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

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Abstract

We use relatively unexplored dimensions of US microdata to examine how US manufacturing employment has evolved across industries, firms, establishments, and regions from 1977 to 2012. We show that these data provide support for both trade- and technology-based explanations of the overall decline of employment over this period, while also highlighting the difficulties of estimating an overall contribution for each mechanism. Toward that end, we discuss how further analysis of these trends might yield sharper insights.

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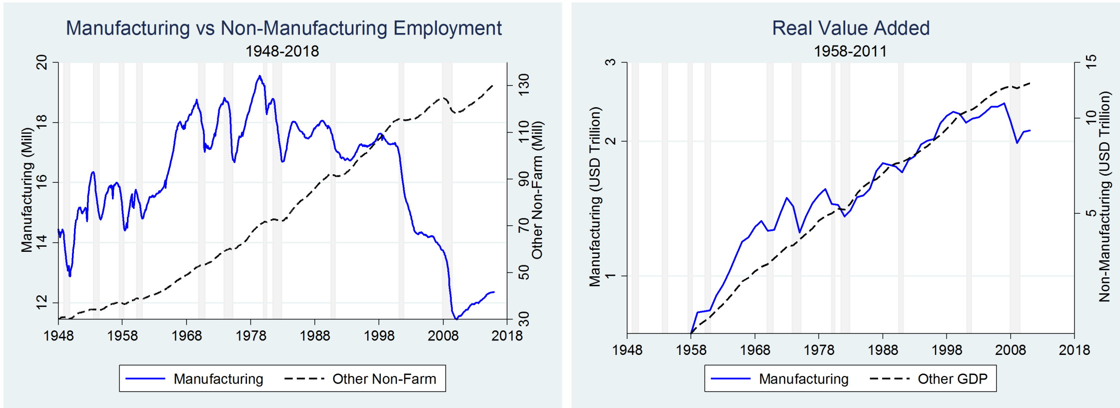
1 Introduction

US manufacturing since World War II exhibits three notable trends, illustrated in the two panels of Figure 1. First, the manufacturing employment has diverged from non-manufacturing employment, as shown on different axes in Figure 1A. While both series move upward until the late 1970s, manufacturing employment then begins to decline, even as other non-farm employment continues a steady rise. As a result, there is a continual decline in manufacturing employment's share of total US non-farm employment, from 32 percent in 1948 to 8 percent in 2017. Second, while US manufacturing employment fell just 12 percent over the 21 years between the post-war peak in 1979 and 2000, it then dropped by more than twice as much – 25 percent – from 2000 to 2012. Third, despite the relative flatness and subsequent sharp decline in US manufacturing employment, the right-hand panel of Figure 1 shows a steady rise in manufacturing real value added at more or less the same rate as non-manufacturing GDP over the same period, at least between the late 1970s and the Great Recession. The combination of relatively steady and then declining employment, and rising output, indicates that, over the long term, labor productivity has risen faster in the manufacturing sector than in the broader economy.

For a variety of reasons, including the perception that workers in manufacturing receive comparatively high wages conditional on education (Langdon and Lehrman (2012); Ebenstein et al. (2014)), these trends have stirred intense discussion among both policy makers and academics. This debate can broadly be summarized as a dispute between views that emphasize the relative importance of trade versus technology. The trade-based explanation contends that import competition has reduced US manufacturing employment by inducing labor-intensive, low-labor-productivity industries to move abroad. The technology view argues that the decline in manufacturing employment stems from innovations in production techniques, such as automation, that have dramatically increased output per worker. If, as implied by Figure 1, consumers spend a constant share of their expenditure on manufactured goods, then an increase in labor productivity means fewer workers are needed to meet demand for those goods.

Discussions about the decline in US manufacturing employment often culminate in a request to decompose the decrease into the part that is due to trade and the part that is due to technology. Our view is that providing a definitive accounting of the amount of employment change attributable to either factor is extraordinarily difficult for two reasons. First, identifying the numerous changes in tariff and non-tariff barriers that have occurred over the last few decades, let alone the wide range of technologies that have been adopted, is a daunting task.[1] More importantly, even if one could

[1] For example, even while *ad valorem* tariff rates have trended downward over time, and regional trade agreements have proliferated, implementation and repeal of contingent protection measures like antidumping and countervailing duties remains frequent and widespread (Bown (2016)). These temporary barriers have been linked to relative declines in physical productivity and increased prices among protected manufacturing plants (Pierce (2011)). Identification of the numerous technological innovations introduced during this period, including computerization, electronic communication, computer-aided design and manufacturing, just-in-time inventory management, and enterprise resource planning, is similarly difficult.



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, both in 2009 dollars. Gray bars indicate duration of recessions as determined by the NBER Business Cycle Dating Committee. Axes of right panel are in logs.

Figure 1: U.S. Manufacturing Employment and Real Value Added

identify all of these changes, it is difficult to see how their intertwined impacts on employment could be teased apart. As an example, consider an anecdote from a recent Wall Street Journal article (reported in Michaels (2017)), which takes place around the time of an important US trade liberalization with China discussed below: "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 investing 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." Are changes in Marlin's employment and output driven by the availability of robots or increased Chinese competition? What about employment and output at other producers of steel wire products, who face increased competition from both China and from Marlin? These questions are even more difficult to answer if robots' availability itself is influenced by trade liberalization, for example, by robot manufacturers' ability to source intermediate inputs from China.

In this paper, we provide a brief overview of recent efforts to answer such questions before turning to relatively unexplored dimensions of US microdata for further input. These data allow us to examine changes in US manufacturing employment across industries, firms, and regions, and thereby offer four new perspectives on how US manufacturing has evolved over the last several decades. We find that while employment changes along these dimensions provide support for both trade- and technology-based explanations, they also highlight the difficulties of cleanly separating one force from the other. Toward that end, we discuss how further analysis of the data we use might yield sharper insights.

Our first perspective examines how the overall growth of US manufacturing employment and value added varies by sector. We find that some sectors – such as transportation equipment – exhibit increases in output even as employment is falling, a potentially clear indication of technology adoption. On the other hand, it is not hard to find examples of sectors, such as apparel, characterized by simultaneous increases in import penetration and reductions in both employment and output. Furthermore, the set of sectors experiencing declines in both employment and output increases after 2000.

Our second perspective analyzes employment loss along firm and establishment margins of adjustment. One of our more striking findings – given conventional expectations about how creative destruction due to trade and technology likely manifest – is that net firm death accounts for just 25 percent of the overall decline in US manufacturing employment between 1977 and 2012. On the other hand, we find a large role for net plant exit within incumbent firms, perhaps because adopting new technologies or adapting to import competition entails high fixed costs that continuing firms are better able to absorb, and which are easier to implement by opening new plants.

Our third perspective breaks down the aggregate change in US manufacturing employment between 1977 and 2012 along regional margins of adjustment. We find a steady reallocation of manufacturing employment away from the north and east towards the south and west until 2000, when employment starts falling in all regions. The earlier transition may reflect "domestic offshoring," that is, a movement from higher- to lower-wage US regions in an era before foreign offshoring was cost-effective.

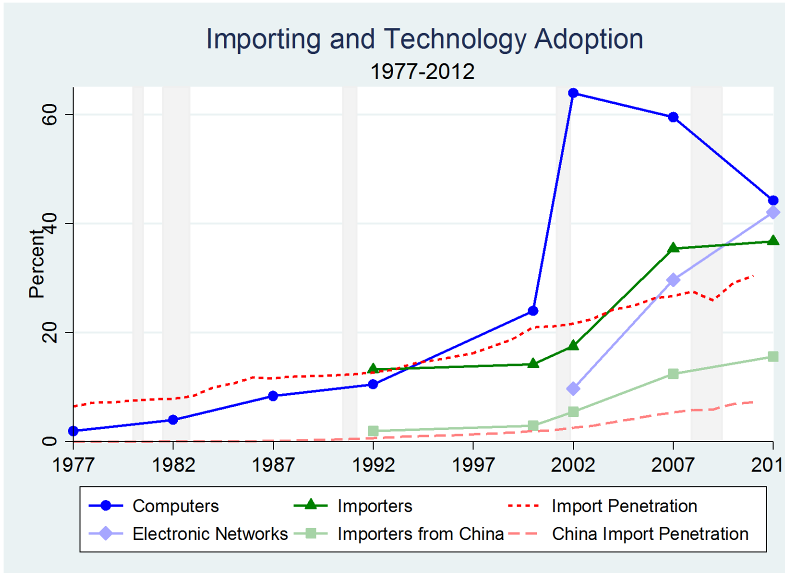
Our final perspective takes a wider view of manufacturing firms by examining their non-manufacturing activities. We find that manufacturing firms' non-manufacturing employment increases until 2000 – primarily via the addition of new non-manufacturing establishments – before leveling off. About a third of this growth is in professional services, a trend that may represent an evolution of US manufacturing firms into "neurofacturers" that increasingly provide intellectual services rather than physical goods (Leamer (2009)). Prominent examples include Pitney Bowes, which has abandoned the production of postage meters to offer logistics services, IBM, which increasingly offers data solutions rather than mainframes, and Apple, which designs the iPhone in the US but uses offshore contractors for assembly .

2 Some of the Evidence Thus Far

The last three decades have witnessed dramatic changes in both trade and technology. We provide a sense of some of these changes in Figure 2, which plots U.S. manufacturing firms' use of two specific forms of technology – computers and electronic networks – at five-year intervals from 1977 to 2012. As indicated in the figure, the share of firms purchasing computers in the noted years increases through the 1990s, with a large jump in the early 2000s. Data tracking use of electronic networks to control or coordinate shipments are available starting in 2002, and exhibit an analogous increase in adoption during the 2000s.[2]

Figure 2 also reports several dimensions of trade activity. First, starting in 1992, we report the share of manufacturing firms that imports from any country as well as

[2]As discussed in Fort (2017), plants' use of electronic networks to control or coordinate shipments involves not just using the internet or other networks, but also integrating electronic communication in the production process. Computer purchase data are not available in 1997, so we supplement the Census of Manufactures data with information from the 2000 Annual Survey of Manufactures.



Source: Data are from the Census of Manufactures, the Annual Survey of Manufactures, the Longitudinal Firm Trade Transactions Database, the NBER-CES Manufacturing Industry Database (Becker et al. 2013), Feenstra (1996) and Schott (2008). "Computers" and "Electronic Networks" are the percent of US manufacturing plants purchasing computers or using electronic networks to control or coordinate shipments. "Importers" and "Importers from China" are the percent of US manufacturing firms importing from any country or importing from China. "Import penetration" is manufacturing imports divided by the sum of domestic manufacturing shipments plus manufacturing imports less manufacturing exports [M/(S+M-X)], all in real terms. "Import penetration from China" is defined analogously but restricts the numerator to imports from China. Gray bars indicate duration of recessions as determined by the NBER Business Cycle Dating Committee.

Figure 2: Technology and Trade Trends

the share that imports from China, by census year. Here, as with our indicators of technology use, we see increases in the early 2000s. Second, we display annual measures of import penetration and import penetration from China. These series are defined as manufacturing imports (or manufacturing imports from China) divided by the sum of domestic manufacturing shipments plus manufacturing imports less manufacturing exports, all in real terms. Import penetration from all sources is rising over time, with a pronounced upward shift after the 1981 recession and relatively rapid growth during the 1990s. Chinese import penetration rises relatively slowly in the 1990s before picking up in the 2000s.[3] A key message of Figure 2 is that both technology adoption and importing, including by US producers, generally rise over the sample period, sometimes simultaneously.

Researchers have adopted several approaches to identify effects of trade "shocks" on employment. Perhaps the narrowest definition of a trade shock is a change in trade policy, such as a reduction in import tariffs, that leads to increased trade flows. Broader definitions include the impact of other factors, such as transport or communication

[3] Appendix Figure A.1 displays the levels of overall U.S. imports, exports, manufacturing value added, and manufacturing absorption (value added plus imports minus exports).

costs, or foreign capital accumulation, that alter comparative advantage and the terms of trade. A complication associated with identifying such shocks is that they can be induced by technology shocks. For example, a trading partner's productivity growth may be driven by its adoption of new technologies or production techniques. Investigating the US steel industry, Oster (1982) shows that large US producers were relatively slow in adopting new blast-furnace technologies during the 1970s, a factor which may have contributed to the rise in steel imports from their faster-adopting Japanese rivals.

A growing empirical literature uses specific trade liberalizations to examine whether US manufacturing employment or wages drop disproportionately in industries with greater exposure to changes in policy. Hakobyan and McLaren (2016), for example, use industry variation in US tariff reductions due to the North American Free Trade Agreement (NAFTA) to document a negative wage effect of NAFTA on less-educated workers between 1990 and 2000. Focusing on the next decade, Pierce and Schott (2016a), show that the post-2000 decline in US manufacturing employment is relatively larger for industries exposed to the granting of Permanent Normal Trade Relations to China in October, 2000. This non-traditional trade liberalization eliminated the possibility of sudden, substantial spikes in US tariffs on many Chinese imports, thereby removing a significant deterrent to greater integration of the two economies.

Research into the broader set of shocks that might alter US terms of trade makes use of changes in imports to identify reallocation. These papers devote considerable effort to excluding variation in imports driven by non-trade factors, such as secular declines in demand or common technology shocks. Bernard et al. (2006), for example, find that US manufacturing plant survival and employment between 1977 and 1997 are negatively associated with increasing import penetration from low-wage countries. To identify a causal effect of trade, they use changes in US import tariffs and ad valorem trade costs over their sample period as instruments for import penetration. Autor et al. (2014) and Acemoglu et al. (2016), show that workers in industries with higher growth in Chinese imports experience increased unemployment between 1992 and 2007. In these papers, Chinese import growth in other countries is used as an instrument for its growth in the United States. The identifying assumption is that Chinese exports to these other countries are driven by productivity growth in China, and not by changes in demand or technology outside of China that might also affect US manufacturing employment.

A related body of work exploits spatial variation in the distribution of manufacturing industries across the United States. Autor et al. (2013) demonstrate that regions with higher initial shares of employment in industries with greater exposure to imports from China experience relatively larger declines in employment and labor force participation. Regions with higher initial shares of employment in exposed industries also exhibit relative declines in the provision of public goods (Feler and Senses (2017)) and marriage rates (Autor et al. (2017)), as well as relative increases in household debt (Barrot et al. (2017)) and crime (Che et al. (2017)). These consequences carry over to health: Pierce and Schott (2016b) show that regions more exposed to US trade liberalization with China exhibit relative increases in "deaths of despair," including drug overdoses. This connection is 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)).

Studies like those noted above are often conducted using a difference-in-differences framework, which does not account for potential general equilibrium effects and thus complicates calculation of a trade shock's effect on the overall level of manufacturing employment (Muendler (2017)). Quantitative models, often drawing on empirical evidence from such studies, do offer such estimates as well as quantifications of the impact of trade on social welfare. Caliendo and Parro (2015), for example, argue that increased trade with China explains approximately one-quarter of the decline in US manufacturing employment between 2000 to 2007, and that the growth of trade with China over this period increased US welfare, though, like Galle et al. (2017), they find that gains vary across regions. Handley and Limão (2017) find that trade liberalization with China in the 2000s benefits consumers via increased imported product variety.

While changes in trade policy and increases in imports, particularly during the 2000s, have received considerable attention, other researchers interpret the long-run decline in the manufacturing employment share implicit in Figure 1 as driven by technology. Edwards and Lawrence (2013), for example, argue that the long, post-war decline in the share of US employment in manufacturing occurs "irrespective of the changing developments in international trade flows, the size of the trade deficit, and other factors." A number of papers assess the role of particular technologies on manufacturing employment. Collard-Wexler and De Loecker (2015) describe the importance of the introduction of mini-mills in the US steel industry for subsequent gains in output and declines in employment. Acemoglu and Restrepo (2017) find that US regions with an industrial mix that pre-disposes them to adopting more industrial robots have also experienced relatively larger employment declines, at a rate of approximately five workers per robot. Similarly, Graetz and Michaels (2017) use cross-country and industry data to show that robot adoption relates to decreased work hours by middle- and especially low-skill workers.

Another strand of research aims to decompose the respective roles of trade and technology on employment and wages. Goos et al. (2014) and Autor et al. (2015) 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 concludes that Chinese imports play a larger role in the decline of US manufacturing employment, especially after 2000. While this research uses careful measures to identify technology and trade, it remains susceptible to the possibility, highlighted in the anecdote presented in the introduction, as well as theoretical work in this area (e.g., Acemoglu (2002)), that a new technology's invention or adoption may itself be in response to a trade shock. Bernard et al. (2006), Khandelwal (2010) and Bernard et al. (2011) show that US firms respond to import competition in part by upgrading their product mix. Bloom et al. (2016) find evidence of technology upgrading within and across European firms that were more exposed to Chinese imports. In the US context, Autor et al. (2016) also find that Chinese import penetration affects manufactures' innovative activities, though they document a negative relationship.[4] Finally, interconnectedness is also found in the other direction. Fort

[4]In related research in labor economics, Clemens et al. (2017) show that imposing restrictions on

(2017) and Steinwender (2018) show that innovations in communications technologies facilitate trade. As a whole, this research highlights the difficulties associated with clean identification of one force over another.

3 Employment and Value Added Reallocation Across Industries

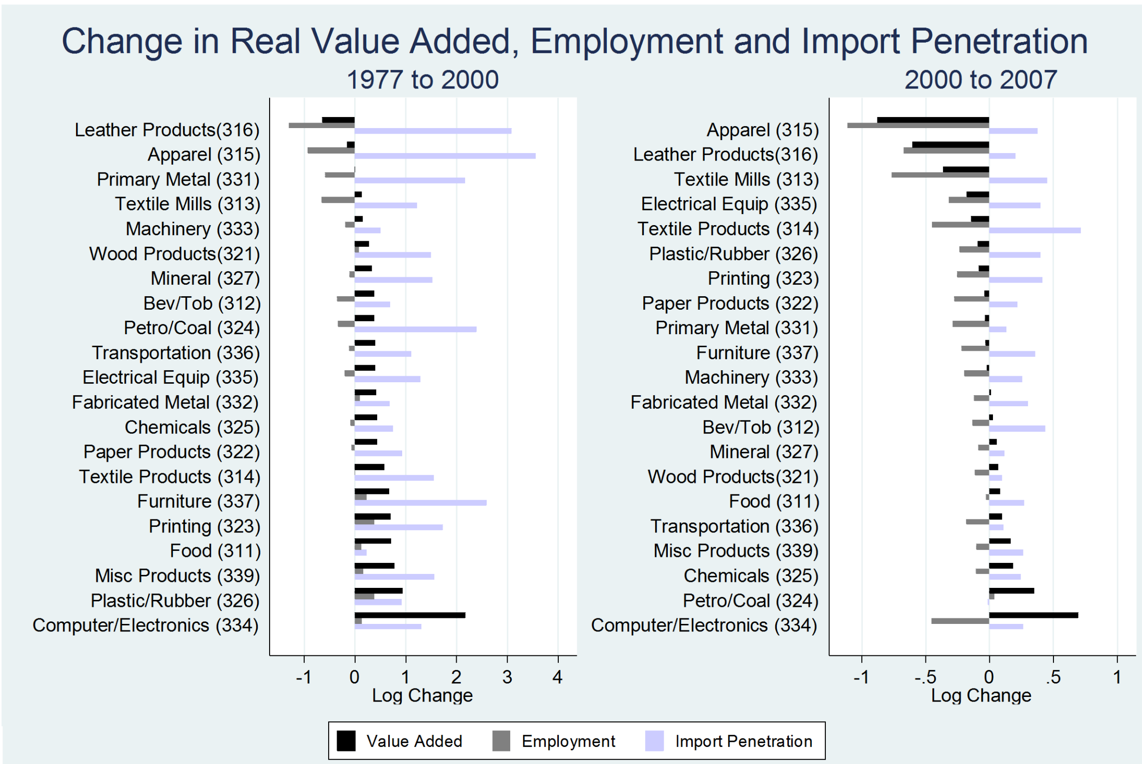
Examination of employment and output changes by industry provides useful context for the trends displayed in Figure 1, while also offering evidence in support of both trade- and technology-based explanations for the overall decline in US manufacturing employment since the late 1970s. Figure 3 displays log changes in real value added, employment and import penetration for the twenty-one three-digit NAICS sectors that constitute manufacturing. Given the sharp drop in manufacturing employment after 2000 displayed in Figure 1, we provide separate decompositions for years before (left panel) and after (right panel) that year, ending the latter period before the Great Recession to avoid its impact. In each period, industries are sorted by their log change in real value added, from low to high.

Figure 3 has three notable features with respect to identifying the influence of trade and technology. The first is the presence of Leather Products (316) and Apparel (315), which exhibit declines in both employment and value added in both time periods. These sectors primarily encompass the production of labor-intensive goods such as clothing and footwear, commonly thought to be inconsistent with US comparative advantage. Apparel, in particular, has been subject to substantial tariff and quota reductions in the United States during the period we study (Khandelwal et al. (2013)), and these liberalizations are reflected in the fact that it displays the largest increase in import penetration across sectors between 1977 and 2000.[5]

A second suggestive feature of Figure 3 is the increase in the number of sectors exhibiting simultaneous declines in real value added and employment in the right panel. Indeed, as illustrated in Appendix Figure A.2, 52 percent of the 473 six-digit manufacturing industries that comprise manufacturing register such reductions between 2000 and 2007, versus 23 percent during the earlier time period. To the extent that this trend captures the exit of labor-intensive, low-labor-productivity firms within sectors whose products most overlap with Chinese manufacturers, this trend is consistent with the increase in Chinese import competition displayed in Figure 2 affecting US employment, and the research into trade liberalization with China discussed above. On the other hand, as Figure 2 also illustrates, the 2000s is a period when firms' use of computers and electronic networks increases. An intriguing possibility worthy of further attention, motivated by the anecdote in the introduction, is whether technology

low-skill immigration induced adoption of more capital-intensive production techniques and shifts in product mix in the agricultural sector.

[5] Reallocation may operate through occupations as well as industries, presenting another challenge to identifying the impacts of trade and technology. That is, the characteristics that make occupations susceptible to offshoring, such as routineness, also render them susceptible to automation (Ebenstein et al. (2014); Oldenski (2014)).



Source: NBER-CES Manufacturing Industry Database (Becker et al 2013), Feenstra (1996), Schott (2008) and authors' calculations. Real value added is deflated using shipment price deflators. "Import penetration" is manufacturing imports divided by the sum of domestic manufacturing shipments plus manufacturing imports less manufacturing exports [M/(S+M-X)], all in real terms. Industries are sorted by real value added growth over each period. Scales are different in each panel.

Figure 3: Changes in Employment and Output by Industry

adoption during this period was hastened by trade liberalization with China.

The third noteworthy feature of Figure 3 with respect to trade and technology is the presence of sectors such as Chemicals (325), Transportation Equipment (336) and Miscellaneous Products (339; second panels only), in which value-added rises even as employment falls. These divergent outcomes, and the large growth in labor productivity they imply, suggest labor-saving technological change. In automobiles, for example, the replacement of workers with robots is widespread. On the other hand, to the extent that import competition induces selection away from low-labor-productivity industries within sectors, trade might also be playing a role (Schott (2003, 2004)). Indeed, the industries within Miscellaneous Products with the largest loss and gain in employment between 1977 and 2000 are dolls and surgical instruments, respectively.

A particularly interesting sector exhibiting rising output along with falling employment in recent years is Computers and Electronic Products (334). As pointed out in Houseman et al. (2011), and suggested by its presence at the bottom of both panels of Figure 3, this sector accounts for the vast majority of real value added growth in manufacturing over our sample period.[6] The two most influential industries in terms of aggregate real value-added growth within this sector are Semiconductors (334413) and Electronic Computer Manufacturing (334111). The latter has experienced significant growth in Chinese import penetration and is particularly well-known for its offshoring and outsourcing. Physical production of hard disk drives, like many other consumer electronic devices, has moved almost completely offshore during our sample period, even as their design centers remain in the United States (Igami (2018)). The iPhone, in particular, is well known for being "designed in California" and assembled – using physical inputs from many countries, including the United States – in China (Folbre (2013)).

The growing prevalence of such supply chains highlights a subtle but potentially important distinction between trade as import competition and trade as a technology. Although the bulk of US imports from China represent finished goods imported by US wholesalers and retailers (Bernard et al. (2010)), Figure 2 reveals that a growing share of manufacturing firms import goods directly. These direct imports may have different consequences than import penetration: empirical analysis of US manufacturing firms by Antràs et al. (2017) finds that while a firm's presence in an industry subject to increasing levels of Chinese import penetration is associated with declining firm-level employment between 1997 and 2007, increases in the value of its direct imports from China are associated with either growing or no change in employment. In their quantitative model, the authors' provide a rationale for this difference, showing how greater access to foreign sourcing opportunities can allow importers to lower prices and raise output, even as non-importing firms shrink. Bernard et al. (2017) also find that Danish firms exposed to increased import competition from China were more likely to offshore activities to Eastern Europe, which led to decreased domestic employment but not domestic output. Exploring the role of global value chains in the divergence between real output and employment is an important area for future research.

[6] Houseman et al. (2011) also note that growth in manufacturing real value added may be overstated due to mismeasurement of prices for imported inputs.

4 Reallocation of Manufacturing Employment Across and Within Firms

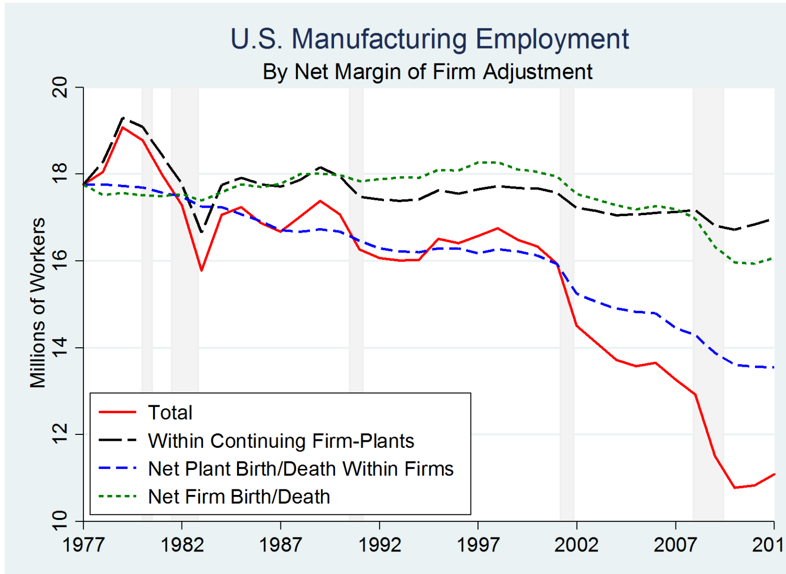
In this section we dissect the overall shift in US manufacturing employment between 1977 and 2012 along firm and establishment margins of adjustment. We perform this decomposition using data from the Longitudinal Business Database (LBD) of the US Census Bureau, which links all private, non-farm employer establishments and firms over time starting in 1977 (Jarmin and Miranda (2002)). Each establishment is assigned a single industry code in each year based on its predominant activity.[7] The data make a useful distinction between an "establishment" and a "firm." An establishment denotes a single physical location where business transactions take place and for which payroll and employment records are kept, such as a manufacturing plant. In our analysis, as in official statistics, employees are grouped into industries based on the classification of the establishment in which they work. As a result, all employees in a manufacturing plant are classified as manufacturing employees, regardless of their occupation.

A "firm" is an organizational structure that can include one or more establishments, and therefore can span multiple industries. To capture all manufacturing employment in the LBD, our decomposition includes all firms observed to have at least one manufacturing establishment at any point during the 1977 to 2012 sample period. The employment totals reported in this section are restricted solely to the manufacturing establishments at these firms; employment at their non-manufacturing establishments is analyzed later in the paper.

We examine three mutually exclusive firm margins of adjustment: changes in employment within the continuing establishments of continuing firms (also referred to as the "intensive" margin of continuing firm-plants), changes due to the birth and death of establishments within continuing firms, and changes due to the birth and death of entire firms.[8] Figure 4 illustrates the results. The solid line displays overall US manufacturing employment, showing the same pattern since 1977 as in Figure 1. The dashed lines trace out the cumulative employment in year t along the margins of adjustment, in each case relative to the firms and plants present in base year 1977. So, for example, the final value for the intensive margin indicates that firm-plants present in both 1977 and 2012 experience a decline in employment of approximately -0.8 million. Together, all three margins account for the -6.7 million overall decline in manufacturing

[7] 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.

[8] We follow Haltiwanger et al. (2013) and define a firm death as occurring when all establishments of a firm exit from the LBD. Analogously, firm birth occurs when all a firm's establishments are new to the LBD. While this approach avoids spurious firm birth and death due to merger and acquisition activity, future research into the extent to which these types of ownership changes are important factors in understanding manufacturing might be useful.



Source: Longitudinal Business Database and authors' calculations. Each line reports the change in employment along the noted net margin of firm adjustment relative to the firms and plants present in 1977. Gray bars indicate duration of recessions as determined by the NBER Business Cycle Dating Committee.

Figure 4: US Manufacturing Employment by Net Margins of Adjustment

employment registered by the solid line, from 17.8 to 11.1 million.

We find that most of the change in US manufacturing employment between 1977 and 2012 – 75 percent – takes place within firms that already existed in 1977 1977 (consider the two lines "within continuing firm-plants" and "net plant birth/death within firms"). Most striking is the contribution of net plant birth/death within these firms, which by itself accounts for 63 percent of the overall change. Conversely, the set of firm-plants in continuous operation over the sample period is responsible for relatively little – 12 percent – of the overall decline, with most of that occurring during the early 2000s.

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. Consider three possibilities. If automating existing plants is relatively cost-effective, employment declines may be concentrated along the "intensive" margin – that is, within establishments of ongoing firms. 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.[9] If entrepreneurs at entering firms have an edge in creating or implementing new technologies, as argued by Christensen

[9]For example, Brynjolfsson and Hitt (1998) describe a medical manufacturer's experience transitioning to computer-integrated manufacturing. The firm's initial attempt to do so at an existing plant failed to generate productivity gains because current workers did not understand how to exploit the new processes. When the firm then opened a new plant with young employees, it realized such significant gains that it painted the plant windows black to prevent competitors from replicating its new techniques.

(1997), then resulting reductions in manufacturing employment may be driven by firm death, as outdated incumbents are pushed from the market.

Responses to increased pressures of international trade can, of course, operate along the same margins. Trade liberalization with low-wage countries might render a US 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. If a broad set of firms' products is subject to increased import competition or if existing firms are unable to reallocate production within or across plants, trade competition may lead to the death of entire firms.

The fact that net firm death accounts for just 25 percent of the overall decline in US manufacturing employment between 1977 and 2012 is surprising given the magnitude of the drop in employment over this period, as well as common expectations of how creative destruction associated with trade and technology shocks likely operate. Indeed, in the right panel of Appendix Figure A.3, we find that net firm birth accounts for the bulk of employment growth among non-manufacturing firms–firms that never have a manufacturing establishment–over the same period. On the other hand, most of the decline in employment along the net firm death margin occurs in the 2000s, which, as discussed above, may plausibly be related to import competition from China. As illustrated in Appendix Figure A.4, we find a similar break with respect to the number of US manufacturing establishments: according to the Census Bureau's publicly available Business Dynamics Statistics (BDS), this series peaks in 1996. Overall, the small role of net firm death in the aggregate decline of US manufacturing employment suggests that incumbents may have an advantage relative to entrants.

The relatively sharp drop in employment associated with net plant death within continuing firms in the early 2000s, along with the contribution of net firm death during that period, may help rationalize the large distributional losses associated with increased import competition from China found in the literature. That is, to the extent that firm and plant closures were geographically concentrated, displaced workers may have found it more difficult to find new employment in their local labor market. On the other hand, the more-or-less constant decline of employment associated with net plant death within continuing firms prior to 2000 is consistent with firms continually replacing outmoded plants with new ones in response to a steady introduction of new technologies. To what extent do workers displaced by dying establishments find employment at new plants?

Simple descriptive regressions provide support for both trade and technology in plant turnover. For example, we find a negative correlation between the probability of a plant's death within a firm and the plant's purchases of computers. This correlation disappears after 2000, presumably due to the ubiquity of that technology, but during the 2000s we find another such correlation with respect to use of electronic networks to control or coordinate shipments.[10] In other words, there is heterogeneity within firms

[10]As discussed further in Appendix Section A.2, these correlations are found by regressing indicator variables for plant death over years t to $t+5$ on indicator variables for the noted activities in year t,

in terms of the establishments that adopt various technologies, and plants that do adopt these technologies have lower exit probabilities. With respect to trade, similar regressions indicate that before 2000, plant death within firms was correlated with increased import penetration in that plant's industry. After 2000, when firm death becomes a more important margin in the aggregate decline, these correlations are no longer present at the plant level, but firms facing increased import competition from China are more likely to exit.[11] One potential explanation for this result is that the firms that could re-orient themselves away from import-competing industries did so early on, either by shuttering plants or switching industries. For firms specializing in import-competing products, however, increased import penetration led to death.

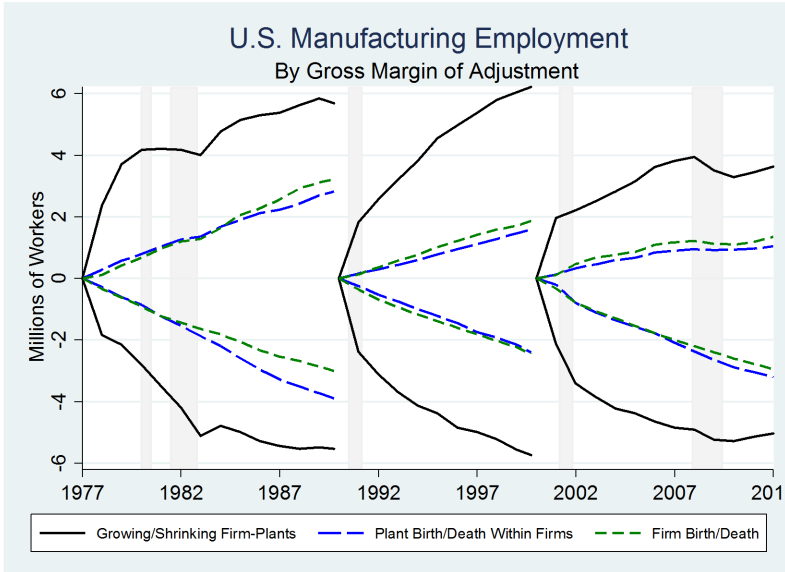
The relatively small, -12 percent change in employment among continuing firm-plants masks substantial gross flows associated with continuing firm-plants' expansion and contraction. We illustrate the magnitude of these gross flows in Figure 5, which decomposes the three net margins displayed in Figure 4 into their constituent gross job creation and destruction parts. In each case, job creation margins are displayed in lines above zero, while their corresponding job destruction margins are displayed in similarly patterned lines below zero. Here, to compare gross margins over time, and in contrast to Figure 4, we break the 1977 to 2012 sample period into three intervals that begin in base years 1977, 1990, and 2000. As a result, the gross margins for any year t in Figure 5 are computed with respect to their nearest prior base year. So, for example, the final values for the gross continuing firm-plant margins indicate that firm-plants whose employment grew between 2000 and 2012 account for positive 3.6 million of the change in US manufacturing employment between 2000 and 2012, while continuing firm-plants whose employment fell accounted for negative 5.0 million.

The dominance of the intensive margin in gross employment changes represents another potentially fruitful area of study. To what extent is the adoption of new technologies, exposure to trade, or either importing or exporting associated with plant contraction? Plant expansion? Large levels of job creation and destruction at continuing firms also suggest a potentially important role for technology and trade in worker reallocation. Are some workers more likely than others to shuffle among continuing plants? In Appendix A.2, we show that firms' technology and trade activities are correlated with subsequent changes in their employment and output, which is consistent with a role for both trade and technology in the reallocation of activities across continuing establishments.

Another noteworthy feature of Figure 5 is the decline of all three gross job creation margins over time. These decreases are indicative of a drop in US business dynamism that has been documented across all sectors by Decker et al. (2016). One potential explanation for this decline is a reduction in firms' responsiveness to productivity shocks due to rising adjustment frictions (Decker et al. (2018)), such as regulatory constraints, or the use of offshore rather than domestic capacity to make adjustments. Another is a reduction in competition, perhaps as a result of increasing entry barriers associated with

along with firm fixed effects.

[11]Unfortunately, given that trading is observed at the firm level, we are unable to examine whether plants that import are more or less likely to survive within firms over either period.



Source: 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 the nearest past base year, either 1977, 1990 or 2000. Gray bars indicate duration of recessions as determined by the NBER Business Cycle Dating Committee.

Figure 5: US Manufacturing Employment by Gross Margins of Adjustment

adopting technology or adapting to globalization. De Loecker and Eeckhout (2017) document a steady rise in market power as measured by markups among US firms since the 1980s, with a sharp tick upwards in the early 2000s. A potentially intriguing area for further exploration is whether costs associated with trade or technology contribute to entry barriers. Using simple regressions of firm attributes on indicators for adoption and industry fixed effects, we find across census years – and display in Appendix Figure A.5 – that firms purchasing computers and using electronic networks are significantly larger and have higher labor productivity than non-adopters.[12] Inspired by Acemoglu and Restrepo (2017), we find similar premia for firms that import industrial robots (Harmonized System product code 84.7950.0000) starting in 1997. These adoption premia are analogous to the size and productivity premia found for importers and exporters in the international trade literature (Bernard et al. (2007)). As such, they may reflect the fact that adoption of technology, like expansion into foreign markets, requires the payment of high fixed costs that only the largest and most productive firms find it optimal to incur.

Trade may also play a role in the decline of gross manufacturing job creation by pushing the US economy away from goods production and towards services. Pierce and Schott (2012) and Asquith et al. (2017) show that during the 2000s, industries with

[12] These regressions are described in greater detail in Online Appendix Section A.1.

relatively greater exposure to trade liberalization with China exhibit both suppressed job creation as well as exaggerated job destruction. To what extent might the US transition from goods to services occur within firms? Relatedly, the decline in gross manufacturing job creation along the firm birth and plant birth within continuing firm margins may indicate that smaller, more capital-intensive firms and plants are entering at the expense of larger, more labor-intensive establishments and firms. In fact, as shown in Appendix Figure A.4, we find that the average number of workers per US manufacturing establishment fell 29 percent between 1977 and 2012, while the number of manufacturing establishments only begins to decline in the 1990s. Are these smaller entrants producing different goods more in line with US comparative advantage, or are they producing the same goods with a different technology?

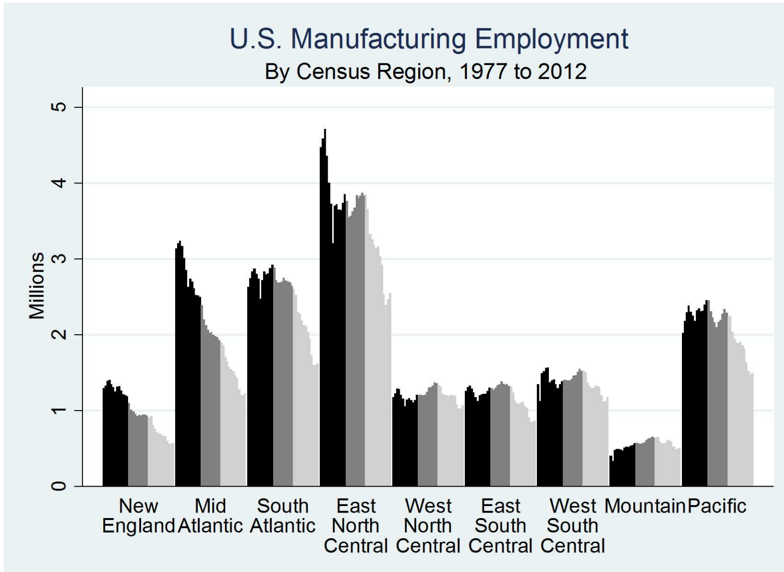
A final question related to the gross margins displayed in Figure 5 is the extent to which the decline in business dynamism in other sectors of the US economy might be related to the actions of manufacturing firms, or vice versa. Such relationships may occur through various channels, such as local labor markets or input-output linkages between manufacturing and non-manufacturing industries. Below, we show that another important dimension of such contact is the fact that manufacturing firms possess a sizable presence in non-manufacturing industries.

5 Reallocation of Employment Across Regions

While a significant portion of the literature on both trade and technology has exploited regional variation in the distribution of manufacturing activities to identify causal impacts, plant and firm relocation within the United States remains a relatively unexplored dimension of firm adjustment to trade and technology shocks.

We find substantial reallocation of manufacturing employment across US regions over time, as well as differences in the extent to which regional declines in employment are driven by firm death versus continuing firms. Figure 6 plots US manufacturing employment from 1977 to 2012 by the nine US Census regions that comprise the United States. Each bar represents manufacturing employment in a given year and region, and bars are shaded to correspond to the three intervals used in Figure 5: 1977 to 1989 (black); 1990 to 1999 (dark grey); and 2000 to 2012 (light grey). As indicated in the figure, manufacturing employment in New England, Mid-Atlantic, and East North Central declines more-or-less steadily over the sample period. In the rest of the country, by contrast, it is either relatively flat or growing until 2000, after which manufacturing employment in all regions shrinks. Indeed, between 1977 and 2000, combined manufacturing employment in New England, Mid-Atlantic and East North Central falls by -2.3 million, while the increase for all other regions as a whole is 0.8 million. After 2000, the largest decline, in percentage terms, occurs in South Atlantic (-38 percent).

Regions also display interesting variation in terms of the margins of firm adjustment. In Appendix Figure A.7, we show that employment loss due to net firm death is concentrated in New England and Mid-Atlantic, which together account for 16 percentage points of the overall 25 percentage point decline in US manufacturing employment



Source: Longitudinal Business Database and authors' calculations. Panels report manufacturing employment across years and census regions. Years from 1977 to 1989, 1990 to 1999 and 2000 to 2012 are shaded black, dark gray and light gray, respectively. Census regions are defined as follows. New England: CT, ME, 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: US Manufacturing Employment by Census Region

attributable to that margin. East North Central, by contrast, stands out in terms of its disproportionate loss of employment within continuing firm-plants.

Reallocation of manufacturing activity within the United States might shed useful light on reallocation internationally. Indeed, movement of US manufacturing employment from the north and east towards the west and south up to 2000 may have been a precursor to international offshoring. Bernard et al. (2013), for example, show that US labor markets exhibit substantial and persistent variation in relative skill endowments and wages over this period, and that labor markets with different relative wages tend to specialize in different groups of industries. Fort (2017) shows that US manufacturing establishments in high wage locations are more likely to fragment production, especially domestically. Anecdotal evidence suggests firms do in fact relocate in response to variation in wages across local labor markets. Radio Corporation of America (RCA), for example, continually moved production of its most labor-intensive products west and south in search of lower wages before moving it to Mexico in the 1990s (Cowie (2001)). Such activity is consistent with the Holmes (1998) finding that manufacturing employment is relatively low in more union-friendly states compared to neighboring right-to-work states, which are clustered in the South Atlantic, West Central, and Mountain regions whose manufacturing employment was stable or growing prior to 2000. Were such reallocations also a response to international competition? Were they facilitated by technologies that allow firms to serve customers from more remote, lower-cost labor markets? Do incumbents have an advantage in making use of such technologies?

A thornier question raised by Figure 6 is whether relocation within the United States, either within or across firms, coincides with labor-saving technology upgrades, as suggested by a the long-running decline in the average number of employees per establishment referenced above? If so, how can a causal impact of technology be identified?

6 Manufacturing Firms' Non-Manufacturing Establishments

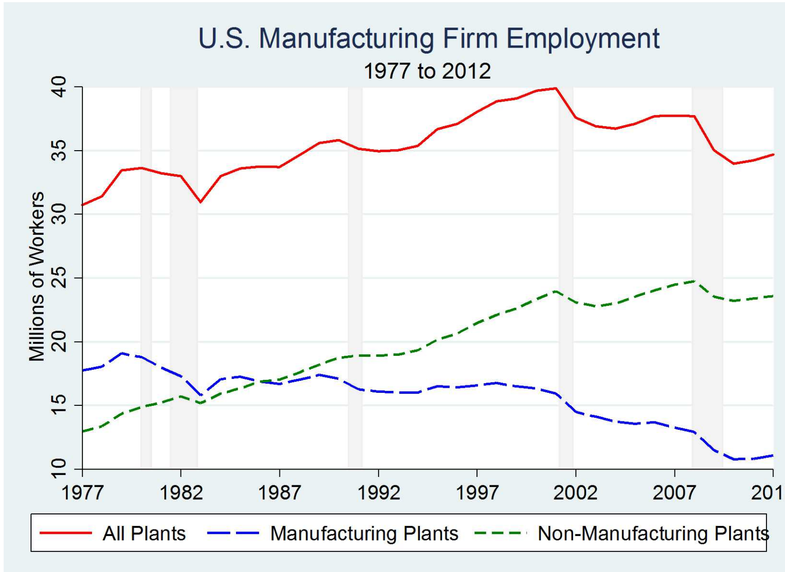
Manufacturing firms can also have non-manufacturing establishments. In this section, we broaden our analysis to investigate how employment at manufacturing firms' non-manufacturing establishments has evolved, and in what non-manufacturing industries they participate. As noted earlier, we define a manufacturing (M) firm broadly to encompass any firm observed to have an M establishment during our 1977 and 2012 sample period. The non-manufacturing (NM) employment of M firms, therefore, is simply the sum of employment at any NM establishments owned by an M firm. While we focus on this comprehensive set of firms in order to capture all M employment, it is important to bear in mind that this definition includes firms not traditionally thought of as manufacturers – for example, big box retailers that may encompass relatively small food preparation facilities – and that such firms might have an outsized impact on the trends in NM employment we display below.

With this caveat in mind, Figure 7 displays M firms' total employment across their M versus NM establishments. As indicated in the figure, NM employment rises more-or-less steadily until 2000, when it levels off. As a result, M firms' total employment rises until 2000 before declining afterwards due to the sharp drop in employment at their M establishments.[13] As illustrated in the left panel of Appendix Figure A.3 most of the growth in M firms' NM employment occurs via net NM plant birth within continuing firms.

The growing share of M firm employment at NM establishments might indicate that a growing number of workers at NM establishments is needed to support M production, that M firms' scope is widening to include additional NM activities, or simply that employment growth at firms' NM establishments reflects the broader shift of US employment toward NM activities.[14] Further insight into these explanations comes

[13]In work not reported here, we find that the trends displayed in Figure 6 are sensitive to how M firms are defined. For example, requiring firms to have at least some threshold level of employment in manufacturing in at least one year of the sample results in flatter growth of NM employment over the sample period. In addition, the growth of NM employment at M firms, even with our broad definition of manufacturing firms, is slower than the growth of NM employment at NM firms. This differential is also worthy of further exploration.

[14]While recent research suggests that US manufacturers increasingly outsource ancillary services such as cleaning to domestic contractors (Dey et al. (2012); Berlingieri (2014); Katz and Krueger (2016)), such activity would not be captured in Figure 7 as it traces NM employment within M firms.



Source: Longitudinal Business Database and authors' calculations. Figure displays total employment at US manufacturing firms as well as its decomposition into employment at manufacturing firms' manufacturing versus non-manufacturing establishments. Manufacturing firms are defined as any firm observed to have a manufacturing establishment between 1977 and 2012. Gray bars indicate duration of recessions as determined by the NBER Business Cycle Dating Committee.

Figure 7: Employment at Manufacturing Firms' Manufacturing vs Non-Manufacturing Establishments

from analysis of the particular activities occurring at M firms' NM plants. Toward that end, we break NM industries into three groups based on their two-digit NAICS sectors: retail (NAICS 44 to 45), professional services (NAICS 51 to 56), and all other NM industries. Perhaps unsurprisingly, given the broad definition of M firms noted above, we find in Online Appendix Figure A.8 that about one-third of the overall growth in M firms' NM employment between 1977 and 2012 is in retail, while another third falls into the "other" category.

However, 32 percent of the increase in non-manufacturing employment at manufacturing firms is driven by professional services, which captures 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 growing use of workers in such industries may reflect the influence of both trade and technology. For example, one action US manufacturers might take in response to growing import competition in goods is to move into "neurofacturing" (Leamer (2009)), either by diversifying away from goods production entirely or by making use of various communications and management technologies to focus on the engineering, design or marketing of goods rather than their physical production (Bernard and Fort (2015, 2017)).[15]

[15]Consistent with this explanation, Magyari et al. (2017) finds that, in certain cases, US manufac-

These findings raise a number of intriguing questions. Does increasing use of design, marketing and other management services facilitate the product differentiation and upgrading US firms undertake to compete with producers from low-wage countries? Does it help explain the rising market power of US producers documented in De Loecker and Eeckhout (2017)? Do US manufacturing firms expand their service activities in the same geographic areas in which they used to produce physical goods? As illustrated in Appendix Figure A.6, though 46 percent of M firms' NM employment growth takes place in the western half of the United States, the South Atlantic exhibits the fastest pace of employment growth, at 27 percent. Further analysis of the broader scope of US manufacturing firms' activities across both geographic and regional dimensions seems promising.

7 Conclusion

The decline in US manufacturing jobs and concerns over the competitiveness of US manufacturers in a global market place have sparked considerable commentary and research in recent years, including several articles in this journal by Charles et al. (2016), Baily and Bosworth (2014), Tassey (2014), and Houseman et al. (2011). A natural question arising in these discussions is whether trade or technology plays a larger role in the sector's outcomes. As we have explained, we find that question to be overly broad. It may also distract needed attention away from research into how to facilitate reallocation among displaced manufacturing workers. Given that few economists advocate for restricting either technology or trade, such research seems both timely and prudent.

Instead, we have sought to gain new perspective on the decline of US manufacturing employment by examining relatively unexplored dimensions of microdata tracking US manufacturing firms over time, and considering how patterns in those data might be explained by various mechanisms associated with trade, technology, and other forces. Here, we summarize a few of the empirical facts we report, and follow-up questions that are worth pursuing.

We find that 75 percent of the -6.6 million decline in manufacturing employment between 1977 and 2012 took place within continuing firms, largely through plant closures. Why is the primary adjustment within firms, and in the form of plant closures? What barriers to entry – regulatory or otherwise – might have dampened firm creation or suppressed firm destruction? How do entrants' technology and production functions differ from those of incumbents and deaths? What are the implications of these plant closures and new production techniques for displaced workers?

Manufacturing firms' activities outside manufacturing might offer some clues for the persistence of incumbent manufacturing firms. Before 2000, the drop in manufacturing firms' manufacturing employment is more than offset by increases in non-manufacturing workers. 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 – like designers and engineers –

turing firms expand their NM employment in response to import competition from China.

account for approximately a third of the non-manufacturing workers added by manufacturing firms. Are incumbents firms better suited to engage in these activities? Does manufacturing firms' greater focus on services mimic the growth in services that 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?

Finally, trade and technology can interact with different parts of manufacturing in very different ways. Manufacturing firms that adopt specific technologies, such as computers or industrial robots, are significantly different from those that do not: in particular, they are larger and more productive upon adoption. Importing is associated with different outcomes at the firm and industry levels: while exposure to greater import competition is associated with employment decline, firms increasing their use of imported goods conditional on such exposure can exhibit employment gains. Should direct use of imported goods be considered a technology?

US manufacturing has many dimensions: manufacturing and non-manufacturing establishments, overall trends of falling employment and rising value added, incumbents and non-incumbents, geographical movements within US regions, sunset and sunrise industries, differences in firm-level choices regarding importing inputs and use of technology, and differences across industries from import penetration and the spread of technology. Our understanding of how trade and technology affect US manufacturing must seek to be multifaceted as well.

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Appendix for Online Publication

This online appendix contains additional figures referenced in the main text as well as more detailed information about the regression results referenced in the main text.

A Regression Detail

A.1 Premia Regressions

We examine the correlation between use of technology and both firm employment and labor productivity via a series of cross-sectional OLS regressions in each census year of the form

$$ln(Attribute_f^t\} = \alpha + \beta 1\{Activity_f^t\} + \eta_j^t + \epsilon_f^{t:}. \tag{A.1}$$

The left-hand side variable is either the log employment or the log labor productivity (shipments divided by employment) for firm f in census year t. The first right-hand side variable represents participation in one of the following technology or trade activities in census year$t$: purchase of computers, use of electronic networks to control or coordinate shipments, direct importing of industrial robots (HS 84.7950.0000) or direct importing of any good from any country. η_j^t represents industry fixed effects. We estimate separate regressions for each activity and each census year from 1977 to 2012. Data for computer purchases is not available in 1997. Data for importing, importing robots, and use of electronic networks are not available before 1992, 1997 and 2002, respectively. Point estimates and ninety-five percent confidence intervals for each activity and year are displayed in Appendix Figure A.5. As indicated in the figure, firms engaged in each of the examined activities are larger and more productive than those not engaging in the activities. These size and productivity premia generally shrink over time, though the decreases are considerably larger for the technology activities versus direct importing.

A.2 Plant Death Regressions

We examine the correlates of plant death *within* multi-establishment firms by estimating the following OLS regression,

$$1\{Death_{pf}^{t:t+5}\} = \alpha + \beta 1\{Activity_{pf}^t\} + \gamma ln(Emp_p^t) + \delta_f + \rho^t + \epsilon_{pf}^{t:t+5}. \tag{A.2}$$

The left-hand side variable is an indicator for whether the plant exits between census years t and $t + 5$. After the constant, the second variable on the right-hand side represents indicators for whether the plant engages in a particular activity, such as purchasing computers or using an electronic network to control or coordinate shipments in census year t. The third variable on the right hand side is the natural log of plant employment, the fourth covariate represents firm fixed effects, and the fifth covariate represents year fixed effects. We estimate this equation separately across census years before and after 2000, i.e., 1977 to 1997 and 2002 to 2012. Data for computer purchases are available in all census years except 1997, when this information was not collected. Data for use of electronic networks are available starting in 2002. We also estimate a variant of equation A.2 in which we replace $Activity_{pf}^{t}$ with either the change in import penetration or the change in import penetration from China in the plant's industry between years t and $t+5$.

Coefficient estimates are reported in the first two columns of Table A.1. Because the regressors are endogneous and no instrumental variables are employed, these coefficient estimates should be treated as correlations, with no claim of causality.

Dependent variable is an indicator equal to one if a plant or firm exits in the next 5 years

	Plant Death		Firm Death	
	Pre 2000	2000s	Pre 2000	2000s
Computer Purchases$_{pf}^{t}$	-0.057***	0.00	0.060***	-0.019***
	(0.003)	(0.003)	(0.00)	(0.00)
Electronic Networks$_{pf}^{t}$		-0.039***		-0.027***
		(0.003)		(0.00)
Robots$_{f}^{t}$				0.097***
				(0.03)
Importer$_{f}^{t}$			0.043***	0.002
			(0.00)	(0.00)
China Importer$_{f}^{t}$			0.070***	0.031***
			(0.01)	(0.00)
ΔImport Penetration$_{pi}^{t:t+5}$	0.251***	0.06	0.003	0.034
	(0.059)	(0.046)	(0.06)	(0.05)
ΔChinese Import Penetration$_{pi}^{t:t+5}$	0.721***	0.09	-0.036	0.204***
	(0.121)	(0.084)	(0.13)	(0.06)
Initial log of firm employment	Yes	Yes	Yes	Yes
Fixed Effects	Firm and Year		Industry and Year	

Notes: First two columns panel reports the results of OLS panel regressions of an indicator for *plant* death between years t and t+5 on indicators for noted *plant* activities in year t. The sample period for the first column is census years from 1977 to 1997 while the sample period for the second column is census years from 2002 to 2012. Regressions in the first two columns include both firm and year fixed effects. Third and fourth columns reports the results of analogous OLS panel regressions of indicators of *firm* death between years t and t+5 on indicators of *firm* activity. Firm-level regressions include industry and year fixed effects. Each cell in the table reports the results of a separate regression. Activities examined are the purchase of computers, use of electronic networks to control or coordinate shipments, direct importing of industrial robots (HS 84.7950.0000) and direct importing of any good from any country. Final two rows of table examine the association between plant or firm death and year t to t+5 changes in import penetration of plants' or firms' major industry. Importing data are not available until 1992 and are available only at the firm level. Computer purchase data are not available in 1997. All regressions control for initial plant or firm size. Standard errors for regressions with industry import penetration are clustered at the industry level. *, **, *** signify statistical significance at the 10, 5, and 1 percent level respectively.

Table A.1: Plant and Firm Death Regressions

For comparison, we also report a series of analogous firm death regressions in the second two columns of Table A.1,

$$1\{Death_{f}^{t:t+5}\} = \alpha + \beta 1\{Activity_{f}^{t}\} + \eta_{j}^{t} + \rho^{t} + \epsilon_{f}^{t:t+5}, \tag{A.3}$$

where η_j^t captures industry fixed effects. In these regressions, we are also able to investigate the association between firm death and being a direct importer of industrial robots (HS 84.7950.0000) in year t as well as being a direct importer or being a direct importer from China of any good in year t. As noted in the main text, we are unable to examine these relationships at the plant level given that trading is observed only at the firm level.

A.3 Continuing-Firm Regressions

To assess the potential role of trade and technology in US manufacturers' employment changes within continuing firms, we examine how firm outcomes relate to various activities using firm-level OLS panel regressions of the form

$$\Delta log(Outcome_f^{t:t+5}) = \beta Activity_f^t + \eta_j^t + \rho_t + \epsilon_f^{t:t+5}. \tag{A.4}$$

$\Delta log(Outcome_f^{t:t+5})$ represents the log difference in firm-level manufacturing employment, total employment, real value added in manufacturing, or real value added in manufacturing per manufacturing worker between census years t and $t+5$. $Activity_f^t$, as above, represents one of several actions, including purchasing computers, using electronic networks to control or coordinate shipments, being a direct importer of industrial robots (HS 84.7950.0000), being a direct importer of any good from any country, or being a direct importer from China. When considering the latter two activities, we also include contemporaneous t to $t+5$ changes in the analogous industry-level import penetration, that is, change in overall import penetration or the change in import penetration from China. These additions allow for the possibility, discussed in Section 3 of the main text, that import competition and direct foreign sourcing may have different associations with firm outcomes. We note that these regressions are purely descriptive and should not be interpreted as providing causal evidence. As an additional caveat, we note that regressions are unweighted.

Results are presented in Table A.2, where the top and bottom panels display results for census years before and after 2000. The top panel reports the results of three regressions for each outcome variable, where the three regressions are separated into rows. The first regression examines the relationship between computer purchases and the outcome variables while the second and third examine relationships with respect to being an importer or being an importer from China. Computer purchase data are not available in 1997, and importing data are not available until 1992. As a result, the number of observations for the first regression is larger than for the second and third regressions. The bottom panel of Table A.2 considers years after 2000 and reports the results of five regressions for each outcome variable. All regressions in this panel have the same number of observations. We note that observations are rounded to the nearest thousand per Census Bureau disclosure guidelines.

Before 2000, computer purchasers exhibit declines in employment and real value added relative to non-purchasers, with the declines in the former being somewhat larger in absolute value. As a result, during this period, computer purchases are associated with increases in labor productivity. Results for being an importer or an importer from China are similar. A second notable trend in this panel is that for all three activities, the coefficients in regressions considering total firm employment (column 2) are smaller than those for manufacturing employment (column 1), indicating that employment adjustment to the noted activities occurs disproportionately among manufacturing establishments.

After 2000, we find a different pattern of results for firms that purchase computers and are direct importers. These activities are now associated with rising employment and rising real value added. Moreover, we find the same pattern of results for firms that use electronic networks to control or coordinate shipments. In contrast, firms that import industrial robots see relatively less manufacturing employment growth than firms that do not import these robots, though there is no significant relationship with their total employment and a positive and significant relationship with real value added and labor productivity. These results are consistent with the premise that technology may replace workers even as it boosts output. Finally, importing from China is associated with a statistically significant decrease in manufacturing employment after 2000, but no statistically significant relationship with total employment or real value added.

Results for changes in either overall or Chinese import penetration at the industry level indicate negative correlations with employment after 2000. Table A.2 contains two other suggestive results. First, being an importer in post-2000 years is correlated with relatively higher growth in employment and real value added, whereas increased import penetration in the firm's initial and primary (based on employment) manufacturing industry is associated with statistically significant relative reductions in growth in both outcomes. Higher growth in Chinese import penetration is associated with relatively lower growth in manufacturing and total employment, while the relationship with real value added growth is negative but statistically insignificant at conventional levels (p-value=0.12). Furthermore, the divergence in firm-level employment versus output correlations for robot importing and importing from China highlight the possibility that technology and trade may be factors in decreased manufacturing employment and increased output of US manufacturing firms.

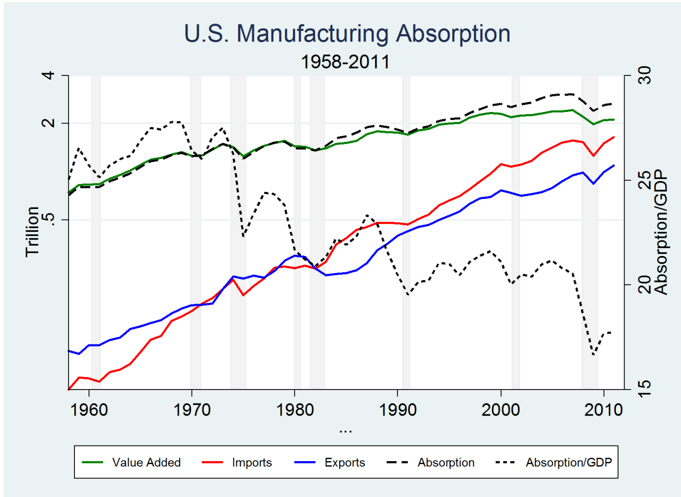
Dependent variable is 5-year differences in firm variable listed in colum:

	PANEL A: Pre-2000 Years			
	Δlog Employment		Δlog	Δlog VA
	Manuf	Total	Value Added	per Worker
Computer Purchases$_f^t$	-0.061***	-0.036***	-0.038***	0.023***
	(0.01)	0.00	(0.01)	(0.01)
Observations	323,000	323,000	323,000	323,000
Years: 1977, 1982, 1987, 1992				
Importer$_f^t$	-0.039***	-0.024**	0.01	0.046***
	(0.01)	(0.01)	(0.02)	(0.01)
ΔImport Penetration$_i^{t:t+5}$	-0.21	-0.12	0.26	0.474**
	(0.21)	(0.19)	(0.36)	(0.21)
ΔChina Importer$_f^{t:t+5}$	-0.169***	-0.130***	-0.097***	0.071***
	(0.02)	(0.02)	(0.03)	(0.02)
ΔChinese import Penetration$_i^{t:t+5}$	-0.15	-0.01	-0.24	-0.09
	(0.26)	(0.24)	(0.41)	(0.27)
Observations	91,000	91,000	91,000	91,000
Years: 1992-1997				
	PANEL B: 2000 Years			
	Δlog Employment		Δlog	Δlog VA
	Manuf	Total	Value Added	per Worker
Computer Purchases$_f^t$	0.026***	0.021***	0.013***	-0.013***
	0.00	0.00	0.00	0.00
Electronic Networks$_f^t$	0.009**	0.018***	0.030***	0.022***
	0.00	0.00	(0.01)	0.00
Robots$_f^t$	-0.069*	-0.01	0.105**	0.174***
	(0.04)	(0.03)	(0.05)	(0.05)
Importer$_f^t$	0.026**	0.025**	0.064***	0.038***
	(0.01)	(0.01)	(0.01)	(0.01)
ΔImport Penetration$_i^{t:t+5}$	-0.346**	-0.211*	-0.420**	-0.07
	(0.14)	(0.11)	(0.20)	(0.12)
China Importer$_f^t$	-0.023**	-0.02	0.02	0.039***
	(0.01)	(0.01)	(0.01)	(0.01)
ΔChinese Import Penetration$_i^{t:t+5}$	-0.743***	-0.522***	-0.34	0.402***
	(0.17)	(0.13)	(0.21)	(0.10)
Observations	178,000	178,000	178,000	178,000
Years: 2002, 2007, 2007				

Notes: Table reports the results of a series of firm-level OLS panel regressions of year t to year t+5 log changes in firm attributes on indicators of firm-level activities and, in some cases, changes in firms' initial industry import penetration. The left-had side variables examined are log changes in manufacturing employment, total employment, manufacturing real value added and manufacturing real value per manufacturing worker. Year t firm-level activities examined are purchasing computers, using electronic networks, being a direct importer of industrial robots (HS 84.7950.0000), being a direct importer of any good from any country, or being a direct importer from China. Panel A reports estimations across census years from 1977 to 1997, while panel B reports results for census years from 2002 to 2012. Computer purchase data are not available in 1997, and importing data are not available until 1992; as a result, the number of observations for the first regression in Panel A is larger than for the second and third regressions in Panel A. Observations are rounded to the nearest thousand per U.S. Census Bureau disclosure guidelines. There are three regressions for each dependent variable reported in Panel A, and five regressions reported for each dependent variable in Panel B. All regressions include year fixed effects. Standard errors for regressions with industry import penetration are clustered at the industry level. *, **, *** signify statistical significance at the 10, 5, and 1 percent level respectively.

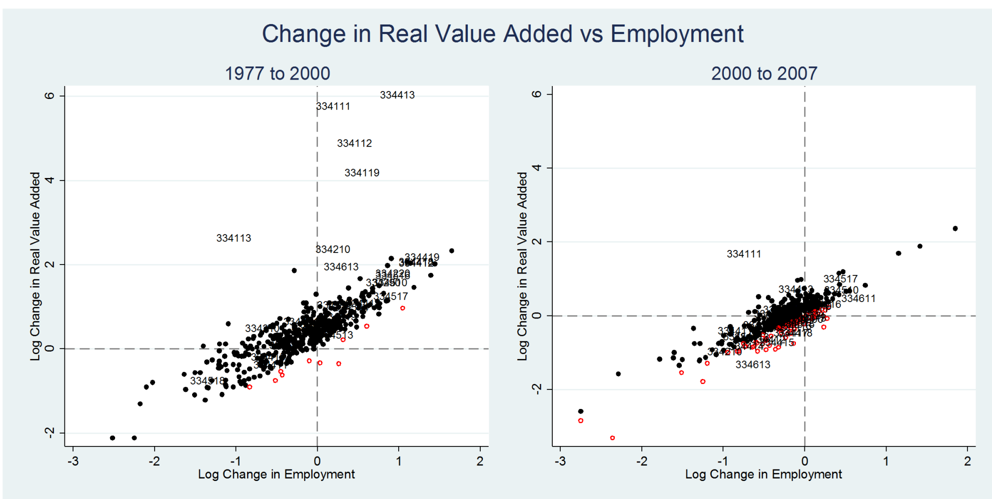
Table A.2: Continuing-Firm Regressions

B Additional Figures



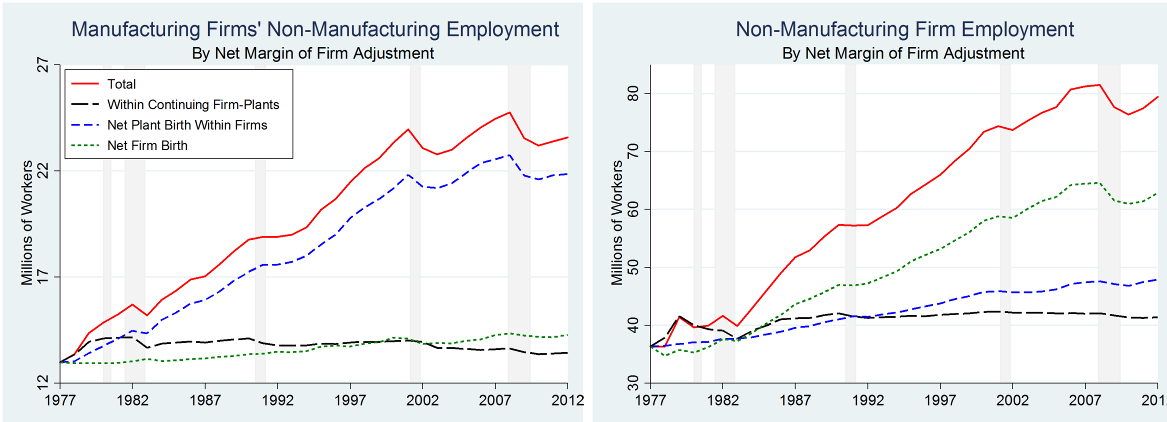
Source: Annual manufacturing real value added (VA) is from NBER-CES Manufacturing Industry Database (Becker et al. 2013). Annual manufacturing imports (M) and exports (X) are from Feenstra (1996) and Schott (2008). Manufacturing absorption is defined as the sum of value added and imports less exports (VA+M-X), all in real terms. Real GDP is from the US Bureau of Economic Analysis. Units for value added, imports, exports and absorption are on left axis. Units for absorption as a percent of GDP are on right axis. Gray bars indicate duration of recessions as determined by the NBER Business Cycle Dating Committee.

Figure A.1: US Manufacturing Absorption



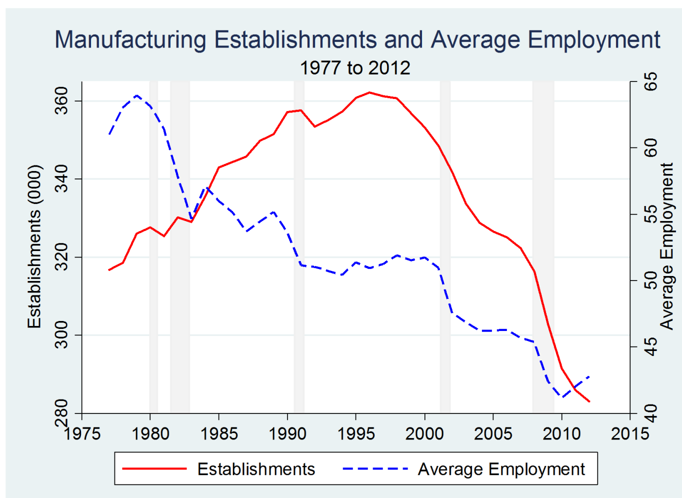
Source: Publicly available NBER-CES Manufacturing Industry Database (Becker et al. 2013) and authors' calculations. Value added is deflated using shipment price deflators contained in the database. Industry codes for Computer and Electronic Product (334) are highlighted. Industries below the 45 degree line, that is, with falling labor productivity, are indicated by open red circles.

Figure A.2: Employment versus Value Added Growth Across Six-Digit NAICS Sectors



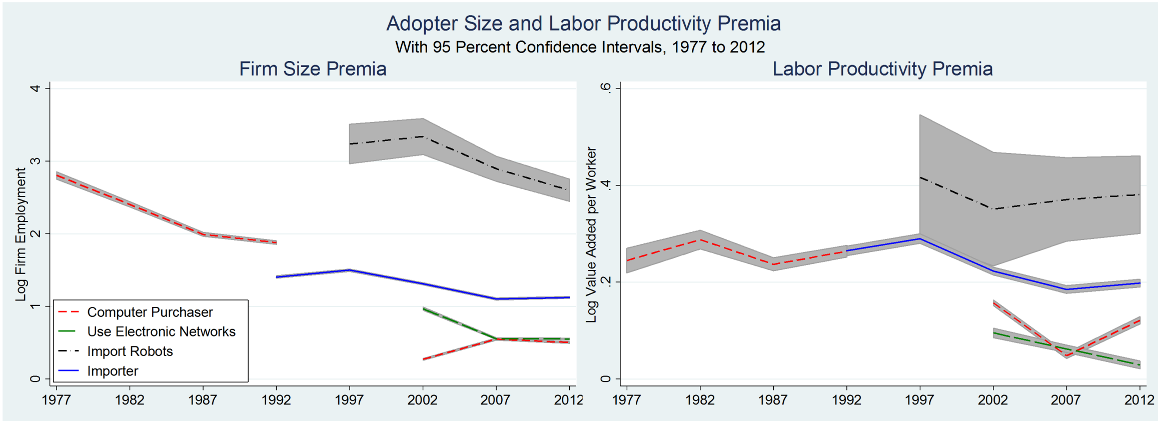
Source: Longitudinal Business Database and authors' calculations. Left panel decomposes U.S. manufacturing firms' non-manufacturing employment by noted net margins of firm adjustment. Right panel performs similar decomposition for non-manufacturing firms, which, by definition, do not have any manufacturing establishments. In both panels, change in employment along the noted net margins of firm adjustment are relative to the firms and plants present in 1977, the "base" year. Gray bars indicate duration of recessions as determined by the NBER Business Cycle Dating Committee.

Figure A.3: US Non-Manufacturing Employment by Net Margins of Adjustment



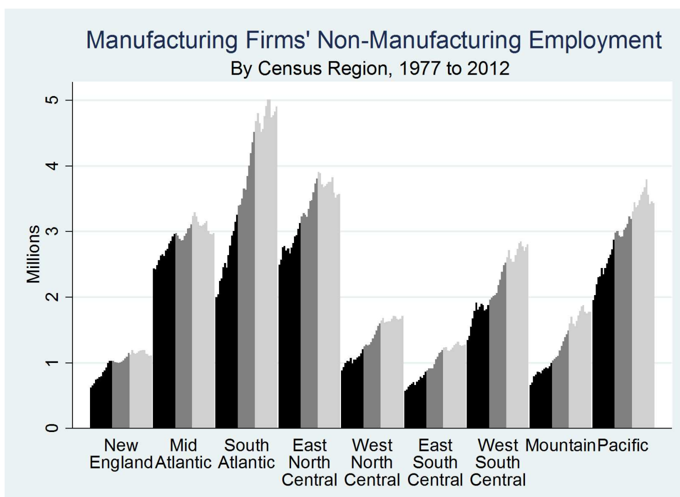
Source: Business Dynamics Database and authors calculations.

Figure A.4: US Manufacturing Establishment Count



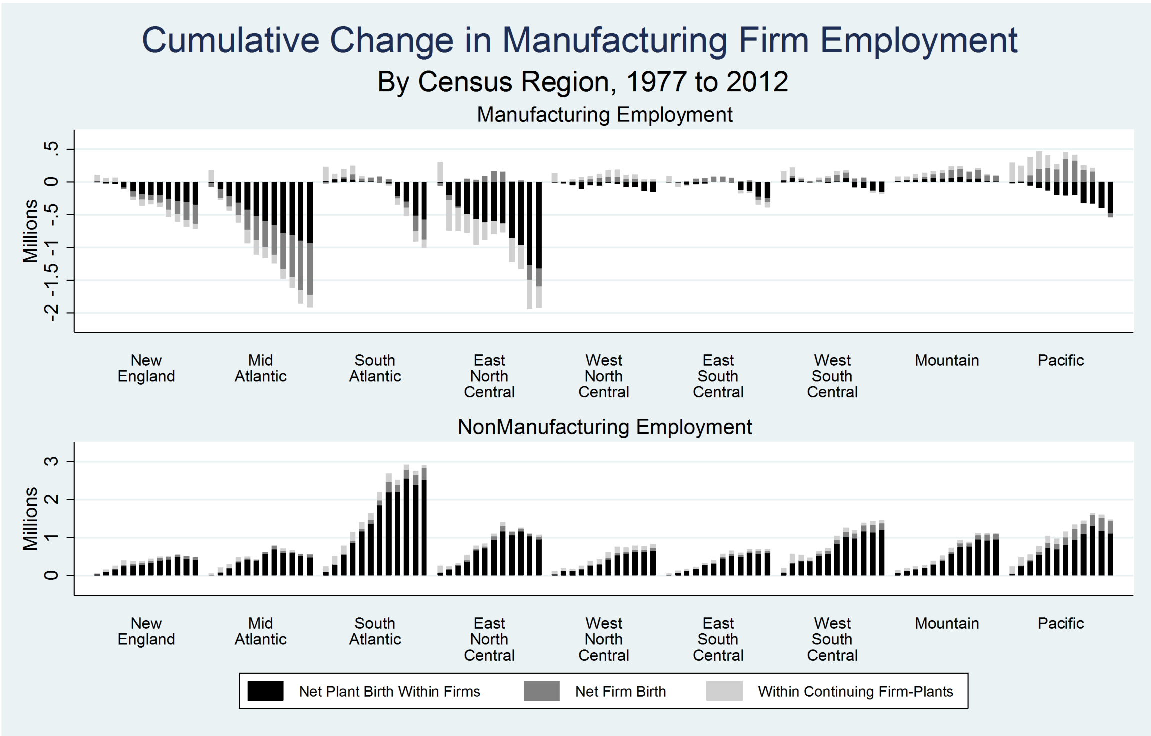
Source: Census of Manufactures and Longitudinal Trade Transactions Database and authors' calculations. Figure reports the results of cross-sectional regressions of noted firm characteristics on a dummy variable for noted firm activity. A separate regression is run for each Census year and activity. Point estimates and confidence intervals for a given activity are connected across years. The break in line for computer purchases in 1997 represents unavailable data in that year. Data for importing, importing robots, and use of electronic networks is not available before 1992, 1997 and 2002, respectively. In the right panel, the connection of the confidence intervals for computer purchases and importing in 1992 is coincidental.

Figure A.5: Technology Adopters' Size and Productivity Premia



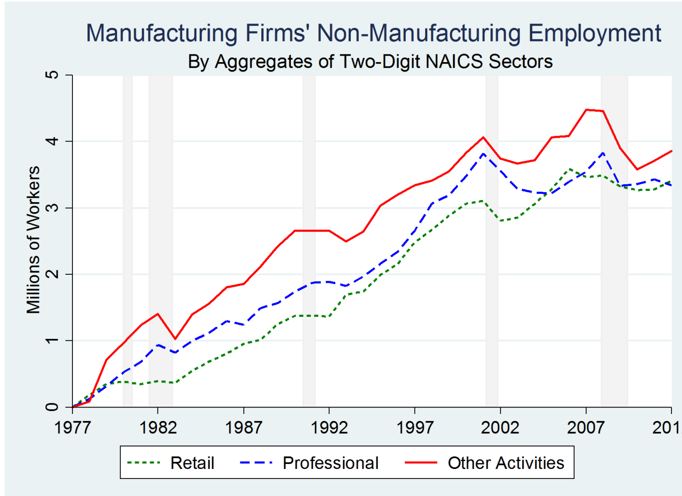
Source: Longitudinal Business Database and authors' calculations. Figure reports manufacturing firms' non-manufacturing employment across years and census regions. Years from 1977 to 1989, 1990 to 1999 and 2000 to 2012 are shaded black, dark grey and light grey, respectively. Census regions are defined as follows. New England: CT, ME, 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 A.6: US Manufacturing Firm Non-Manufacturing Employment, by Census Region



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 England: CT, ME, 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 A.7: US Manufacturing Firm Employment by Net Margin of Adjustment and Region



Source: Longitudinal Business Database and authors' calculations. Retail is NAICS sectors 44 to 45. Figure displays cumulative changes in manufacturing firms' non-manufacturing employment since 1977. 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. Gray bars indicate duration of recessions as determined by the NBER Business Cycle Dating Committee.

Figure A.8: US Manufacturing Firm Non-Manufacturing Employment, by Super NAICS Sectors