor-intensive goods.



Source: Publicly available NBER-CES Manufacturing Industry Database and authors'calculations. Value added is deflated using shipment price deflators contained in the database. Industries are sorted by real value added (RVA) growth. "All manufacturing" is a weighed average across three digit NAICS codes.

Figure 8: Manufacturing Employment vs Real Value Added, 1977 to 2011

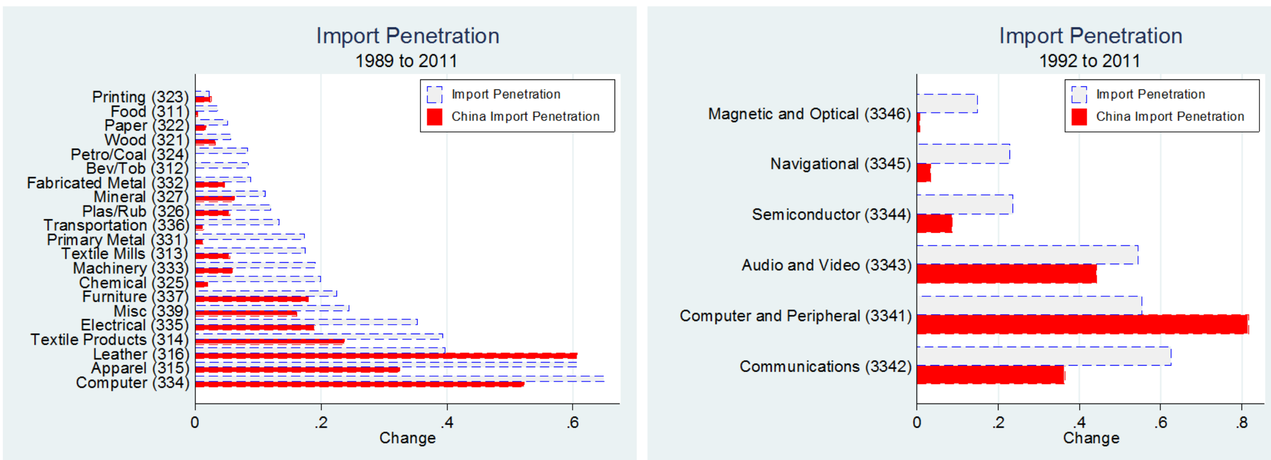
We investigate such co-movements in Figure 8 using publicly available data from the NBER-CES Manufacturing Industry Database, which extends to 2011. This figure compares log changes in real value added produced in US manufacturing establishments, to those plants' employment, and real value added per worker across relatively broad, three-digit NAICS manufacturing sectors, as well as for the manufacturing sector as a whole. We report changes for three periods, the last two of which isolate the two stark declines in employment after 2000: 1977 to 2000, 2000 to 2007, and 2007 to 2011.[3]

The best candidates for sunset industries are Leather (NAICS 316) and Apparel (NAICS 315), which exhibit declines in both value added and employment across all three time periods. These sectors are canonical labor-intensive sectors that are among the first adopted by industrializing developing economies. Apparel, in particular, has also been subject to substantial trade liberalization in the United States during the period we study (Khandelwal et al. (2013)). Combined, these two sectors account for a decrease in employment of -1.5 million workers between 1977 and 2011, or about a fifth of the overall decline in manufacturing employment during that period. It is notable that the surviving subsets of these industries exhibit labor productivity growth about equal to manufacturing as a whole.

The best example of a sunrise industry, by contrast, is Computers and Electronics (NAICS 334). It experiences increases in real value added across all three time periods, even the Great Recession. Indeed, it increases nearly 1700 percent between 1977 and 2011, and accounts for the bulk – 70 percent – of the increase in total manufacturing real value added over this interval. This increase is concentrated in Semiconductors (NAICS 334413) and Electronic Computers (NAICS 334111), whose real value added

[3]The NBER-CES Manufacturing Industry Database contains data through 2011. The employment totals in this database also do not match perfectly with those reported above, but they are highly correlated them. Real value added is computed using the deflators for shipments contained in the database.

grows from 0.5 to 680 billion dollars, and 0.2 to 90 billion dollars, respectively, between 1977 and 2011. Analysis at even these three-digit NAICS industries masks substantial variation in changes in employment and real value added. At the six-digit NAICS-level, 192 industries (41 percent of manufacturing industries) experience reductions in both real value added and employment from 1977 to 2011, including seven of the 29 industries within NAICS 334.



Source: Publicly available NBER-CES Manufacturing Industry Database and authors' calculations. Import penetration is imports divided by the sum of domestic shipments plus imports less exports. All values are deflated by the six-digit NAICS shipment deflators contained in the database before aggregating to the three-digit NAICS level. Sectors are sorted by import penetration.

Figure 9: Change in U.S. Import Penetration, 1977 to 2011

Given the significant focus in the literature on using variation in industry import penetration, and Chinese import penetration in particular, we present similar figures for import penetration. The left panel of Figure 9 uses publicly available trade data starting in 1989 from Schott (2008) to report the 1989 to 2011 change in overall U.S. import penetration (imports divided by the sum of domestic shipments and imports, less exports), and import penetration from China by the same three-digit NAICS industries displayed above.

Unsurprisingly, apparel and leather exhibit substantial increases in both measures. More surprising are the large increases in the two measures for Computer and Electronic Product Manufacturing (NAICS 334). The right panel of Figure 9 reports a breakdown of that sector by four-digit NAICS codes. As indicated in the figure, the increase in penetration for Semiconductors (NAICS 3344) appears to be fairly small, while that for Computers and Peripherals (NAICS 3341), the next most important contributor to U.S. value added growth, is more substantial, especially with respect to import penetration from China. This divergence suggests that industry-level measures of import penetration likely reflect both increased foreign competition as well as foreign sourcing decisions of U.S. firms. The "productivity boost" from sourcing inputs overseas may have allowed some firms in the sector to grow significantly, while still exerting increased competitive pressure on non-importers.[4] For example, Antras et al.

[4]Although import penetration by semiconductor manufacturers appears relatively low, this was one of the first sectors in which factory-less goods producers (FGPs) appeared, as documented in

(2017) show that offshoring can lead to a productivity effect in which lower input costs induce expansion as well as a substitution effect in which the use of overseas labor decreases domestic employment. They estimate that in 2007 the former dominates for U.S. manufacturers, thus predicting that importers will expand their domestic sourcing, even as the they substitute some domestic inputs with foreign imports. We explore this possibility more specifically in the next section.

4 Adoption of Technology and Trade Practices

In this section we examine U.S. manufacturing firms' adoption of several specific technological innovations and trade practices for further insight into the margins of adjustment described above. This analysis exploits proprietary quinquennial data from the U.S. Census Bureau's Census of Manufactures (CM) from from 1977 to 2012, and annual data from the Longitudinal Linked Trade Transactions Database (LFTTD) assembled by Bernard et al. (2009).[5]

Technology Variables: We examine the use of three specific technologies observable in the CM. We identify computer usage from a question that asks establishments about their total expenditures on "computers and peripheral data processing equipment" which is available in every economic census year starting in 1977, except for 1997. At the establishment level, we construct an indicator variable equal to one if the establishment purchases computers in a given census year. We define an analogous indicator variable at the firm level that equals one if any establishment within the firm purchases computers in a given census year. Computer purchases are rare prior to 2000 but commonplace afterwards, with over 80 percent of firms that exist from 2002 forward purchasing computers in at least one census year. After 2000, 40 percent of firms purchase computers in every census year in which they exist, 23 percent purchase once but not all of their years in existence, and 18 percent purchase twice but not all years in existence.

Our second technology variable, available in census years starting in 2002 and inspired by Fort (2017), tracks whether a firm makes use of an electronic network to control or coordinate shipments that year. Our final technology variable, motivated by Acemoglu and Restrepo (2017), captures adoption of industrial robots, where this adoption is inferred for census year t by the firm's importing of HS code 84.7950.0000 from Germany or Japan, two of the three main producers of industrial robots, prior to that year. Unfortunately, we do not observe firms' purchases of industrial robots from the United States, the other major producer.

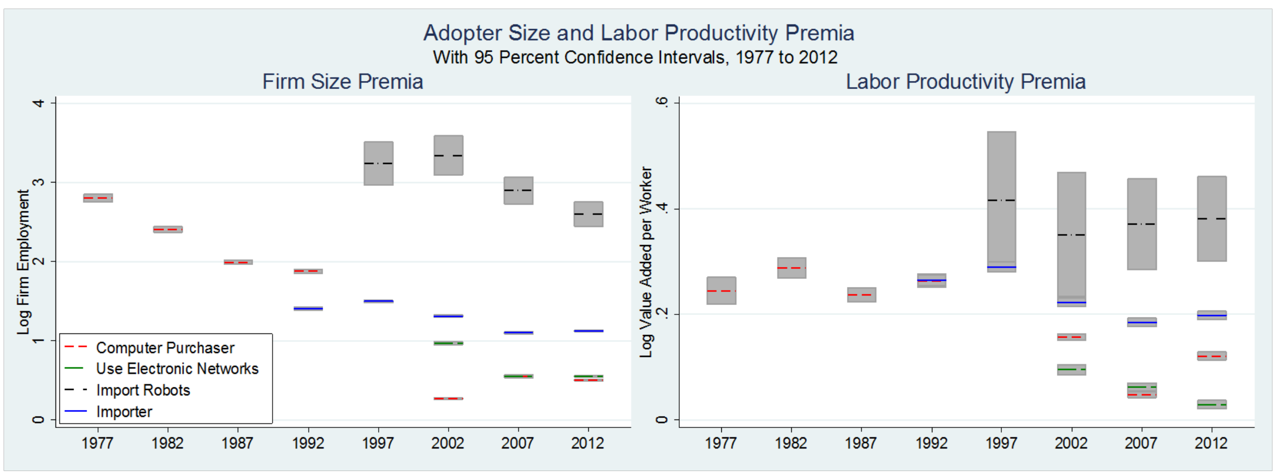
Bayard et al. (2015). An interesting question for future work is the extent to which US manufacturers in that sector continue to design and market their products while moving the majority of the physical transformation activities overseas.

[5]The CM only includes plants that are classified under manufacturing in the year the data is collected, so establishments that are classified as manufacturing under NAICS, but were outside of manufacturing under SIC are necessarily excluded from the analyses in this section. A firm's industry in a given year is the six-digit NAICS code in which it has the largest employment across its establishments.

Trade Variables: We define two indicator variables to characterize a firm's trade practices. The first merely indicates whether the firm imports. The second tracks whether it imports from China.

4.1 Adopters are Different

We begin by comparing the attributes of firms that adopt the technology practices noted above to the well-known size and productivity premia observed among trading firms (Bernard et al. (2007)). The left panel of Figure 10 plots the estimated coefficient and 95 percent confidence intervals derived from separate regressions in each census year of the log of manufacturing firms' manufacturing employment on the indicator variables defined above. As is common in estimating these premia, all regressions include industry fixed effects. The right panel performs an analogous exercise with respect to firms' labor productivity (value added per worker). Note that there is a break in the computer premia in 1997 due to data unavailability.



Source: Census of Manufactures and Longitudinal Trade Transactions Database and authors' calculations. Figure reports the results of firm-level regressions of noted firm characteristics on a dummy variable for noted activities. A separate regression is run for each Census year and activity. The gray bars in the figure display the 95 percent confidence intervals for the average difference between adopters and non-adopters of the noted activity in each year. Data for computer purchases is unavailable in 1997. Data for importing, importing robots, and use of electronic networks is not available before 1992, 1997 and 2002, respectively. In the left panel, confidence intervals for computer purchase and use of electronic networks overlap in 2007 and 2012. In the right panel, confidence intervals for importing and importing robots overlap in 1997 and 2002.

Figure 10: Size and Productivity Premia of Technology and Trade Adopters

The most striking feature of this figure is the decline in the technology premia over time. As expected, importers are larger and more productive than non-importers in every year. Computer purchasers also exhibit large premia in the 1970s and 1980s, but these premia decline substantially in the 2000s. This drop may reflect a reduction in the price of computers as PCs replace mainframes, or the added benefits of their use as electronic communication and computer-aided design and manufacturing (CAD/CAM) were developed. Brynjolfsson and Hitt (1998), for example, estimate that the quality-adjusted prices of computers decline by about 25 percent per year. Industrial robot use exhibits the largest premia, with mixed evidence regarding a decline over the short interval they are observed. Use of electronic networks exhibit the smallest premia; they too appear to be declining.

To assess whether these premia represent fixed firm attributes, or whether firm attributes are relatively higher in years of adoption, Table 1 reports the results of a series of firm-level panel regressions of firm characteristics on our trade and technology indicators. All regressions include year and firm fixed effects. Separate estimations are performed across census years before (top panel) and after (bottom panel) 2000.

	Census Years Before 2000					
Activity	Manufacturing Employment	Total Employment	Value Added	Value Added per Worker	Skll Intensity	Labor Share
Computer Purchaser	0.208***	0.178***	0.242***	0.034***	-0.002	-0.012
	(0.006)	(0.005)	(0.007)	(0.005)	(0.001)	(0.023)
Importer	0.145***	0.152***	0.170***	0.025***	0.001	0.005
	(0.007)	(0.007)	(0.009)	(0.007)	(0.002)	(0.031)
	Census Years After 2000					
Activity	Manufacturing Employment	Total Employment	Value Added	Value Added per Worker	Skll Intensity	Labor Share
Computer Purchaser	0.072***	0.062***	0.113***	0.042***	-0.002***	-0.045**
	(0.002)	(0.002)	(0.003)	(0.003)	(0.001)	(0.022)
Importer	0.151***	0.138***	0.173***	0.023***	-0.005***	-0.103***
	(0.003)	(0.003)	(0.004)	(0.004)	(0.001)	(0.038)
Use Electronic Networks	0.108***	0.063***	0.095***	-0.012***	0.005***	0.011
	(0.003)	(0.003)	(0.004)	(0.003)	(0.001)	(0.022)
Import Industrial Robots	0.081**	0.098***	0.07	-0.011	-0.01	-0.015
	(0.039)	(0.033)	(0.048)	(0.036)	(0.007)	(0.024)

Source: CM, LBD, LFTTD and authors' calculations. Table reports the results of a series of panel regressions of noted firm attributes, e.g., employment, on indicator varirables for the noted firm actions, e.g., computer purshases. Each cell contains the coefficient and standard error for the indicator variable. All regressions include year and firm fixed effects. Top and bottom panels restricted to census years before and after 2000, respectively. Data on computer purchases is not available in the 1997 census. Data on use of electronic networks and industrial robots is available starting in the 2002 and 1997 cenus years, respectively. *, ** and *** signify statistical significance at the 10, 5 and 1 percent level.

Table 1: Firm Attributes and Technology or Trade Adoption

As indicated in the table, we find positive relationships between adoption and the two activities – computer purchases and importing – that can be observed in both periods, though coefficients for computer usage are lower after 2000 versus before. These results confirm not only that adopters are larger and more productive than non-adopters, but also that a particular firm changes so that its employment, real value added, and productivity are all larger in adoption years relative to non-adoption years. These results suggest one potential mechanism behind the increase in U.S. manufacturing firms' labor productivity displayed in Figures 1 and 8. They also offer insight into the employment loss documented in those figures. That is, a subset of firms that import within an industry may experience growing employment even as, at the industry level, import competition drives many of their competitors from the market. To account for this potential divergence, we also examine the relationship between firm outcomes and industry import penetration below.

4.2 Adoption and Survival

The decompositions in Section 3 reveal that the net closing of establishments by continuing firms plays a dominant role in the decline of U.S. manufacturing employment. Here, we gauge whether trade or technology adoption are related to plant and firm exit using a series of panel regression whose results are summarized in Table 2. Each cell in the table reports the results of a separate panel regression of an indicator for manufacturing firm or manufacturing establishment death between census years t and $t+5$ on either an indicator for a given activity or, for comparison, the change in industry import penetration.

	Census Years Before 2000		Census Years After 2000	
	$Death_{ft:t+5}$	$Death_{pt:t+5}$	$Death_{ft:t+5}$	$Death_{pt:t+5}$
Computer Purchaser	0.060***	-0.057***	-0.019***	0.000
	(0.003)	(0.003)	(0.002)	(0.003)
Importer	0.043***	.	0.002	.
	(0.003)		(0.002)	
China Importer	0.070***	.	0.031***	.
	(0.005)		(0.003)	
Use Electronic Networks	.	.	-0.027***	-0.039***
			(0.002)	(0.003)
Import Robots	.	.	0.097***	.
			(0.027)	
ΔIndustry Import Penetration	0.003	0.251***	0.034	0.06
	(0.060)	(0.059)	(0.048)	(0.046)
Δindustry China Import Penetration	-0.036	0.721***	0.204***	0.091
	(0.126)	(0.121)	(0.057)	(0.084)

Source: CM, LBD, LFTTD and authors' calculations. Each cell reports the results of a different firm- or plant-level regression of an indicator for manufacturing firm (f) or manufacturing establishment (p) death between census years t and t+5 on the noted activity or industry (j) attribute. First and third columns relate firm death to firm activities and include firm employment and industry and census year fixed effects as additional covariates whose estimates are not reported. For those results, the noted activities are *firm-level*. Second and fourth columns relate plant death within firms to plant activities. These regressions are restricted to manufacturing firms with multiple plants and include firm and year fixed effects as well as a control for plant employment as additional covariates whose estimates are not reported. For those results, the noted activities are *plant-level*. First and second two columns examine census years before and after 2000, respectively. Data on computer purchases are not available in the 1997 census. Data on use of electronic networks and industrial robots are available starting in the 2002 and 1997 cenus years, respectively. *, ** and *** signify statistical significance at the 10, 5 and 1 percent level.

Table 2: Death and Technology or Trade Adoption

The first and third columns relate firm death to firm activities and include firm employment, industry, and census year fixed effects as well as additional covariates whose estimates are suppressed. In particular, the regressions include controls for firm size, which is highly correlated with the adoption activities we examine. The first column reveals that firms that purchase computers, firms that import, and firms that import from China are relatively *more* likely to die in census years prior to 2000. By comparison, the regressions summarized in the final two rows of the first column indicate that there is no relationship between firm exit and the growth of either overall import penetration or of import penetration from China. After 2000 (column three), firms purchasing computers or using electronic networks are more likely to survive, while those importing from China or importing robots are more likely to exit.

These results are intriguing in that they suggest the relationship between a given technology and survival can vary over time. One possibility is that successful adoption requires accompanying organizational change, and early adopters must figure out precisely what that change should be. For example, Brynjolfsson and Hitt (1998) emphasize that "[c]hanging incrementally, either by making computer investments without organizational change, or only partially implementing some organizational changes, can create significant productivity losses" (p. 25). Computerization may thus be initially disruptive, with benefits that rise after learning or network effects associated with wider usage. The results in Table 2 also highlight an important challenge associated with estimations of the impact of "technology" on firm outcomes, as different technologies may have different effects. Here, we find that computer purchases and use of electronic networks are associated with lower exit probabilities in the 2000s, while imports of industrial robots are associated with higher exit probabilities.

Results reported in the second and fourth columns of Table 2 examine plant death among establishments within firms. These estimations are restricted to computer purchases and use of electronic networks as the other variables cannot be computed at the establishment level. In both cases, regressions are restricted to manufacturing firms with multiple plants and include firm fixed effects as well as a control for plant employment. For comparison, we report analogous regressions with respect to changes in import penetration and import penetration from China in plants' initial industries.

As indicated in the table, we find that plants within firms that purchase computers are 5.7 percentage points less likely to exit in the pre-2000s than plants in the same firm that do not purchase computers. After 2000, plants' purchases of computers are no longer related to survival within the firm, but plants that use electronic networks are 3.9 percent less likely to exit than plants in the same firm that do not use these networks. These results are consistent with the premise that firms upgrade technology at some plants, while shuttering those that become outmoded.

Comparison of these estimates with the regressions summarized in the final two rows of the table reveal that changes in import penetration, while strong predictors of plant exit within firms before 2000, are no longer associated with death after 2000. One potential explanation for this result is that the plants that were most susceptible to either form of import competition had already exited prior to the 2000s, or that they switched their industry. Bernard et al. (2006b) for example, find evidence of such switching in their analysis of U.S. manufacturing establishments' responses to reductions in import tariffs during the 1990s. Magyari (2017) also studies manufacturing and non-manufacturing employment at U.S. manufacturing firms and finds that they reallocate activity towards industries less exposed to import competition from China. An interesting question for future work is the extent to which this switching might be related to firms' increasing reliance on non-manufacturing establishments evident in Figure 5.

4.3 Outcomes after Adoption

We now examine how adoption, as well changes in industry-level import penetration, relate to subsequent firm outcomes.

	Panel A: Census Years Before 2000					
Activity	Manufacturing Employment	Total Employment	Value Added	Value Added per Worker	Skll Intensity	Labor Share
Computer Purchaser	-0.061***	-0.035***	-0.038***	0.023***	-0.004***	-0.005
	(0.005)	(0.004)	(0.006)	(0.005)	(0.001)	(0.073)
Importer	-0.039***	-0.024**	0.007	0.046***	0.001	0.072
	(0.011)	(0.010)	(0.018)	(0.012)	(0.002)	(0.062)
ΔIndustry Import Penetration	-0.21	-0.123	0.264	0.474**	0.011	0.381
	(0.208)	(0.192)	(0.357)	(0.214)	(0.022)	(0.482)
China Importer	-0.169***	-0.130***	-0.097***	0.071***	0.012***	-0.063
	(0.019)	(0.015)	(0.026)	(0.018)	(0.004)	(0.062)
ΔIndustry China Import Penetration	-0.145	-0.008	-0.239	-0.094	-0.019	0.048
	(0.261)	(0.238)	(0.413)	(0.273)	(0.049)	(0.366)
	Panel B: Census Years After 2000					
Activity	Manufacturing Employment	Total Employment	Value Added	Value Added per Worker	Skll Intensity	Labor Share
Computer Purchaser	0.023***	0.019***	0.007	-0.017***	0.001	0.075***
	(0.006)	(0.005)	(0.006)	(0.004)	(0.001)	(0.022)
Importer	0.023*	0.023**	0.063***	0.040***	-0.003	0.047
	(0.012)	(0.010)	(0.013)	(0.006)	(0.002)	(0.045)
ΔIndustry Import Penetration	-0.340**	-0.207*	-0.418**	-0.079	0.037*	0.384
	(0.141)	(0.111)	(0.194)	(0.118)	(0.022)	(0.255)
Computer Purchaser	0.026***	0.021***	0.012**	-0.014***	0.001	0.073***
	(0.006)	(0.005)	(0.005)	(0.004)	(0.001)	(0.021)
China Importer	-0.026**	-0.018*	0.015	0.041***	0.001	0.131
	(0.011)	(0.010)	(0.012)	(0.007)	(0.002)	(0.109)
ΔIndustry China Import Penetration	-0.735***	-0.515***	-0.337	0.398***	0.052	0.167
	(0.166)	(0.129)	(0.209)	(0.103)	(0.033)	(0.338)
Use Electronic Networks	0.009**	0.018***	0.030***	0.022***	-0.008***	0.056
	(0.003)	(0.003)	(0.005)	(0.004)	(0.001)	(0.038)
Import Industrial Robots	-0.069*	-0.012	0.105**	0.174***	-0.008	-0.142
	(0.038)	(0.033)	(0.050)	(0.045)	(0.012)	(0.416)

Source: CM, LBD, LFTTD and authors' calculations. Table reports the results of a series of firm-level panel regressions of census year t to t+5 changes in noted firm attributes on adoption and, in some cases, industry import penetration. Each set of coefficients between horizontal lines within a column represent the results from a different regression. All regressions include year fixed effects. Top and bottom panels restricted to census years before and after 2000, respectively. Data on computer purchases are not available in the 1997 census. Data on use of electronic networks and industrial robots are available starting in the 2002 and 1997 cenus years, respectively. *, ** and *** signify statistical significance at the 10, 5 and 1 percent level.

Table 3: Technology and Trade Adoption and Subsequent Outcomes

Table 3 reports the results of a series panel regressions of changes in firm attributes from year t to $t+5$ on adoption in year t, as well as controls for contemporaneous changes in industry import penetration, either overall or with respect to China. As above, the top and bottom panels display results for census years before and after 2000. In the pre-2000 period, we analyze computer purchasing and importing separately because they are available for different sets of years. We estimate them jointly with changes in industry import penetration for census years after 2000.

Before 2000, we find that computer purchasers exhibit declines in real value added and employment relative to non-purchasers, though more so for the latter. As a result, computer purchases are associated with increases in labor productivity. Results for being an importer or an importer from China are similar. For all adoption variables, the estimated coefficient on total firm employment is smaller than the coefficient for manufacturing employment, indicating that employment adjustment to adoption occurs disproportionately among manufacturing establishments. A question for future work is whether firms' non-manufacturing establishments are less susceptible to technological change, or if they also adopt other technologies that affect them similarly.

After 2000, the patterns for computer purchasers and being an importer change substantially.[6] That is, we find that computer purchases and importing are now associated with rising employment and real value added. Importing from China, is associated with statistically insignificant increases in the 2000s, whereas the relationship was negative and significant before the 2000s. Firms that import from China continue to see relative declines in their manufacturing employment, though of much lower magnitudes than in the pre-2000s period.

Results for contemporaneous changes in either overall or Chinese import penetration at the *industry* level indicate consistently negative relationships with employment and value added both before and after 2000, though the coefficients are statistically significant at conventional levels only in the latter period. In terms of labor productivity, overall import penetration has a positive but insignificant relationship prior to 2000, and a negative but insignificant association after 2000. Increases in Chinese import penetration, are associated with statistically significant declines in manufacturing employment and increases in labor productivity in the 2000s, while these relationships are statistically insignificant before the 2000s.

An important and consistent message from Table 3 is that firms that import (from anywhere or from China) always have higher labor productivity growth relative to non-importers. This result suggests that U.S. manufacturers' foreign sourcing decisions may play an important role in explaining the divergence between manufacturing employment and real value added noted in Figures 1 and 8. Perhaps more importantly, Panel B shows that importers may increase their manufacturing employment relatively more than non-importers, even while increased industry import penetration is associated with a relative decline in employment. This distinction between foreign import competition versus foreign sourcing opportunities highlights the possibility that imposition of import protection may have the unintended consequence of stifling growth.

The final two rows of Table 3 show that firms using electronic networks subsequently exhibit growth in employment, real value added, productivity, and skill intensity relatively more than non-electronic network users. In contrast, firms that import industrial robots are associated with almost 7 percent lower employment growth, though both their real value added and labor productivity grow relatively faster than non-robot importers. These results provide further support for the message from Table 2 that the effects of technology differ across both periods and technology type, and that technology may be initially disruptive.

5 Conclusion

This journal has published several papers exploring trends in U.S. manufacturing in the last decade, including, most recently, Charles et al. (2016), Baily and Bosworth

[6] The estimated coefficients are generally similar whether computer purchases are in a separate regression, or included in the same specification with import measures. For example, in a regression of real value added on computer purchases in post 2000 years, the estimated coefficient and standard error are 0.013 and (0.004).

(2014) and Houseman et al. (2011)). These papers explore a number of issues related to the divergence of employment and real value added, the transition of displaced manufacturing workers to other sectors, and the possibility that accurate assessment of U.S. manufacturers' performance may be clouded by measurement issues. Their popularity highlights the importance of this sector to the overall U.S. economy.

Here, we use microdata from the U.S. Census Bureau to provide a detailed description of how U.S. manufacturing employment declined along firm, geographic and industry margins of adjustment, and to explore how firms' adoptions of various technologies and trade practices might help explain these trends. Our analysis yields a number of facts, including:

- Seventy-five percent of the -6.6 million decline in manufacturing employment between 1977 and 2012 takes place within continuing firms, largely through plant closures.

- Before 2000, the drop in manufacturing firms' manufacturing employment is more than offset by increases in non-manufacturing workers; this addition occurs predominantly via non-manufacturing establishment births within continuing firms.

- After 2000, a sharp decline in those firms' manufacturing employment and a flattening of their non-manufacturing employment leads to a decrease in their total employment.

- Relatively high-skill professional workers – e.g., designers and engineers – account for approximately a third of the non-manufacturing workers added by manufacturing firms.

- Prior to 2000, the United States experienced a substantial shift in manufacturing employment, with declines in the north and east partially offset by growth in the south and west

- Manufacturing firms that adopt specific technologies, such as computers or industrial robots, are significantly different from those that don't: as with trading firms, they are larger and more productive upon adoption. Plants within manufacturing firms that adopt such technologies appear more likely to survive suggesting a potential explanation for the importance of the continuing firm margin in overall employment loss.

- Importing is associated with different outcomes at the firm and industry levels: firms that import subsequently exhibit increases in employment and output, while increased import penetration in a firm's industry is associated with decreased employment and output.

Our hope is that these facts will motivate additional research into the evolution of U.S. manufacturing and the boundary of the manufacturing firms.

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