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New Perspectives on the Decline of US Manufacturing Employment

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US manufacturing since World War II exhibits three notable trends, illustrated in the two panels of Figure 1. First, manufacturing employment has diverged from non-manufacturing employment, as shown on different axes in Figure 1A. While both series moved 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 bottom 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.

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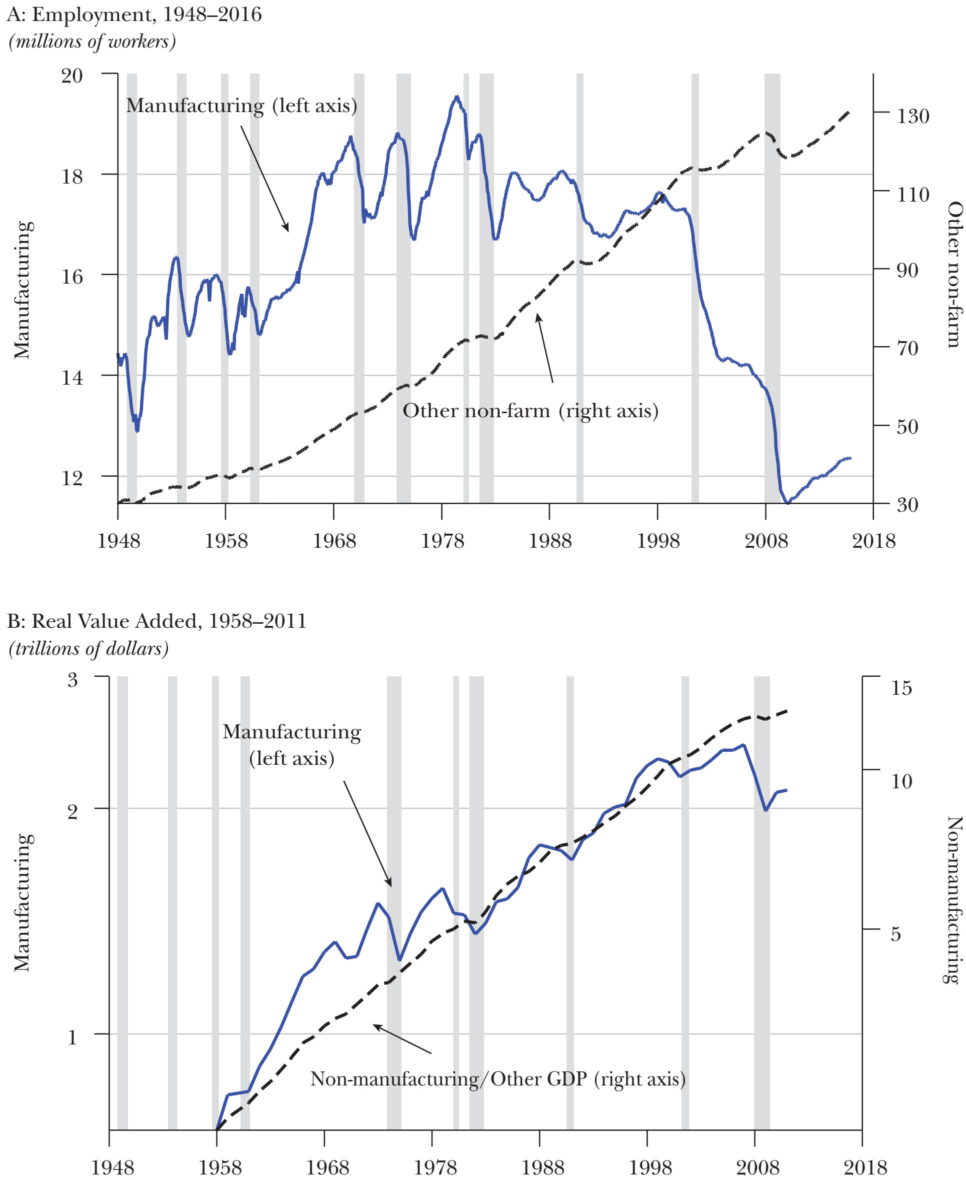
Figure 1
US Employment and Value Added within and outside Manufacturing



Source: Monthly employment data are from the US Bureau of Labor Statistics. Annual manufacturing real value added data are from NBER-CES Manufacturing Industry Database (Becker, Gray, and Marakov 2013). Annual real GDP data are from US Bureau of Economic Analysis. Non-manufacturing value added is real GDP less manufacturing real value added.
Note: Shading corresponds to NBER-dated recessions.

For a variety of reasons, including the perception that workers in manufacturing receive comparatively high wages conditional on education (Langdon and Lehrman 2012; Ebenstein, Harrison, McMillan, and Phillips 2014), these trends have stirred intense discussion among both policymakers and academics. This debate can be summarized broadly 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 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 nontariff 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] Second and more importantly, even if one could 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 by increased Chinese competition? What about employment and output at other producers of steel wire products, who face increased competition from both China

[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.

and from Marlin? These questions are even more difficult to answer if the availability of robots is itself 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 themselves—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 shuttering outmoded plants and opening new ones.

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," which refers to 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 the non-manufacturing employment of manufacturing firms increases until 2000—primarily via the addition of new non-manufacturing establishments—before leveling off. About one-third of this growth is in professional services, a trend that may represent an evolution of US manufacturing firms into "neuro-facturers" 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 United States but uses offshore contractors for assembly.

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 US 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]

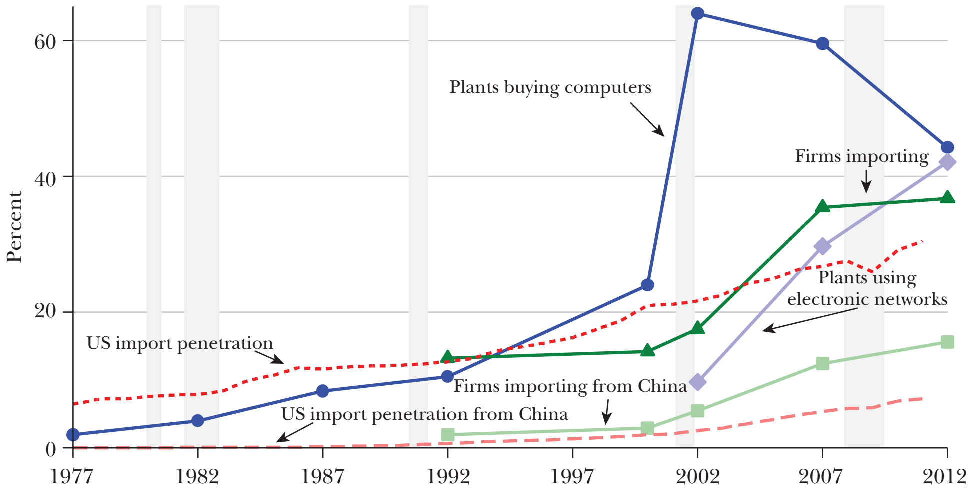
Figure 2 also reports several dimensions of trade activity. First, starting in 1992, we report the share of manufacturing firms that imports from any country as well as the share that imports from China, by census year. Here, as with our indicators of technology use, we see increases in the early 2000s. 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 real 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 costs, or foreign capital accumulation, that alter comparative advantage and the terms of trade. A complication associated with identifying such trade 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. Examining the US steel industry, Oster (1982) shows that large US producers were relatively slow in adopting new blast-furnace technologies

[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.

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

Figure 2
Technology Adoption and Importing in US Manufacturing Sector, 1977–2012



Source: Data on share of firms purchasing computers and using electronic networks are from the Census of Manufactures (1977, 1982, 1987, 1992, 2002, 2007 and 2012) and the Annual Survey of Manufactures (2000). Data on firm-level importing are from the Longitudinal Firm Trade Transactions Database. Electronic Networks include the internet and electronic data interchanges (Fort 2017). Import penetration data are from the NBER-CES Manufacturing Industry Database (Becker, Gray, and Marakov 2013), Feenstra (1996), and Schott (2008).
Note: "Plants buying computers" is the percent of US manufacturing plants purchasing computers during the year. "Plants using electronic networks" is the percent of US manufacturing plants using electronic networks to control or coordinate shipments. "Firms importing" is the percent of US manufacturing firms importing from any country. "Firms importing from China" is the percent of US manufacturing firms importing from China. "US import penetration" is manufacturing imports into the United States divided by real manufacturing domestic absorption in percentage terms, where domestic absorption is the sum of US manufacturing shipments and imports less manufacturing exports. "US import penetration from China" is defined analogously but restricts the numerator to imports from China. For penetration, industries are concorded from 1972 SIC codes to 1987 SIC codes in 1995, and from 1987 SIC codes to NAICS codes in 1997. Shading corresponds to NBER-dated recessions.

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 investigate 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 following decade, Pierce and Schott (2016) 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 nontraditional 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 that had been in place since the 1980s.

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 nontrade factors, such as secular declines in demand or common technology shocks. Bernard, Jensen, and Schott (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, Dorn, Hanson, and Song (2014) and Acemoglu, Autor, Dorn, Hanson, and Price (2015) 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. Acemoglu, Autor, Dorn, Hanson, and Price (2015) show that industries with higher growth in Chinese imports experience larger declines in employment between 1992 and 2007, and Autor, Dorn, Hanson, and Song (2014) find that workers in such industries experience relative declines in cumulative earnings. Regions with higher initial shares of employment in exposed industries also exhibit relative declines in the provision of public goods (Feler and Senses forthcoming) and marriage rates (Autor, Dorn, and Hanson 2018), as well as relative increases in household debt (Barrot, Loualiche, Plosser, and Sauvagnat 2017) and crime (Che and Xu 2016). These consequences carry over to health: Pierce and Schott (2017) 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 von 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, Dvorkin, 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, Rodríquez-Clare, and Yi (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–World War II 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 to 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, Manning, and Salomons (2014) and Autor, Dorn, and Hanson (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 (for example, Acemoglu 2002), that a new technology's invention or adoption may itself be in response to a trade shock. Bernard, Jensen, and Schott (2006), Khandelwal (2010), and Bernard, Redding, and Schott (2011) show that US firms respond to import competition in part by upgrading their product mix. Bloom, Draca, and Van Reenen (2016) find evidence of technology upgrading within and across European firms that were more exposed to Chinese imports. In the US context, Autor, Dorn, Hanson, Pisano, and Shu (2016) also find that Chinese import penetration affects the innovative activities of manufacturers, though they document a negative relationship.[4] Finally, interconnectedness is also found in the other direction. Fort (2017) and Steinwender (2018) show that innovations in communications technologies facilitate trade. When viewed as a whole, this research highlights the difficulties associated with clean identification of one force over another.

[4] In related research in labor economics, Clemens, Lewis, and Postel (2017) show that imposing restrictions on low-skill immigration induced adoption of more capital-intensive production techniques and shifts in product mix in the agricultural sector.

Reallocation of Employment and Value Added 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 21 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 (Figure 3A) and after (Figure 3B) 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. First note there are two sectors, Leather Products (316) and Apparel (315), that 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, Schott, and Wei 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]

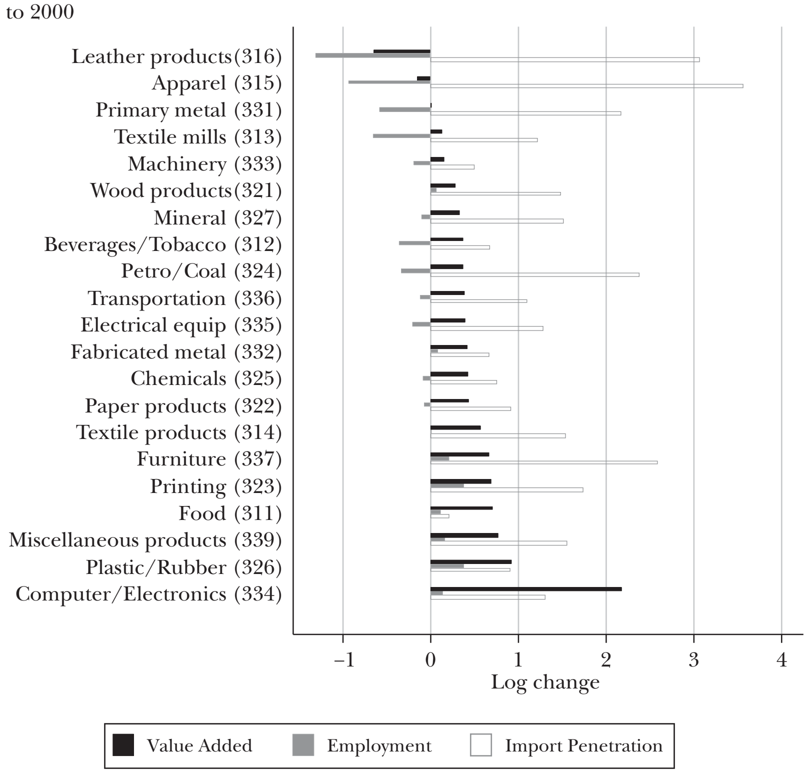
A second suggestive feature of Figure 3 is the increase in the number of sectors exhibiting simultaneous declines in real value added and employment in the panel B. Indeed, 52 percent of the 473 six-digit manufacturing industries that comprise manufacturing register such reductions between 2000 and 2007, 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 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 panel only), in which value-added rises even as employment falls. These divergent outcomes, and the large growth in

[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, Harrison, McMillan, and Phillips 2014; Oldenski 2014).

Figure 3
Change in Real Value Added, Employment, and Import Penetration Across Manufacturing Industries

A: 1977 to 2000



(continued on next page)

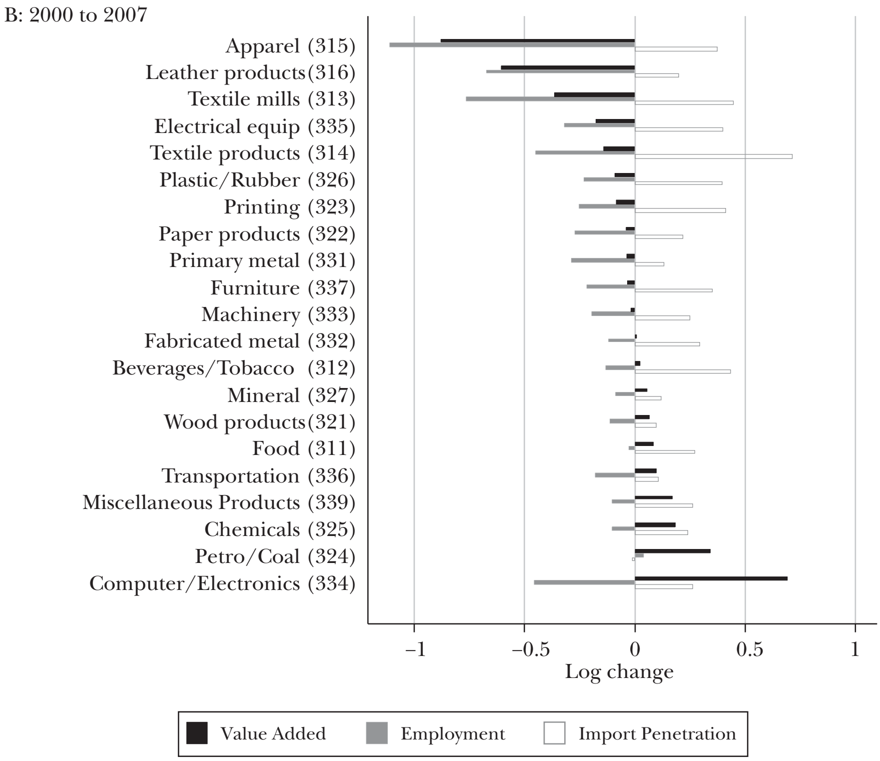
labor productivity they imply, suggest labor-saving technological change. In automobiles, for example, the replacement of workers with robots is widespread. On the other hand, to the extent that import competition induces selection away from low-labor-productivity industries within sectors, trade might 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, Kurz, Lengermann, and Mandel (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 within this sector in terms of aggregate real

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

Figure 3 (continued)

Change in Real Value Added, Employment, and Import Penetration Across Manufacturing Industries



Source: NBER-CES Manufacturing Industry Database (Becker et al. 2013), Feenstra (1996), Schott (2008) and authors' calculations.
Note: Real value added is deflated using shipment price deflators contained in the first source. Import penetration is real manufacturing imports divided by the sum of real shipments and real imports less real exports, in each case restricted to manufacturing industries. Industries are sorted by real value added growth over each period. Scales are different in each panel.

value-added growth 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, Jensen, Redding, and Schott 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, Fort, and Tintelnot (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, Fort, Smeets, and Warzynski (2018) also find that Danish firms exposed to increased import competition from China were more likely to offshore activities to Eastern Europe, which was associated with 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.

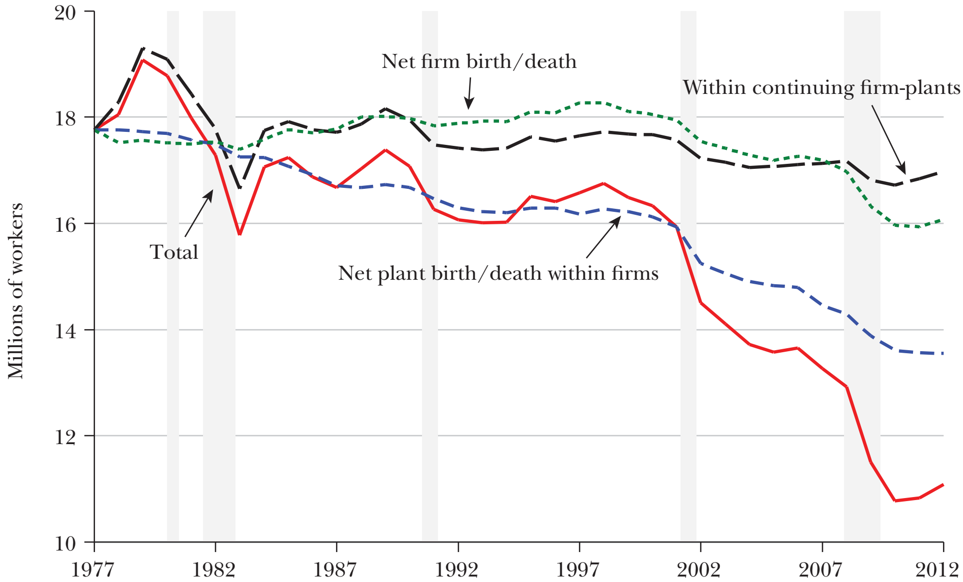
Reallocation of Employment Across and Within Firms

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, nonfarm 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 Longitudinal Business Database, our decomposition includes all firms observed to have at least one manufacturing establishment at any point during

[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 Longitudinal Business Database 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.

Figure 4
US Manufacturing Employment by Net Margin of Firm Adjustment



Source: Longitudinal Business Database and authors' calculations.
Note: Each line reports the change in employment along the noted net margin of firm adjustment relative to the firms and plants present in 1977. The shading corresponds to NBER-dated recessions.

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 each year along the margins of adjustment, in each case relative to the firms and plants present in base year 1977. 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

[8] We follow Haltiwanger, Jarmin, and Miranda (2013) and define a firm death as occurring when all establishments of a firm exit from the Longitudinal Business Database. 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.

the 6.7 million overall decline in manufacturing 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 (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 (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, as shown in online Appendix Figure A.3, we find that net firm *birth* accounts for the bulk of employment growth among non-manufacturing firms 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 online Appendix

[9] For example, Brynjolfsson and Hitt (2000) 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.

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?

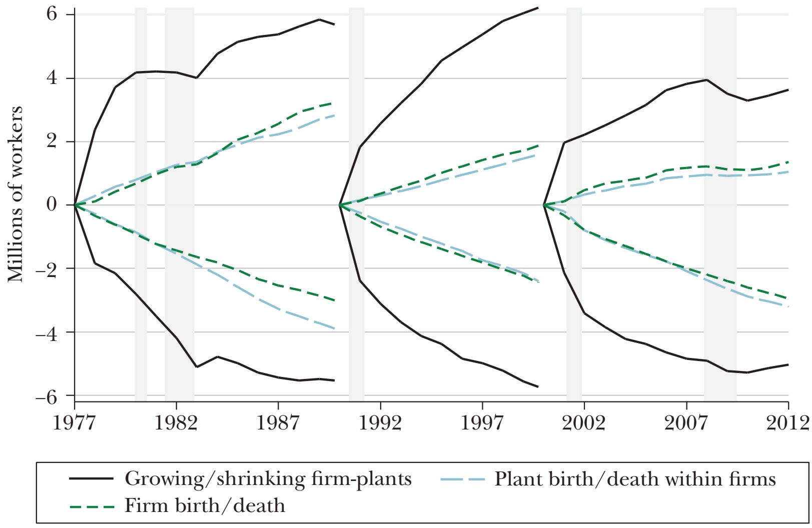
Simple descriptive regressions provide support for both trade and technology in plant turnover. For example, we find a negative correlation between the probability of a plant's death within a firm and the plant's purchases of computers. This correlation disappears after 2000, presumably due to the ubiquity 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 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 drop 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

[10] As discussed further in the online Appendix, 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 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.

Figure 5
US Manufacturing Employment by Gross Margins of Adjustment



Source: Longitudinal Business Database and authors' calculations.
Note: Lines above zero are gross job creation margins and lines below zero are gross job destruction margins. For example, the solid line above zero displays employment growth associated with expanding plants among continuing firms, while the 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. The shading corresponds to NBER-dated recessions.

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 in Figure 5 are computed with respect to their nearest prior base year. 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? To what extent are they related to 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 the online Appendix, 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 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 (Decker, Haltiwanger, Jarmin, and Miranda 2016). One potential explanation for this decline is a reduction in firms' responsiveness to productivity shocks due to rising adjustment frictions, such as regulatory constraints (Decker, Haltiwanger, Jarmin, and Miranda 2018), 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 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 the online 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 Restreppo (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, Jensen, Redding, and Schott 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, most productive firms find it optimal to incur.

Trade also may 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 (2012b) and Asquith, Goswami, Neumark, and Rodriguez-Lopez (2017) show that during the 2000s, industries with relatively greater exposure to trade liberalization with China exhibit both suppressed job creation as well as exaggerated job destruction. Relatedly, the decline in gross manufacturing job creation along the margins of firm birth and plant birth within continuing firms 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 online Appendix Figure A.4, using data from the Business Dynamics Statistics database referenced above, 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?

[12] These regressions are described in greater detail in the online Appendix.

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.

Reallocation of Employment across Regions

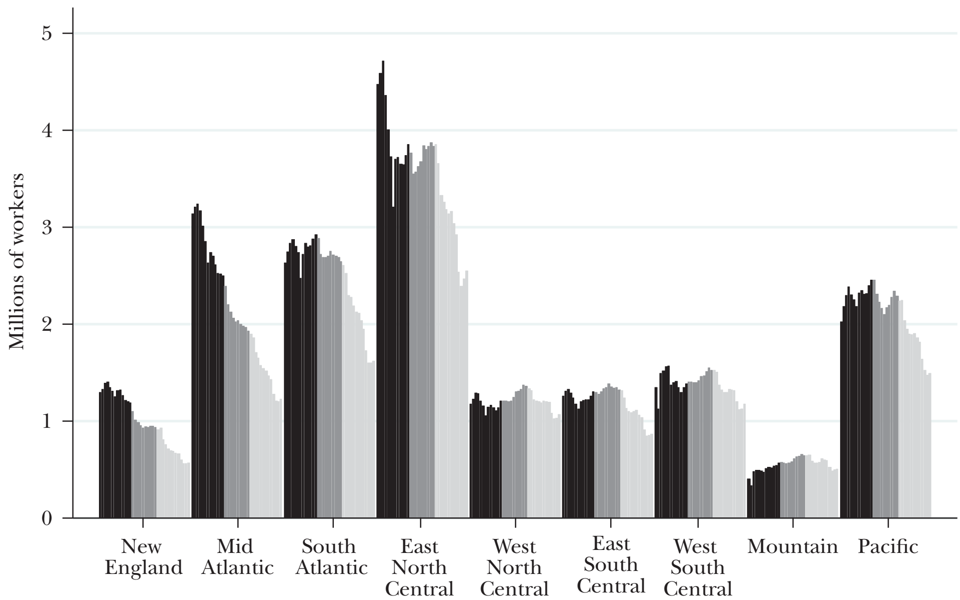
While a significant portion of the literature on both trade and technology has exploited regional variation in the distribution of manufacturing activities to identify causal impacts, plant and firm relocation within the United States remains a relatively unexplored dimension of firm adjustment to trade 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 the New England, Mid-Atlantic, and East North Central regions 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 the New England, Mid-Atlantic, and East North Central regions 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 the South Atlantic region (a drop of 38 percent).

Regions also display interesting variation in terms of the margins of firm adjustment. In results reported in online Appendix Figure A.7, we show that employment loss due to net firm death is concentrated in the New England and Mid-Atlantic regions, which together account for 16 percentage points of the overall 25 percentage point decline in US manufacturing employment attributable to that margin. The East North Central region, 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, Redding, and Schott (2013), for example, show that US labor markets exhibit substantial and persistent variation in relative skill endowments and wages over this period, and that

Figure 6
US Manufacturing Employment by Census Region, 1977–2012



Source: Longitudinal Business Database and authors' calculations.
Note: 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 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.

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 1999). 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. These right-to-work states are clustered in the South Atlantic, West Central, and Mountain regions, where 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 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?

The Non-Manufacturing Establishments of Manufacturing Firms

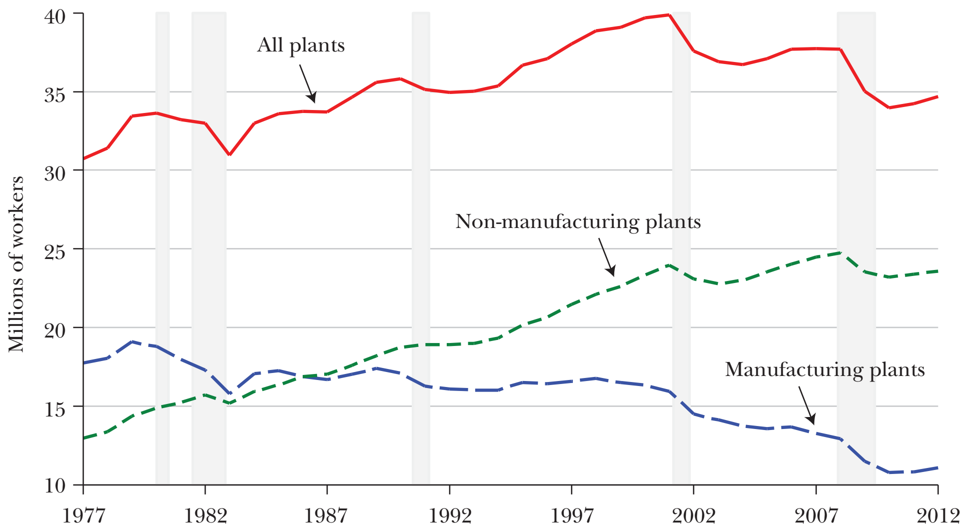
Manufacturing firms can also have non-manufacturing establishments. In this section we broaden our analysis to investigate how employment at manufacturing firms' non-manufacturing establishments has evolved, and in what non-manufacturing industries they participate. As noted earlier, in this paper we define a manufacturing firm broadly to encompass any firm observed to have at least one manufacturing establishment during our 1977 and 2012 sample period. The non-manufacturing employment of manufacturing firms, therefore, is simply the sum of employment at any non-manufacturing establishments owned by a manufacturing firm. While we focus on this comprehensive set of firms in order to capture all manufacturing 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 non-manufacturing employment we analyze here.

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

The growing share of manufacturing firm employment at non-manufacturing establishments might indicate that a growing number of workers at non-manufacturing establishments is needed to support manufacturing production, or that the scope of manufacturing firms is widening to include additional non-manufacturing activities, or simply that employment growth at firms' non-manufacturing establishments reflects the broader shift of US employment toward non-manufacturing

[13] In work not reported here, we find that the trends displayed in Figure 7 are sensitive to how manufacturing 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 non-manufacturing employment over the sample period. In addition, the growth of non-manufacturing employment at manufacturing firms, even with our broad definition of manufacturing firms, is slower than the growth of non-manufacturing employment at non-manufacturing firms. This differential is also worthy of further exploration.

Figure 7
Employment at Manufacturing Firms Decomposed into Employment at Manufacturing versus Non-Manufacturing Establishments, 1977–2012



Source: Longitudinal Business Database and author's calculations.
Note: Manufacturing firms are defined as any firm observed to have a manufacturing establishment during the sample period. The shading corresponds to NBER-dated recessions.

activities.[14] Further insight into these explanations comes from analysis of the particular activities occurring at non-manufacturing plants of manufacturing firms. Toward that end, we break non-manufacturing 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 non-manufacturing industries. Perhaps unsurprisingly, given the broad definition of manufacturing firms noted above, we find that about one-third of the overall growth in non-manufacturing employment of manufacturing firms 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

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

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 neuro-facturing (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). Consistent with this explanation, Magyari (2017) finds that in certain cases, US manufacturing firms expanded their non-manufacturing employment in response to import competition from China.

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 manufacturing firms' nonmanufacturing employment growth takes place in the western half of the United States, the South Atlantic exhibits the fastest pace of non-manufacturing employment growth by manufacturing firms, at 27 percent. Further analysis of the broader scope of US manufacturing firms' activities across both geographic and regional dimensions seems promising.

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, Hurst, and Notowidigdo (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 necessary.

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 mention some 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 firms that have died? 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 growth leads to a decrease in their total employment. Relatively high-skill professional workers—like designers and engineers—account for approximately one-third of the non-manufacturing workers added by manufacturing firms. Are incumbents firms better suited to engage in these activities? Does the greater focus of manufacturing firms 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; incumbent and non-incumbent firms; 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.

■ *Any opinions and conclusions expressed herein are those of the authors and do not necessarily represent the views of the US Census Bureau, the Board of Governors, or its research staff. All results have been reviewed to ensure that no confidential information is disclosed. Part of this research was conducted while Teresa Fort was a Peter B. Kenen Fellow in the International Economics Section at Princeton University. She thanks the IES for financial support. We thank the editors for comments and Jim Davis for his exceptional help with the disclosure review process.*

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