

# Relative Prices, Hysteresis, and the Decline of American Manufacturing

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## Abstract

This study uses new measures of real exchange rates to study the collapse of US manufacturing employment in the early 2000s in historical and international perspective. To identify a causal impact of RER movements on manufacturing, I compare the US experience in the early 2000s to the 1980s, when large fiscal deficits led to a sharp appreciation of the dollar, and to Canada's experience in the mid-2000s, when high oil prices and a falling US dollar led to an equally sharp appreciation of the Canadian dollar. Using disaggregated sectoral data and a difference-in-difference methodology, I find that an appreciation in relative unit labor costs for the US led to disproportionate declines in employment, output, investment, and productivity in relatively more open manufacturing sectors. I also find that the impact of a temporary shock to real exchange rates is surprisingly long-lived (evidence of hysteresis), and that the appreciation of US relative unit labor costs can plausibly explain more than two-thirds of the decline in manufacturing employment in the early 2000s.

***JEL Classification:*** F10, F16, L60

***Keywords:*** Exchange Rates, American Manufacturing, Hysteresis, Trade

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American manufacturing employment suddenly collapsed in the early 2000s, falling by three million (17.4%) from 2000 to 2003 (Figure 1)<sup>1</sup> after declining by just 3% from the late 1960s to 2000.<sup>2</sup> As the economy grew from 2003 to 2007, the lost jobs did not return.

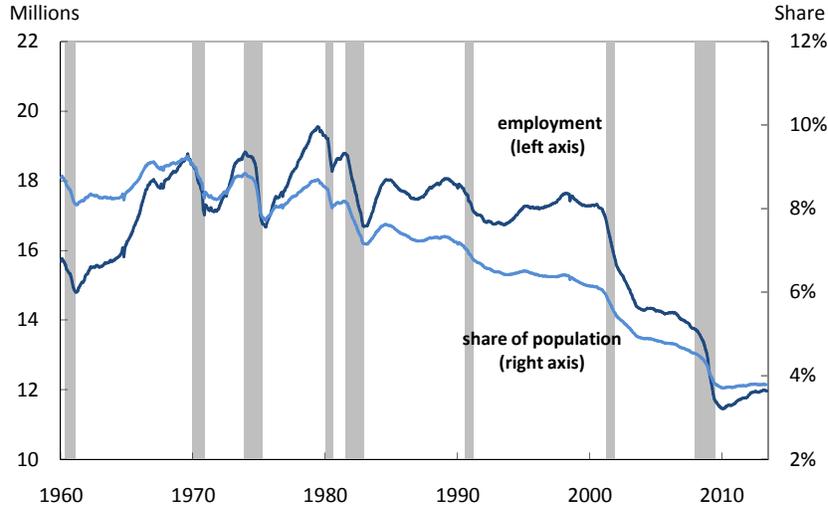


Figure 1: American Manufacturing Employment, 1960-2013.

Source: BEA

What caused the sudden collapse? Economists generally believe that answer is out-sized productivity gains in manufacturing and a sectoral shift toward services.<sup>3</sup> However, aggregate labor productivity growth in manufacturing has remained relatively constant over the post-war period, whereas productivity for the median manufacturing sector *declined* in the 2000s.<sup>4</sup> Additionally, the decline in the services share of consumption from its average in the late 1990s to 2005 was just .5% of GDP (Table 8), whereas the services share of exports surprisingly has remained constant over the past few decades

<sup>1</sup>A plot of the manufacturing share of total employment also indicates that manufacturing employment was below trend in the 2000s, although it is less obvious. Yet, this could be misleading. If any location, (*e.g.*, Detroit) loses 50% of its tradable-sector jobs then eventually 50% of the non-tradable sector jobs may also be lost. In this case the (unchanging) share of manufacturing jobs is not informative.

<sup>2</sup>If one extrapolates from the trend in manufacturing employment as a share of the population from 1970 to 2000, then manufacturing employment becomes *negative* by 2065. Thus, it is more natural to expect the decline in manufacturing employment as a share of the population to slow over time, as has been the case in agriculture.

<sup>3</sup>*E.g.*, Baily and Bosworth, 2014; Edwards and Lawrence, 2013; Kehoe, Ruhl, and Steinberg, 2014; Alessandria and Choi, 2014

<sup>4</sup>Houseman *et al.* (2010) present evidence that perhaps one-fifth to one-half of the measured growth in manufacturing value-added per worker from 1997 to 2007 reflects upward bias caused by the dramatic increase in low-priced imported intermediate inputs. Houseman (2014) notes that, excluding computers, US manufacturing output increased just 7% from 1997 to 2012, an historical anomaly.

(Figure 16(b)).<sup>5</sup>

These facts support recent research on trade liberalization and the rise of China as explanations for the collapse of US manufacturing. In a seminal contribution, Autor, Dorn, and Hanson (2013) find that increasing competition with Chinese imports explains one-quarter of the aggregate loss in manufacturing employment through 2007. Acemoglu *et al.* (2015) argue that the “sag” in *overall* U.S. employment in the 2000s, a decade which began with the Federal Reserve narrowly missing the zero lower bound and which ended with the US mired in a liquidity trap, was partly caused by the collateral damage from increasing Chinese manufacturing imports to other sectors via input-output linkages. Pierce and Schott (2015) find that China’s accession to the WTO caused a flood of imports and the “surprisingly swift” decline in U.S. manufacturing employment.<sup>6</sup>

A second strand of literature studying the impact of real exchange rate movements on manufacturing mostly finds that manufacturing employment is sensitive to currency appreciations (Klein, Schuh, and Triest 2003; for an overview see Klein *et al.* 2002).<sup>7</sup> Although the dollar appreciated sharply from 1996 to 2002, to my knowledge these two strands of literature – on the manufacturing collapse in the early 2000s and the impact of exchange rate movements – do not intersect. This paper shall therefore endeavor to fill the gap by asking how much of the collapse in manufacturing in the early 2000s can be explained by movements in relative prices. The answer is that the dollar’s appreciation in the early 2000s, in conjunction with the rise of China, China’s WTO accession, and the ending of textile quotas, is large enough, with the help of input-output linkages, to explain most if not all of the collapse in manufacturing employment and output.

To identify a causal effect of RER movements on manufacturing, I compare the US experience in the early 2000s to the 1980s, when large US fiscal deficits led to a sharp appreciation in the dollar, and to Canada’s experience in the mid-2000s, when

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<sup>5</sup>In fact, the services trade surplus actually shrank by one-third from 1997 to 2004, while the goods trade deficit excluding manufacturing worsened. Thus, the decline in manufacturing in the early 2000s was actually part of a broad-based decline in tradable sectors.

<sup>6</sup>Ebenstein *et al.* (2012) also document a series of facts consistent with the idea that Chinese import competition reduced US manufacturing employment. Autor, Dorn, Hanson and Song (2014) look at worker-level evidence of the impact of the rise of China, while Autor, Dorn, and Hanson (2014) untangle the relative impacts of trade and technology, finding that trade had a large negative impact on manufacturing employment but not on technology. Charles *et al.* (2013) argue that temporary housing bubbles in some local labor markets masked the employment declines associated with manufacturing, yet find that 40% of the increase in non-employment in the 2000s was caused by the decline in manufacturing.

<sup>7</sup>Other key papers in this literature are Branson and Love (1986), (1987), and (1988), Gourinchas (1999), and Campa and Goldberg (2001) for the United States, Berman *et al.* (2012), Moser *et al.* (2012), and Belke *et al.* (2013) for Europe, and Dai and Xu (2015) for China. Chen and D Rose (1991) and McKinnon and Schnabl (2006), by contrast, find no impact of real exchange rate movements on trade, so this question is not settled.

high oil prices and a depreciating US dollar led to an equally sharp appreciation of the Canadian dollar. Both of these periods contained large RER movements which I argue were likely to be exogenous from the perspective of the manufacturing sector. In particular, there is no theoretical or intuitive reason to expect that manufacturing employment collapses would cause a currency to appreciate – one would expect precisely the opposite. Nevertheless, I use a panel difference-in-difference research design using substantial variation in initial exposure to trade across sectors and in real exchange rates over time to identify the impact of currency appreciations on manufacturing sectors with differential exposure to international trade. This allows me to make a weaker identifying assumption – that collapses in relatively more tradable manufacturing sectors do not cause relative price appreciations. Defining openness using a weighted average of import penetration and the export share of shipments<sup>8</sup>, I find that when relative unit labor costs in manufacturing are high, more open sectors experience a relative decline in employment and output. This result holds even when RER appreciations are proxied by the structural budget balance in the US case, or by oil prices for Canada. However, I find that the jobs lost during the previous appreciation do not return even after US relative prices return to fundamentals. When relative prices are elevated, I find evidence of increased job destruction and suppressed job creation, and also find relative declines in investment, shipments, and value-added, and a modest decline in production worker hourly wages. I do not find evidence of a significant impact on inventory, sectoral prices, or non-production worker hourly wages.

Second, I add an international dimension to the “difference-in-difference” framework, asking whether more open manufacturing sectors in the US lose employment when the dollar is strong relative to the same sectors in other major economies.<sup>9</sup> This is an important test, because if the decline in manufacturing employment in the 2000s was caused solely by the rise of China for reasons unrelated to relative prices, then other major economies, such as Canada, should also have had employment declines in the same sectors at the same time (they did not). In fact, from 1998 to 2003, as US manufacturing employment was collapsing, Canadian manufacturing employment actually increased. Once the Canadian dollar appreciated sharply later in the 2000s, Canadian manufacturing employment then promptly collapsed, with the losses concentrated in more open sectors.

Third, I introduce the anecdote of Japan as a quasi-experiment with a large and

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<sup>8</sup>The precise definition is:  $openness = m * (imports / (imports + shipments - exports)) + (1 - m) * (exports / shipments)$ , where  $m = imports / (imports + exports)$ . This measure varies between 0 and 1, which is preferable to the trade share of shipments as it varies between 0 and 89.

<sup>9</sup>I thank Thomas Wu for this suggestion.

plausibly exogenous policy-related movement in real exchange rates in the 1980s. I find that although Japanese industries gained market share in the US when the yen was weak, Japanese industries consolidated their gains but did not make further inroads after the Yen appreciated sharply vs. the dollar. This is further evidence of hysteresis.

A paper linking real exchange rates to the collapse in US manufacturing employment has not been written, likely because of a subtle but crucially important measurement issue: the Federal Reserve’s Broad Trade-Weighted Real Exchange Rate Index, the most commonly-used measure of international competitiveness for the US, suffers from an index numbers problem. It is computed as an “index-of-indices,” which does not reflect compositional changes in trade toward countries, such as China, with systematically lower price levels (Thomas, Marquez, and Fahle 2008, and Campbell 2016). The Fed’s RER index implies that the appreciation in the dollar from 1996 to 2002 was slightly more modest than the dollar appreciation in the 1980s, and yet (ostensibly a paradox) gave rise to a much larger trade deficit as a share of GDP (plotted ex-oil in Figure 2).<sup>10</sup> By contrast, a simple trade-weighted average of relative prices (WARP) using version 8.1 of the Penn World Tables implies a much larger dollar appreciation in the early 2000s, mirroring the trade balance much more closely. The difference is mostly due to two factors: the rising share of trade with countries with relatively low price levels, such as China, and the multiple benchmarking used in the creation of PWT version 8.0 and 8.1.<sup>11</sup>

Traditionally, economists have thought that real exchange rate indices computed using unit labor costs, which reflect labor costs relative to productivity, are the best price-based measure of international competitiveness (Turner and Van’t Dack 1993). However, relative unit labor cost indices produced by the IMF and OECD have several drawbacks, including that they are computed as indices-of-indices, and thus do not properly account for compositional changes in trade with countries, such as China, that have systematically lower unit labor costs.<sup>12</sup> Additionally, China and many other developing

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<sup>10</sup>The Fed’s real exchange rate index is:  $I_t^d = I_{t-1} \times \prod_{j=1}^{N(t)} \left( \frac{e_{j,t} p_t / p_{j,t}}{e_{j,t-1} p_{t-1} / p_{j,t-1}} \right)^{w_{j,t}}$ , where  $e_{j,t}$  is the price of a dollar in terms of the currency of country  $j$  at time  $t$ ,  $p_t$  is the US consumer price index at time  $t$ ,  $p_{j,t}$  is the consumer price index of country  $j$  at time  $t$ ,  $N(t)$  is the number of trading partners, and  $w_{j,t}$  is the trade weight of country  $j$  at time  $t$ . The base year value of the index is arbitrary.

<sup>11</sup>These factors also suggest the superiority of WARP, as China’s rising share of US trade does not affect the Fed’s index. The Fed’s use of country-specific deflators also becomes problematic as these data were collected using different methods and could become biased over time. WARP using version 8.1 of the PWT suffers from neither of these problems.

<sup>12</sup>These issues are explained in more detail in Campbell (2016), who notes that RER indexes computed as indices-of-indices lack theoretical foundations, as they imply that only *changes* in prices matter. By contrast, in most standard theoretical models, relative prices matter. Another important problem with the IMF and OECD series is that manufacturing output is deflated using country-specific deflators

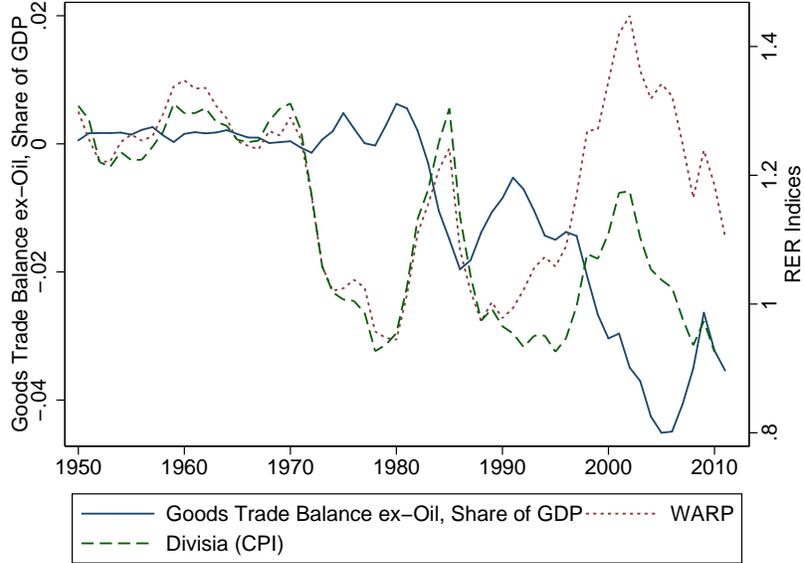


Figure 2: Real Exchange Rate Measures vs. the Current Account  
Sources: BEA and Campbell (2016)

countries are not even included in the IMF’s Relative Unit Labor Cost (RULC) index, which also uses fixed trade weights that have become outdated.

In this paper, I address all of these concerns by using a Weighted Average Relative Unit Labor Cost (WARULC) index computed for the manufacturing sector using data from all six benchmarks from the World Bank’s International Comparison Project (ICP), and which includes developing countries such as China.<sup>13</sup> I find that this index accurately predicts manufacturing employment declines. I also find similar results using other RER measures in the class of “weighted average relative” (WAR) exchange rates such as the WARP index created by Thomas *et al.* (2008) or the Balassa-Samuelson adjusted WARP index created by Campbell (2016).<sup>14</sup>

One puzzle is that RER appreciations have led to declines in employment, whereas depreciations do not seem to help. The solution to the puzzle is that what matters for employment is the level of US relative unit labor costs, rather than the change.<sup>15</sup>

(constructed idiosyncratically), which can lead to bias over time without the use of multiple benchmarks. This same problem afflicts older vintages (predating version 8.0) of the Penn World Tables.

<sup>13</sup>I am greatly indebted to Professor Paul Bergin for suggesting that I apply the Thomas *et al.* (2008) insight to unit labor costs.

<sup>14</sup>The details of the construction of these indices are included in a companion paper by Campbell (2016).

<sup>15</sup>The US has not been undervalued in the past 50 years, perhaps not surprising for a developed country with advanced financial institutions, an open capital market, and a freely floating hard currency. Thus, the periods when the dollar falls correspond to periods in which the level of ULCs are the same as those for US trading partners, whereas the periods of appreciation correspond to periods when US

Conceptually, it is easy to understand that if unit labor costs were the same in the US and in China, then there would be no economic reason to move production, particularly as this could entail substantial fixed costs. On the other hand, when US unit labor costs are 50% higher than they are for trading partners, there is a clear economic incentive to shift production, since firms already located abroad would have a competitive advantage. This finding should not be surprising in light of the central tenet of economics, that prices matter. I also propose a corollary: in a world with sunk costs, historical prices can affect current economic outcomes. Empirically, I find strong evidence that temporary shocks to relative prices have persistent effects on the manufacturing sector. Indeed, the observation that improvements in the US aggregate trade balance lagged the depreciation of the dollar in the late 1980s spawned a large theoretical literature on hysteresis. Progenitors of increasing returns and new trade theory, including Dixit (1989a, 1989b, 1991, 1992), Krugman (1987, 1988), Krugman and Baldwin (1987, 1989), and Baldwin (1988, 1990), all weighed in with multiple contributions. By contrast, more recently, New Trade Theory models often omit sunk costs and make scant reference to path-dependence.<sup>16</sup> Nevertheless, Figure 2 shows that the 1980s pattern is also apparent in the 2000s. US relative prices have become steadily more competitive since 2002. Yet, while the trade deficit shrank due to declining domestic demand during the recession, as demand began to recover by 2011, the trade deficit worsened and lagged behind the improvement in relative prices. The chief contribution of this paper is documenting hysteresis at a disaggregated level for 437 SIC manufacturing sectors for both the 1980s and the 2000s.

A second important finding is that the measured elasticity of manufacturing employment with respect to changes in relative unit labor costs, and the magnitude of the appreciation in relative prices, are large enough to explain the loss of 2.1 million manufacturing jobs directly from 1995 to 2008.<sup>17</sup> If the impact of changes in trade policy, such as China's WTO accession and the expiration of textile quotas, are also taken into account, the total estimate of jobs lost due to trade reaches 2.9 million by 2008.<sup>18</sup> These

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RULCs are higher than those for trading partners.

<sup>16</sup>With some notable exceptions, including Alessandria and Choi (2007, 2014a, 2014b) and Roberts and Tybout (1997) who find evidence for sunk fixed costs of exporting. Campbell (2010, 2013), Eichengreen and Irwin (1998), and Head, Mayer and Ries (2010) also highlight the importance of history for trade. Blanchard and Summers (1986) and Katz (2009) make strong cases for hysteresis in aggregate employment.

<sup>17</sup>While this is a large number, keep in mind that Campbell (2016) shows that, in 2002, the US price level had not been as richly valued relative to trading partners since the worst year of the Great Depression.

<sup>18</sup>One caveat here is that the NBER-CES version of the Annual Survey of Manufactures using SIC data used to derive these estimates also shows somewhat more severe job losses than the establishment

estimates are more than three times as large than the direct estimates produced by Acemoglu *et al.* (2015) for the period from 1991 to 2011. Finally, although economists have long taught crowding out due the impact of fiscal deficits on real interest rates, the results I present suggest that deficit spending may have the strongest effect on the most tradable sectors via relative prices.<sup>19</sup>

## 1 Empirical Approach

RER movements are potentially endogenous to manufacturing employment and output. Exchange rates are also influenced by various macroeconomic forces which also may impact manufacturing. I employ a variety of methods, including a repeated difference-in-difference research design using disaggregated data, out-of-sample testing, the use of RER proxies, and falsification tests in order to mitigate these problems and attempt to identify a causal effect of RER movements on manufacturing.

I first employ a difference-in-difference method, comparing the evolution of employment in the most open sectors vs. less open sectors when the RER, measured by a Weighted Average Relative Unit Labor Cost (WARULC) index for manufacturing, appreciates. The research design is displayed in Figures 3 and 4 as event studies of the 1980s and early 2000s. In Figure 3, the evolution of employment indices by fixed categories of openness (the most open vs. less open sectors) in 1972 is plotted vs. WARULC for the manufacturing sector. Using initial openness in 1972 effectively rules out the possibility that an employment collapse in relatively more open sectors itself increased openness, as an employment collapse in some manufacturing sectors in 1985 could not have caused these same sectors to be more open in 1972. The employment index for each sector is given a base year value of 100 in 1979, and then updated based on changes in employment not due to changes in demand or productivity, or to general movements in all sectors for each year.<sup>20</sup> The pretreatment trends of the top 25% most open sectors

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figures provided by the BEA and plotted in Figure 1, so that that my results do not show t. On the other hand, this figure does not include input-output linkages. Acemoglu *et al.* (2015) estimate a multiplier of about 1.7 for the input-output linkages to affect other manufacturing sectors, and a full economy multiplier of about 3.55. This would suggest a staggering 5 million jobs lost in manufacturing, and over 10 million lost overall. While these numbers appear too large, even if we were to cut these estimates in half, the conclusion would hold that trade shocks had a large impact on the economy in the early 2000s.

<sup>19</sup>I also provide a theoretical motivation in the online appendix, where I sketch a variation of the Melitz (2003) model, and show that sunk costs lead to a dynamic gravity equation (also a new result).

<sup>20</sup>*I.e.*, first I ran the regression:  $\ln \Delta L_{ht} = \alpha_t + \beta_2 \ln \Delta D_{ht} + \beta_2 \ln \Delta (VA/P)_{ht} + \epsilon_{ht}$ ,  $\forall t = 1973, \dots, 2009$ . Then I updated sectoral indices normalized to 100 in 1979 based on the residuals from this regression. Lastly, I plotted the average of these indices separately for the most open and less open sectors. The goal

in 1972 are very similar to the least open 50% of sectors.<sup>21</sup> Yet, when the dollar appreciated in the 1980s, the more open sectors lost roughly 10% of their employment relative to the least open sectors. This result makes intuitive sense given that labor costs were more than 40% of value-added for the average sector during this period. Thus a 50% increase in relative unit labor costs should have had a differential impact on more exposed sectors. Interestingly, after the dollar returned to fundamentals in the late 1980s, this differential impact decayed very modestly, if at all.

Given that the main cause of the appreciation in relative prices in the 1980s was large government deficits, which are arguably exogenous from the perspective of manufacturing employment, this episode deserves to be a canonical example of hysteresis. This is especially the case since an employment (and output) collapse in the most tradable manufacturing sectors should endogenously lead to a RER *depreciation* rather than an appreciation.<sup>22</sup> Thus, in this case endogeneity should lead to a bias in the direction of not finding anything. If the large estimated negative impact of RER appreciations on manufacturing employment is in fact a floor, the results in this paper would only be more salient. In addition, exchange rates impact trade and manufacturing employment with a lag. Thus, it is not clear why an employment collapse in more tradable sectors in 1986 should cause a dollar appreciation at all, but much less in 1985. However, again, this logic does not necessarily mitigate against third factor causality.

The appreciation in the late 1990s and early 2000s (Figure 4) suggests a similar story – steep losses in the early 2000s which then reverted to previous levels only gradually. While the magnitudes appear smaller, this is partly because even the most closed sectors were much more open in the 2000s than the 1980s. In both periods, the declines in more open sectors occurred at the same time as declines in aggregated “structurally adjusted” manufacturing employment (Figure 16 in the appendix).<sup>23</sup>

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is to understand how employment evolved in the most open vs. the least open sectors after controlling for demand and productivity.

<sup>21</sup>In addition, the results are not sensitive to the choice of cutoffs. In the panel regressions which follow, I use continuous measures of openness.

<sup>22</sup>Thus far, it should be said, that many referees disagree with this assessment, as several have argued that both openness and employment are “endogenous”. However, while I agree that endogeneity is “almost always” a problem in empirical trade research, to gauge whether it is a problem in individual cases, it is necessary to spell out the mechanisms by which endogeneity could threaten a result. In this case, it is not clear how an employment decline in 1985 could have possibly led to the same sectors being more open in 1972, nor did they explain why a decline in employment (and output) of more open sectors would lead to a currency appreciation rather than a depreciation. Note that this argument does not apply to third-factor causality or omitted variables, but I see these as separate issues from endogeneity.

<sup>23</sup>“Structurally adjusted” employment was computed at quarterly intervals by subtracting implied employment changes based on movements in GDP from a regression of quarterly changes in manufacturing employment on changes in GDP and lagged changes in the Fed’s Broad Trade-Weighted RER

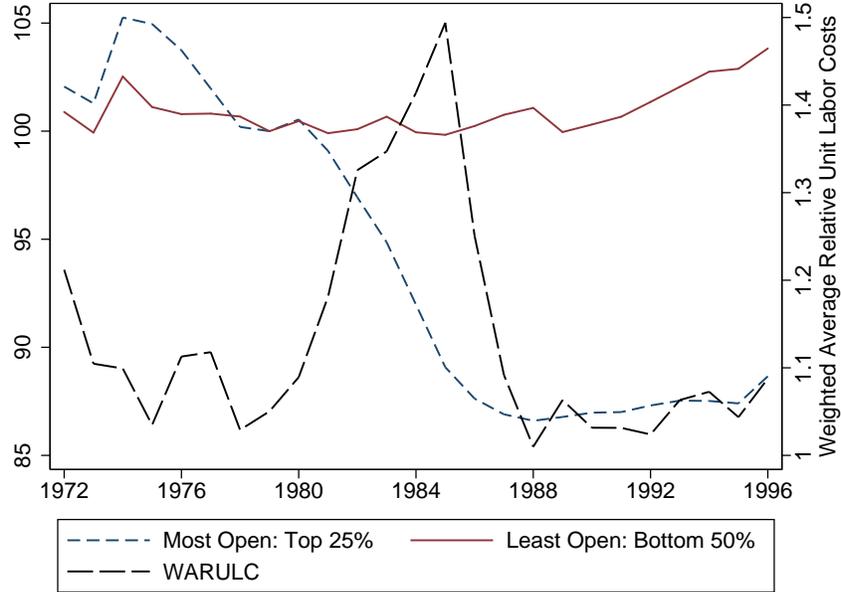


Figure 3: Employment Growth by Degree of Openness in 1972 (SIC)\*

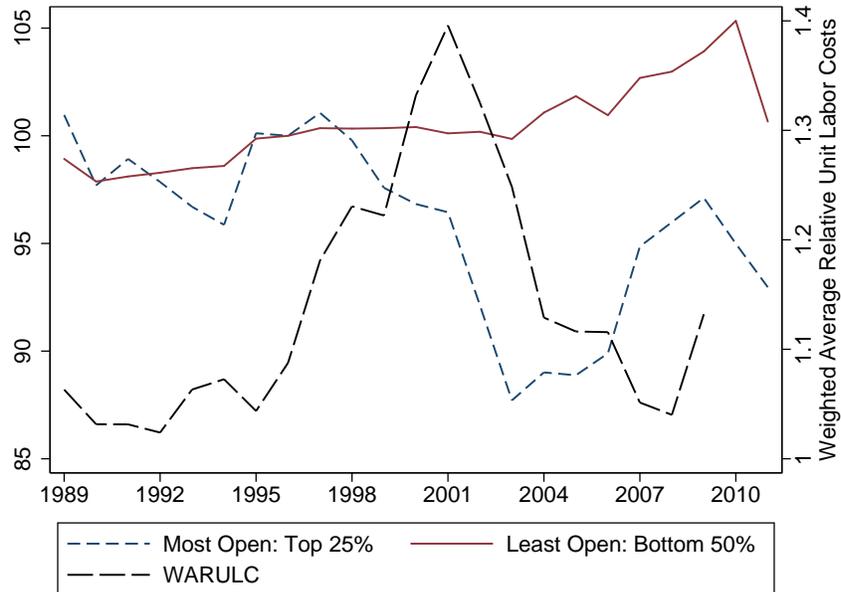


Figure 4: Employment Growth by Degree of Openness in 1989 (NAICs)\*

\*Notes: Employment is indexed to 1979 in Figure 3, which uses SIC data, and to 1996 in Figure 4, which uses NAICs data, and is updated with residuals from a regression controlling for demand, productivity, and year fixed effects. Thus the blue dashed lines in the figures tell us how employment in initially more open sectors evolved after controlling for other key factors. Openness =  $m \cdot \text{imports} / (\text{imports} + \text{shipments} - \text{exports}) + (1 - m) \cdot (\text{exports} / \text{shipments})$ , where  $m = \text{imports} / (\text{imports} + \text{exports})$ . The cutoff for the non-open sectors was 3.8% in 1972 and 9.7% in 1989, and the lower bound for the open sectors was 8.3% in 1972 and 20.9% in 1989. A version including error bounds in the appendix (Figure 22) shows that open sectors experienced a significant decrease in employment.

There is also a serious risk that a third factor could cause both an exchange rate appreciation and a decline in manufacturing. The general solution to this problem is to control for obvious third factors in a panel “difference-in-difference” setting using disaggregated data that tests explicitly whether an appreciation in the RER causes a decline in relatively more open manufacturing sectors (where a continuous measure of openness is defined at a several year lag so that it itself is not endogenous). For example, one might be concerned that high real interest rates (RIRs) could cause an appreciation of the RER and a decline in manufacturing employment. In this case, it is straightforward to include the RIR as a control variable, along with the RIR interacted with sectoral capital intensity and openness, as more capital-intensive or open sectors could potentially be more sensitive to movements in the RIR. However, in fact import-competing sectors tend to be less capital intensive and appear to be less sensitive to movements in the RIR than other sectors. In addition, RIRs were at historic lows during the collapse of manufacturing in the early 2000s. Although RIRs were high in the early 1980s, the timing of the peak in RIRs does not match the 1980s collapse in manufacturing as well as relative prices.

Another plausible third factor is that perhaps China was simply growing fast in the early 2000s for a variety of reasons unrelated to relative prices, and this alone caused the collapse. Yet, US imports from countries other than China increased by more than Chinese imports in the early 2000s, suggesting that China is unlikely to be the only factor.<sup>24</sup> Even so, it is plausible that China’s growth had causes other than relatively low unit labor costs (wages relative to productivity), the chief measure of the RER used in this paper. These factors include China’s accession to the WTO and the MFA agreement, both of which I find had significant effects when I control for them separately. Also note that factors which increased the productivity of China’s manufacturing sector, such as improvements in infrastructure, the institutional environment, educational attainment, learning-by-doing over time as rural workers become accustomed to factory work, government subsidies, and the suppression of labor unions are all be forces that would lower China’s relative unit labor costs (RULCs). Even so, RULCs admittedly may not capture the impact of these various factors perfectly.

An alternative way to test the “it’s just China” hypothesis is to add a third dimension to the “difference-in-difference” regression, and ask whether more open sectors in the US do worse relative to more open sectors in other major economies when US RULCs are

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Index. This index was used because it has data at quarterly intervals.

<sup>24</sup>It is also true that Chinese imports were increasing at a faster pace, but Chinese imports started from a much lower base.

high. If fast export growth from China regardless of relative prices was the cause of the collapse, then other major economies, such as Canada, should have been adversely affected at the same time. I find that they were not. The case of Canada, given that its geographic exposure to Chinese competition is similar to that of the US, provides a particularly illustrative example. When the US dollar was strong in the late 1990s and early 2000s, Canadian manufacturing was increasing even as US manufacturing was collapsing. Then the US dollar began to fall and the Canadian dollar began to rise, strengthened by rising oil prices. Soon after, Canadian manufacturing experienced its own collapse.

Single “difference-in-difference” regressions can fail when researchers omit key variables that happen to coincide with the treatment, resulting in spurious correlation. This problem is prevalent in part because it is often not obvious in advance what factors are really driving a spurious result. While this is a ubiquitous problem, a general mitigating strategy is to use a “repeated difference-in-difference” research design, which repeats the usual “difference-in-difference” method in different time periods and places, effectively testing out of sample. While still not foolproof, repeated difference-in-difference regressions dramatically reduce the number of potential variables that could be perfectly correlated with the treatment. In this case, such a variable would have to be strongly correlated with the US, Canadian, and Japanese RERs over a period of decades. In addition, in each year this omitted variable needs to be strongly correlated with openness by sector. While such a variable may exist, the repeated element of the difference-in-difference methodology make this a high hurdle. Spurious results have a well-known tendency not to hold out of sample.

Another method to reduce the probability of endogeneity, omitted variables, or spurious correlation is to focus on periods in which it can plausibly be argued that movements in exchange rates are the result of known shocks exogenous from the perspective of the manufacturing sector. For example, in the 1980s, a major contributing factor to the dollar’s strength was large fiscal imbalances, which have been found to affect RERs in the way standard theory would suggest (Guajardo *et al.* 2014). For Canada in the 2000s, the cause of the appreciation was a falling US dollar and rising oil prices. In addition, the episodes I study contain very large movements in RERs which increase the signal-to-noise ratio and provide insulation from spurious results. For example, in the US from 1979 to 1985, US relative unit labor costs appreciated 50%. Given that labor costs were 40% of value-added for the average sector, it would be implausible if profit-maximizing firms did not respond to this large change in relative prices.<sup>25</sup>

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<sup>25</sup>In the online Appendix, I also provide a theoretical justification for why RER movements should

Lastly, another guard against spurious findings is various falsification exercises. If employment is impacted by RER movements, then many other variables, such as trade, output, productivity, and investment, should also be affected. On the other hand, RER movements should not cause a differential impact on the input prices of more open sectors (as openness is defined by output). In addition, future leads of the RER should not impact employment or output today. These falsification exercises show that the estimation method is not prone to finding significant relationships when none should exist.

## 2 Data and Measurement

The main measure of the real exchange rate used in this paper is the Weighted Average Relative Unit Labor Cost (WARULC) index designed by Campbell (2016) to address the shortcomings of the IMF’s Relative Unit Labor Cost (RULC) index. The four key problems with the IMF’s index are that it (1) is computed as an index-of-indices, and thus does not reflect compositional changes in trade toward countries that have lower unit labor costs, (2) does not include China, (3) uses fixed trade weights, which have become outdated (Japan still held a 20% weight in the 2000s while China was excluded)<sup>26</sup>, and (4) uses country-specific deflators, which can become biased over time without the benefit of multiple benchmarks. (This last point is the same problem that afflicted older versions of the Penn World Tables predating version 8.0). Campbell’s (2015) measure is instead a simple weighted-average of RULCs which includes China, uses time-varying trade-weights, and also uses multiple-benchmarking of country-specific productivity series using PWT v8.0 methodology.<sup>27</sup> Both measures are plotted in Figure 5 vs. the IMF’s RULC index. The IMF’s index suggests a steady depreciation of US relative unit

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impact manufacturing employment to help motivate the regressions in the sections that follow.

<sup>26</sup>Note that most real exchange rate indices, such as those produced by the Federal Reserve, the OECD, the BIS, and many other central banks, also use time-varying trade weights, and that time-varying trade weight indices are often used in studies on the impact of RER movements on manufacturing, such as in Klein, Schuh, and Triest (2002).

<sup>27</sup>This last point will be subtle for general readers, and so I would refer interested parties to Campbell (2016). Specifically, the WARULC index from Campbell (2016) is computed as  $I_{US,t}^{WARULC} =$

$\prod_{i=1} \left( \frac{ULC_{US,t}}{ULC_{i,t}} \right)^{\Omega_{i,t}}$ , where  $ULC_{i,t} = \frac{w_{i,t}}{e_{i,t}} / \frac{Y_{i,t}}{PPP_{i,t}}$ ,  $\Omega_{i,t}$  are time-varying trade weights (a weighted average of import, export, and third-country competition weights, the same as used by the BIS and very similar to the Fed’s weights), and where  $w_{i,t}$  are manufacturing wages of country  $i$  at time  $t$ ,  $e_{i,t}$  is the local currency price of a dollar, and  $Y_{i,t}$  is manufacturing production, converted to dollars at PPP (which equals one for the US). One of the key differences with the IMF’s index is that for this index the ULCs are actual unit labor costs rather than indices of unit labor costs. Manufacturing PPP data were computed using ICP data for benchmark years, and then interpolated in between using manufacturing deflators from the OECD, or country-specific sources in the case of China.

labor costs over the period, implying that US manufacturing has become steadily more competitive since the 1970s. WARULC, by contrast, implies that US manufacturing became less competitive in the early 2000s.<sup>28</sup>

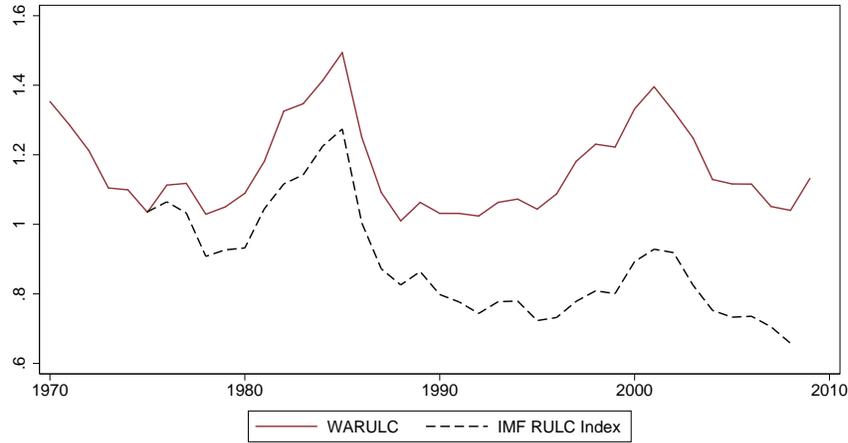


Figure 5: WARULC vs. IMF RULC Index  
Sources: Campbell (2016) and the IMF

Sectoral data on employment, shipments, value-added, wages, investment, and capital, and the prices of shipments, materials, and energy are provided by the Census Bureau’s Annual Survey of Manufactures, via the NBER-CES Manufacturing Industry Database for the 4-digit SIC data from 1958 to 2009. Data were taken directly from the Census Bureau for the NAICS version of the same variables spanning 1989-2011. Trade data from 1991-2011 are from Comtrade WITS when available, and these data are augmented with trade and the cost of insurance and freight data from Feenstra, Romalis, and Schott (2002) from 1972-2005. Sectoral tariff data for 1974-2005 come from Schott (2008) via Feenstra, Romalis, and Schott (2002), as does data on the increase in tariffs China would have faced had MFN status been revoked (the key control in Pierce and Schott, 2015). Additional data on the tariffs US industries face for 1990-2009 were taken from UNCTAD. Data on intermediate imports are from the BEA’s Input-Output tables for the year 1997. The classification of broad industrial sectors by markups is borrowed from Campa and Goldberg (2001).<sup>29</sup>

<sup>28</sup>All four of the adjustments are important. For example, changing the indexing method while using fixed trade-weights would yield an index almost identical to the IMF’s index, even if China is included. Without the multiple benchmarking, WARULC would still have a more negative slope. I refer readers interested in the differences in these indices when some of these adjustments are left out to Campbell (2016).

<sup>29</sup>The Campa-Goldberg classification of low markup industries at the 2-digit SIC level includes primary metal products, fabricated metal products, transportation equipment, food and kindred products,

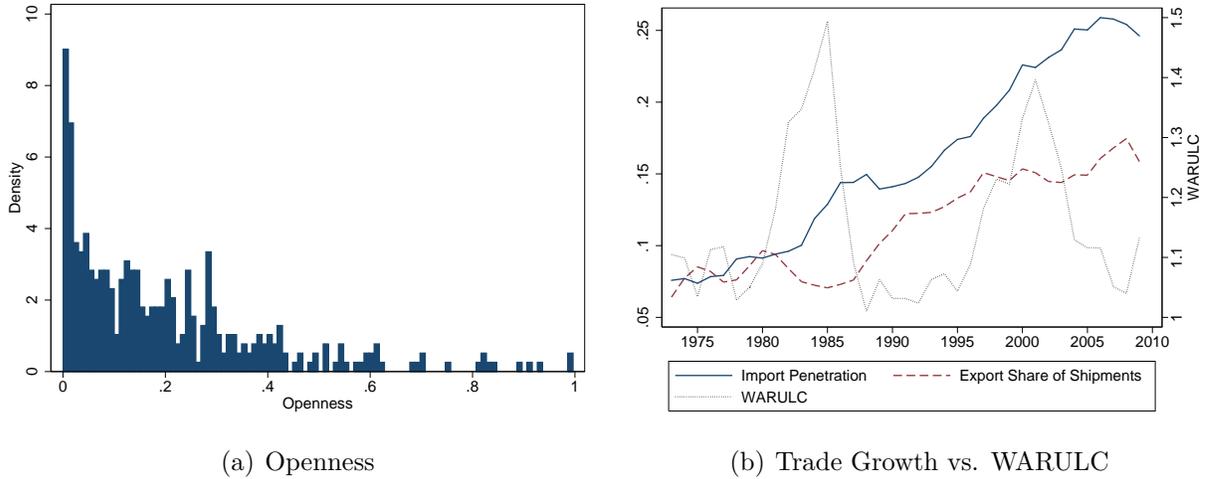


Figure 6: Trade Growth and the Distribution of Openness in 1997  
Sources: Census, Comtrade, and Campbell (2016)

The summary statistics for the most relevant variables in select years are reported in Table 7 in the Appendix. Openness increased from about 7% in 1972 to 24% in 2001 (when China acceded to the WTO) and 27.9% by 2005. It can be seen that labor costs are a large, but declining, share of value-added over the period, declining from 42.6% of value-added to just 32%. The average applied tariff was about 8.2% in 1974, but it fell to just 2.4% by 2005. By contrast, the cost of insurance and freight was 9.6% of customs costs in 1974, and largely unchanged at 9.8% in 2005. The last two entries in Table 7, capital-per-worker and the 5-factor TFP index, also come from the NBER-CES manufacturing data set. The details of their creation are described in Bartelsman and Gray (1996). Finally, panel (a) of Figure 6 shows that there was a large variation in the distribution of openness by sector in 1997, and Panel (b) demonstrates the rise in import penetration relative to export shares when the US WARULC index is elevated.

### 3 Difference-in-Difference Panel Estimation

In the first empirical approach, I compare how employment in relatively more open sectors does when US relative unit labor costs are high compared to when US ULCs at home are close to a weighted average of trading partners. I first run the following

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textile mill products, apparel and mill products, lumber and wood products, furniture and fixtures, paper and allied products, petroleum and coal products, and leather and leather products.

regression on repeated annual cross-sections of the data:

$$\begin{aligned} \ln\Delta L_{ht} = & \alpha_t + \beta_0 Openness_{h,t-1} + \beta_2 \ln\Delta D_{ht} + \beta_2 \ln\Delta(S/P)_{ht} + \\ & \beta_4 (PostPNTR * NTRGap)_h + \beta_5 MFAExposure_{h,t} + \epsilon_{ht}, \forall t = 1973, \dots, 2009. \end{aligned} \quad (3.1)$$

This is a regression of log changes in sectoral employment ( $L_{ht}$ ) on lagged openness, controlling for demand growth ( $D_{ht}$ ), shipments per production worker (a productivity measure of productivity,  $(S/P)_{ht}$ ), and two other China-related controls, following Pierce and Schott (2015). The first is a control for the interaction between China's accession to permanent normal trade relations (PNTR) interacted with a control for the NTR gap by sector. The second is a measure of exposure to the expiration of Chinese textile quotas. As many authors, including Brambilla, Khandelwal, and Schott (2010) and Khandelwal, Schott, and Wei (2013) have highlighted, the end of Chinese textile quotas associated with the end of the Agreement on Textile and Clothing (ATC) (the successor to the Multifiber Arrangement (MFA)), had a large, disproportionate impact on the sectors in which the quotas were binding. Thus, I have also included a control for the weighted average of the fill rate – the imports divided by the allowable quotas – just before the quotas were lifted (also following Pierce and Schott, 2015).<sup>30</sup> Lastly, openness is defined as a weighted average of import penetration and the export share of shipments:

$$Openness_t \equiv \frac{M_t}{M_t + X_t} * \frac{M_t}{M_t + S_t - X_t} + \frac{X_t}{M_t + X_t} * \frac{X_t}{S_t}, \quad (3.2)$$

where  $S_t$  are shipments at time  $t$ ,  $M_t$  are imports,  $X_t$  are exports, and openness was computed for each manufacturing sector separately.

The annual coefficient on openness is plotted in [Figure 7](#) in blue, along with two standard deviation error bounds. I have also plotted a measure of the RER, weighted average relative unit labor costs (WARULC), and the real interest rate, defined here as the interest rate on 30-year mortgages minus the core CPI (both from FRED).<sup>31</sup> The results suggest a strong correlation between the level of relative unit labor costs and the annual coefficient on lagged openness. The annual coefficient becomes significant in 1998,

<sup>30</sup>*I.e.*, the sectors affected by the end of quotas interacted with a post-2005 dummy using data from Brambilla *et al.* (2010) on the pre-2005 fill rates of the Chinese quotas (converting the HS codes to SIC using the concordance provided by Pierce and Schott, 2012).

<sup>31</sup>The real interest rate and the coefficient on relative openness is only approximately correlated in the early 1980s. For example, from 1985 to 1987, the RIR only declined slightly, yet the coefficient on relative openness went from -.02 to 0. Using the Core PCE deflator instead of the Core CPI to calculate the RIR instead would give even more anomalous results, as the RIR measured using the PCE deflator spiked in 1980, a year in which more open sectors did slightly better than non-open sectors.

whereas China was awarded permanent MFN status and joined the WTO in December of 2001. After WARULC returns closer to parity in the latter half of the 2000s, relatively more open sectors stopped hemorrhaging jobs on average, even as imports from China continued to increase.<sup>32</sup>

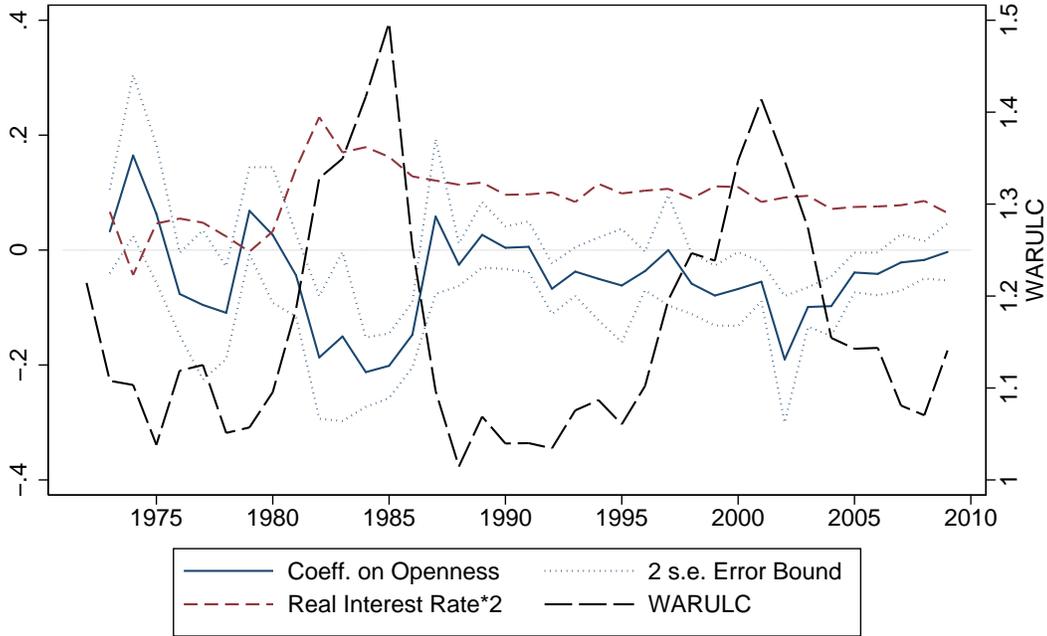


Figure 7: Correlation between Openness and Employment Growth by Year

Notes: Real interest rate data are computed as the 30-year conventional mortgage rate less the Core CPI, from FRED and the BLS (via FRED), WARULC is a measure of the RER from Campbell (2016), and the coefficients came from annual regressions of log changes in employment on changes in demand, productivity, the China Post-PNTR\*NTR Gap and MFA Exposure (explained in the text), with standard errors conservatively clustered at the 2-digit SIC level.

Figures 3, 4, and 7 suggest a functional form for the relationship between relative unit labor costs and the evolution of sectoral manufacturing employment. When unit labor costs are high in the US relative to trading partners, more open sectors lose employment relative to less open sectors. When the level of WARULC is close to one, there does not appear to be a differential change in jobs for more open sectors. This makes intuitive sense, as when unit labor costs are roughly the same at home and abroad, there is no large advantage of foreign firms over domestic firms, nor would there be a reason for domestic firms to incur the costs of moving production abroad, and so we should not

<sup>32</sup>Note that the elasticity of manufacturing jobs with respect to WARULC seems to have fallen slightly in the later period, which is consistent with the declining importance of labor and the increasing globalization of the supply chain. Ahmed *et al.* (2015) make this argument to explain the same phenomenon for a panel of 46 countries.

expect differential employment changes in more open sectors.

The next step is to pool the data and run a panel regression of the log change in employment on the interaction between WARULC and lagged openness, while including controls from the theoretical model presented in the appendix (equation 11.6).

$$\ln\Delta L_{ht} = \alpha_t + \beta_0 \text{Avg.Openness}_{h,t-3,t-6} + \beta_1(\varphi(L)\ln(\text{RER}_{t-1})) * \text{Avg.Openness}_{h,t-3,t-6} + \beta_2 \ln\Delta D_{ht} + \beta_3 \ln\Delta TFP_{ht} + \sum_{i=4}^n \beta_i C_{i,t} + \alpha_h + \nu_t + \epsilon_{ht}, \forall h = 1, \dots, 359, t = 1973, \dots, 2009, \quad (3.3)$$

where  $L_{ht}$  is employment in sector  $h$  at time  $t$ , RER is a measure of the real exchange rate, such as WARULC,  $D_{h,t}$  is real sectoral demand,  $TFP_{h,t}$  is a measure of TFP (I use 4 and 5-factor measures of productivity in addition to value-added and shipments divided by production worker or total employment), and the Cs are various other controls.<sup>33</sup> The function  $\varphi(L)$  is a lag polynomial:  $\varphi(L) = 1 - \sum_{i=1}^p \varphi_i L^i$ , which allows for a flexible functional form for the real exchange rate.  $\text{Avg.Openness}_{h,t-3,t-6}$  is an average of openness (defined as in equation 3.2) at 3, 4, 5, and 6 year lags:

$$\text{Avg.Openness}_{h,t-3,t-6} \equiv (1/4) \sum_{k=3}^6 \text{Openness}_{t-k}. \quad (3.4)$$

This is done precisely to eliminate any potential feedback from the exchange rate to openness. This ensures that the time series changes in the interaction term will be driven primarily by movements in the exchange rate. The rationale for using a (slowly) evolving measure of openness instead of a fixed measure is that, given the long panel covering four decades, many things changed and trade increased substantially over time. Any sector's exposure to RER movements should depend on its current exposure to trade rather than whatever its trade exposure happened to be at the end of the Bretton Woods period. In addition, while openness could theoretically be endogenous, in practice more open manufacturing sectors do not lose jobs when WARULC is close to unity (see Figure 7), thus it is not surprising that our results are robust to using either shorter or longer lags of openness. Lastly, the results are also robust to using initial period openness for the entire sample (see Appendix Table 10, in addition to Figure 3 and Figure 4).

Each regression also includes sectoral fixed effects  $\alpha_h$ , year fixed effects  $\nu_t$ , and two-way clustered errors (Cameron *et al.* 2011), by both industry and by year. All regressions are weighted by initial period value-added (except in Table 2, where I show that the

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<sup>33</sup>This setup is similar to Klein *et al.* (2003) and Bernard *et al.* (2006).

results are robust to various choices of weights). Additionally, the results are robust to clustering at the 3-digit SIC level instead of the SIC level, given the potential for correlation of errors at higher levels of industry aggregation.<sup>34</sup>

I test various functional forms for WARULC, such as using the level of the log of WARULC (equivalent to setting  $\varphi_i = 0, \forall i$ ) vs. an alternative specification using log changes in WARULC (equivalent to setting  $\varphi_1 = -1$ , and  $\varphi_i = 0, \forall i > 1$ ). The most intuitive alternative would be to include log changes interacted with openness and a dummy variable for appreciations, and a second control for log changes interacted with openness and a dummy for depreciations (historically this is what the literature has done, including Klein, Schuh, and Triest, 2003). This flexible specification allows different impacts for appreciations and depreciations.

Table 1, column (1) shows that appreciations in relative unit labor costs are associated with a decline in employment for more open sectors (at 10%), but that depreciations have no significant impact. Column (2) uses the log of the level of WARULC instead as a control, and this time the interaction is significant at 1%, and has a higher R-squared than column (1) despite one fewer control. Column (3) includes controls for productivity, demand, capital-per-worker and capital-per-worker interacted with the real interest rate, defined as the interest rate on 30-year mortgages less the Core CPI, and lagged log changes in wages and the price of shipments. Once again, appreciations are associated with employment declines for more open sectors, but depreciations are not significantly correlated with job gains. In column (4), I also include the log of the level of WARULC interacted with relative openness, and find that the RER appreciation and depreciation variables lose significance, while the level of WARULC continues to have a significant impact. Thus I use the level of WARULC for the remainder of the paper. Since the level of WARULC impacts the log change in employment, this specification by itself implies hysteresis.<sup>35</sup>

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<sup>34</sup>These controls, and many others, are contained in the Additional Appendices in this .pdf and online on my webpage: <http://dougcampbell.weebly.com/>. For instance, the results would not change significantly using a geometric rather than an arithmetic average of export share and import penetration as a measure of openness, or if either or both of the fixed effects were excluded. Additionally, the results are robust to omitting defense and computer-related sectors (Table 2), given that the periods of dollar appreciation are associated with large increases in defense-spending and also since the official productivity data for the computer sector has been called into question by Houseman *et al.* (2010). Changes in import penetration and export share are also highly correlated with changes in employment—a necessary condition for lagged relative openness interaction with the real exchange rate to predict innovations in employment.

<sup>35</sup>That it is the level of relative prices which matters for changes in employment rather than changes in relative prices is another reason to prefer the class of ‘WAR’ exchange rate indices to divisia based indices (also called Tornquist indices). That is because levels matter in the ‘WAR’ indices while divisia-based indexes implicitly assume that they do not matter.

The coefficient of  $-.38$  suggests that in 1985, when US ULCs were 50% (or 1.5, for a log value of  $.4$ ) above a weighted average of ULCs of US trading partners, an industry with 50% lagged average openness (making it one of the most exposed sectors in the economy) would have lost an additional 7.4% of employment from 1985 to 1986 ( $=\exp(-.38*0.4*.5)-1$ ), as compared with a completely closed industry (which would have lost nothing), and 6.2% more than an industry with average openness (which was  $.076$  in 1985). Over the entire 1982-1986 period, this industry would have lost a cumulative 25.6% of employment relative to a closed industry, and 21% more than an industry with average openness.<sup>36</sup>

Column (5) adds additional controls, including controls for sectoral input prices (materials, energy, and investment) and sectoral input prices interacted with sectoral input shares lagged one period. I also control for low-markup industries (as used by Campa and Goldberg, 2003) interacted with the level of WARULC and shares of intermediate imports interacted with WARULC. Neither are significant in column (5). I also add in the two China-related controls from Pierce and Schott (2015), the Post-PNTR\*NTR gap variable, and a second control for MFA exposure (both of these were described previously), and find that both had significant adverse impacts on employment (the NTR gaps are all negative).

Lastly, to control for the possibility that more open sectors also may be more sensitive to movements in real interest rates, I include an interaction between openness and the real interest rate, defined as the yield on 30-year mortgages minus the Core CPI. I find that employment in more open sectors is not generally more sensitive to movements in interest rates.<sup>37</sup>

Column (6) repeats the specification using a quantile regression, reporting errors

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<sup>36</sup>These annual losses can be visualized in Appendix Figure 24. I thank an anonymous referee for the suggestion.

<sup>37</sup>The results are also unchanged when including controls for tariffs, the cost of insurance and freight, unionization, unionization interacted with RER movements, tariffs faced by US industries, tariffs faced by US industries in China, and tariffs faced by US industries interacted with the share of shipments bound for China. Since these variables did not have complete coverage, there was no space to include each of these robustness checks in this table. US tariffs and freight costs did not exhibit sharp changes during this period, and perhaps as a result neither variable was significant in any specification or with alternative dependent variables. Even as of 2008, on average industries only sent 1.4% of shipments to China, so it is not surprising to find no effect of Chinese tariff policy. Unionization has been steadily declining in the manufacturing sector over this period, and had already declined from 38.9% in 1973 to 16.3% in 1997. There is a positive raw correlation between unionization in the 1990s and job growth in the early 2000s, but this correlation does not survive the inclusion of controls and is unlikely to be causal. Data on unionization came from unionstats.org, and data on Chinese tariffs came from Brandt *et al.* (2012). Other China-related variables from Pierce and Schott (2015), such as Chinese production subsidies and export eligibility by sector, are not yet publicly available but were not generally found to be significant predictors of employment changes.

Table 1: Exchange Rates, Openness, and US Manufacturing Employment

	(1)	(2)	(3)	(4)	(5)	(6)
	$\ln\Delta L$	$\ln\Delta L$	$\ln\Delta L$	$\ln\Delta L$	$\ln\Delta L$	$\ln\Delta L$
L.Avg.Openness	-0.061*** (0.022)	-0.023 (0.020)	-0.049* (0.026)	-0.00048 (0.029)	0.023 (0.024)	0.0068 (0.017)
L.Avg.Openness*ln $\Delta$ WARULC*Pos.	-0.62* (0.33)		-1.29* (0.72)	-0.62 (0.77)		
L.Avg.Openness*ln $\Delta$ WARULC*Neg.	0.11 (0.31)		0.11 (0.36)	-0.0099 (0.32)		
L.ln(WARULC)*L.Avg.Openness		-0.31*** (0.081)		-0.38*** (0.091)	-0.45*** (0.10)	-0.39*** (0.084)
$\ln \Delta$ Demand			0.44*** (0.064)	0.44*** (0.063)	0.37*** (0.068)	0.53*** (0.047)
L.(K/L)			0.052* (0.029)	0.051* (0.029)	0.032 (0.032)	0.078 (0.048)
L.(K/L)*Real Interest Rate			-0.30 (0.26)	-0.37 (0.26)	-1.32*** (0.49)	-1.20** (0.54)
L.ln $\Delta$ Wages			0.024 (0.024)	0.022 (0.024)	0.024 (0.027)	0.012 (0.012)
L.ln $\Delta$ Price of Shipments			0.030* (0.016)	0.030* (0.016)	0.037** (0.016)	0.018 (0.014)
$\ln\Delta$ VA-per-Production Worker			-0.21*** (0.036)	-0.21*** (0.036)		
$\ln\Delta$ TFP					-0.061 (0.076)	-0.25*** (0.052)
Post-PNTR x NTR $Gap_i$					0.040*** (0.013)	0.042*** (0.013)
MFA Exposure					-0.053*** (0.016)	-0.036*** (0.011)
Low Markup*L.ln(WARULC)					0.025 (0.027)	0.017 (0.017)
Imported Inputs*L.ln(WARULC)					0.062 (0.17)	-0.23** (0.11)
L.Avg.Openness*Real Interest Rate					-0.014 (0.085)	-0.0045 (0.038)
L.ln $\Delta$ PM*(M/S)					-0.16** (0.078)	-0.13** (0.063)
L.ln $\Delta$ PI*(I/S)					-1.17** (0.55)	-0.28 (0.65)
L.ln $\Delta$ PE*(E/S)					-0.25 (0.18)	-0.21 (0.19)
Observations	12469	12469	12469	12469	12357	

Two-way clustered standard errors in parentheses, clustered by year and by 4-digit SIC industry. \* $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . All regressions are weighted by initial sectoral value-added, and include 359 SIC industry and year fixed effects over the period 1975-2009. The dependent variable is the log change in sectoral manufacturing employment. The last column is a quantile regression minimizing the sum of absolute deviations, the other regressions are OLS. Sectoral changes in the cost of investment, energy, and materials are omitted for space. L.Avg.Openness equals average openness lagged 3, 4, 5, and 6 years.

clustered by SIC and year. While the magnitude of the interaction term on the RER interacted with relative openness is little changed, the impact of faster TFP growth on employment becomes negative and significant, which is what we would expect theoretically. Thus this would appear to be a textbook case in which the quantile regression, which is less sensitive to outliers since it minimizes the sum of absolute deviations, may be preferable to OLS. In addition, sectors with more imported intermediate inputs are also shown to lose more jobs when domestic unit labor costs rise relative to foreign when using a quantile regression (not so with OLS), which is consistent with a rise in offshoring induced by relative price movements.

## 4 Robustness Exercises

In [Table 2](#), I include a variety of robustness checks. First, in Panel A, I show that the results are robust to various combinations of year and industry fixed effects, and to excluding the full controls included in [Table 1](#). In Panel B, I show the results are robust to using openness lagged a single period (rather than as a moving average). In Panel C, I show that the key results are insensitive to different choices of weights: initial value-added, no weights, initial employment or shipments, average value-added, or value-added lagged one period. In Panel D, I add and subtract industries which one might want to exclude for various reasons. In the baseline regressions in [Table 1](#), I excluded unbalanced sectors and publishing, as publishing was eventually re-classified out of manufacturing. In the second and third columns of Panel D, I add these sectors back in, and find that the results are little-changed. In column (4), I subtract defense-related sectors (as government spending in these sectors boomed in the 1980s and 2000s), and in column (5), I deduct computer-related sectors (given the questions about the official productivity numbers in these sectors), and then add all the sectors back in column (6). The results are little-changed.

In Panel E, I separate import and export-weighted WARULC (iWARULC and eWARULC) and import penetration from the export share of shipments. Over the full period, I do not find a significant difference between the coefficients on the interaction between iWARULC and relative import penetration, and eWARULC and the relative export share of shipments. This was part of my rationale for using overall openness rather than separating them from the outset, or focusing on import penetration, which appears to account for much, if not all, of the action in the period since 1990 (column 2 of Panel E). However, the correlation between import penetration and export share across sectors increases dramatically over time, as the correlation was negative in the

Table 2: Robustness Exercises

	$\ln\Delta L$					
A. Altering FEs, Controls						
L.ln(WARULC)*L.Avg.Openness	-0.48*** (0.10)	-0.48*** (0.10)	-0.50*** (0.10)	-0.45*** (0.086)	-0.60*** (0.12)	-0.45*** (0.095)
Year FE	No	Yes	No	Yes	No	Yes
Industry FE	No	No	Yes	Yes	No	Yes
Full Controls	Yes	Yes	Yes	No	No	Yes
B. Using Openness (one lag)						
L.ln(WARULC)*L.Openness	-0.39*** (0.12)	-0.39*** (0.12)	-0.44*** (0.14)	-0.38*** (0.12)	-0.55*** (0.14)	-0.36*** (0.12)
Year FE	No	Yes	No	Yes	No	Yes
Industry FE	No	No	Yes	Yes	No	Yes
Full Controls	Yes	Yes	Yes	No	No	Yes
C. Altering Weights						
L.ln(WARULC)*L.Avg.Openness	-0.45*** (0.095)	-0.44*** (0.095)	-0.48*** (0.10)	-0.43*** (0.090)	-0.41*** (0.12)	-0.41*** (0.13)
Weights	VA, 1972	None	Emp., 1972	Ship., 1972	Avg. VA	L.VA
D. Adding and Subtracting Sectors						
L.ln(WARULC)*L.Avg.Openness	-0.45*** (0.095)	-0.45*** (0.095)	-0.45*** (0.094)	-0.45*** (0.095)	-0.42*** (0.094)	-0.45*** (0.094)
Unbalanced Sectors	No	Yes	No	No	No	Yes
Defense Related Sectors	Yes	Yes	Yes	No	Yes	Yes
Publishing	No	No	Yes	No	No	Yes
Computers	Yes	Yes	Yes	Yes	No	Yes
Number of Sectors	359	437	363	352	354	448
E. Imports, Exports, and China						
L.Avg.Import Pen.*ln(iWARULC)	-0.58* (0.31)	-0.31*** (0.11)	-0.34** (0.16)			
L.Avg.Export Share.*ln(eWARULC)	-0.46* (0.24)	0.026 (0.13)	-0.21 (0.19)			
L.Avg.MPPen.(ex-China)*FedRER				-0.43*** (0.11)	-0.40*** (0.11)	-0.46*** (0.12)
L.Avg.Chinese Pen.*ln(RULC)				-0.044 (0.034)	-0.061 (0.038)	-0.095*** (0.025)
Industry FE	Yes	Yes	Yes	Yes	Yes	No
Time Period	1973-1989	1990-2009	1973-2009	1973-2009	1990-2009	1990-2009

Two-way clustered standard errors in parenthesis, clustered by year and 4-digit SIC sectors. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . There are five sets of six regressions, for 30 regressions total, with the same controls as in column (5) of Table I, the baseline regression in the paper, with the other controls suppressed for space. Panel A varies the fixed effects (SIC industry effects, and year effects) and whether or not the full list of controls are included. L.Avg. Openness is again defined as the average of openness lagged 3, 4, 5, and 6 years. Panel B uses the interaction between  $\ln(\text{WARULC})$  and openness lagged just one year as the key variable of interest, and also includes a control for the weighted average of lagged opennes. Panel C varies the weighting scheme used in the paper, between using initial Value-Added (VA), vs. no weights, initial employment or shipments, average VA or VA lagged one period. Panel D adds and subtracts industries which are either unbalanced, or for which there are logical reasons why they should be excluded. In the first three columns of panel E, the key variables are now the import-Weighted Average RULC index interacted with import penetration, and export-WARULC interacted with the export share of shipments. In the last three columns, I interact the Fed's RER index with the Import Penetration ex-China versus Chinese Import Penetration interacted with bilateral Sino-American RULCs.

1970s, but strongly positive by the late 1990s. By the early 2000s, there were very few remaining sectors with substantial exports but no imports, thus there may be a slight multi-collinearity problem in the later period.

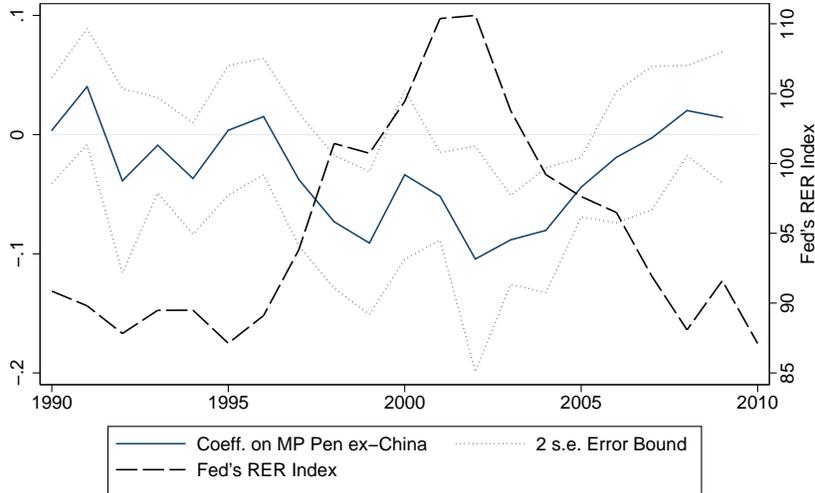


Figure 8: Was it Just China?

Note: This figure reports the coefficient on Import Penetration excluding China from the following regression:  $\ln\Delta L_{ht} = \alpha_t + \beta_0 MPPen.exChina_{h,t-1} + \beta_1 ChineseMPPen_{h,t-1} + \beta_2 \ln\Delta D_{h,t} + \beta_3 \ln\Delta TFP_{h,t} + \beta_4 PostPNTR * NTRGap_h + \beta_5 MFAExposure_{ht} + \epsilon_{ht}$ , for 359 sectors. Note that the Fed's Index is calculated using an index-of-indices approach that doesn't reflect the role of rising trade integration with China. Standard errors conservatively clustered at the 3-digit SIC level.

Finally, in columns 4-6 of Panel E of Table 2, I interact the Fed's Broad Trade-Weighted RER Index with Import Penetration ex-China, and separately control for Chinese Import Penetration interacted with the log of Sino-American bilateral Relative Unit Labor Costs (RULC).<sup>38</sup> The reason to run this regression is to show that the collapse in manufacturing in the early 2000s was not *solely* about the rise of China. One may have worried that Chinese import growth happened for reasons aside from either faster GDP growth in China or due to low RULCs, and that this growth itself, which is highly autocorrelated, increased WARULC and led to a collapse in manufacturing, generating spurious results.<sup>39</sup> However, this should not be a concern with these regressions, since the Fed's RER measure uses an index-of-indices method which does not reflect the role of rising trade integration with China, India and other low price/wage economies. And Figure 8 shows that after the Fed's RER index depreciated in the mid-2000s, relatively import-competing sectors (ex-China) stopped hemorrhaging jobs.

<sup>38</sup>*I.e.*, Import Penetration Ex-China = (Total Imports - Chinese Imports)/(Shipments - Exports + Imports).

<sup>39</sup>I thank Noam Yuchtman for highlighting this possibility.

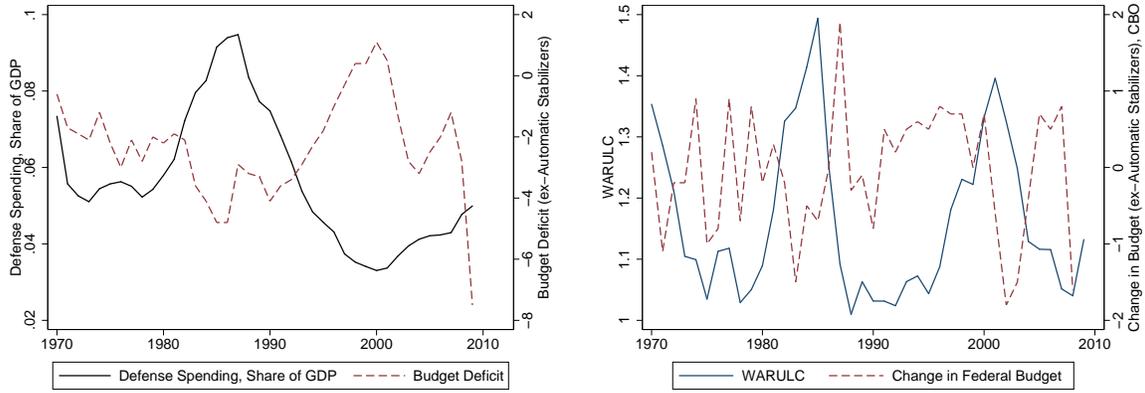
## 5 Proxies and Alternative Measures of RER Indices

Large US fiscal deficits were a likely cause of the dollar's strength during the early 1980s. Fiscal deficits can affect the tradable sector in at least four ways. First, even in a closed economy setting, higher government spending could induce more resource allocation away from manufacturing via rising wages or real interest rates. Secondly, direct government purchases of defense equipment could impact those sectors directly (part of the motivation for controlling for domestic demand growth, and for dropping defense-related sectors). Thirdly, in an open economy, higher real interest rates can cause currency appreciation due to international interest rate parity. Additionally, a larger supply of US Treasuries may induce foreign purchases of dollars given that there is a globally limited supply of safe, highly liquid, positive-yielding assets whose value appreciates during periods of financial turmoil. Empirically, Guajardo *et al.* (2014) examine the impact of fiscal changes on RERs in OECD countries, finding that fiscal consolidation leads to RER depreciation precisely as textbook theory predicts.

Hence, in this section, I estimate reduced-form regressions using changes in defense spending and the budget deficit ex-automatic stabilizers to predict differential changes in employment in more tradable sectors. The benefit of this research design is that the changes in defense spending and budget posture were the result of longstanding campaign promises that came to fruition after the outcomes of close presidential elections. Thus, I would argue that these elections were exogenous from the perspective of the subsequent evolution of manufacturing employment in more open sectors.

Figure 9(a) shows that defense spending as a share of GDP increased dramatically after the US election of 1980, and then increased again after the election in 2000. Changes in the US budget deficit appear to be related to changes in WARULC (Figure 9(b)), although the correlation with other measures of the real exchange rate, such as WARP or the Fed's index, is even more pronounced.

In Table 3 column (1), I regress lagged relative openness interacted with log changes in defense spending over GDP (divided by ten to normalize the coefficient). Once again, I get a negative, statistically significant coefficient, which implies that in 1985, when defense spending as a share of GDP increased by 10%, a sector with a relative openness of twice the average would have experienced a decline in employment by two percent relative to a closed sector. This effect is not driven by GDP as the denominator, since if we deflate defense spending with total manufacturing shipments instead, as in column (2), the results only get stronger. In column (3), I use the interaction of relative openness with changes in the budget deficit ex-automatic stabilizers and find that increases in the



(a) Defense Spending vs. Budget Deficit

(b) Structural Budget Deficit vs. WARULC

Figure 9: Defense Spending, the Structural Budget Deficit, and RULCs

Sources: FRED and CBO

budget balance are also good for relatively more tradable sectors.

Next I consider alternative measures of relative prices. Figure 10 compares several state-of-the-art measures of relative prices which use PWT v8.0 data and methodology to more commonly used measures provided by the Federal Reserve Board and IMF. Indexing the IMF’s RULC series to begin at the same level as the WARULC index in 1975, the IMF’s index implies that US ULCs were nearly 40% lower than trading partners by the 2000s, which is implausible. I have also plotted an updated version of Thomas *et al.*’s (2008) Weighted Average Relative Prices (WARP) using PWT v8.1, and Penn-Adjusted Weighted Average Relative Prices (PWARP), introduced in Campbell (2016). The Federal Reserve’s CPI-based Broad Trade-Weighted Real Exchange Index, plotted in yellow, also implies that the dollar tended to depreciate over the period. The three “Weighted Average Relative” (WAR) indices all yield broadly similar results, although there are certainly differences in the details and in the implied degree of overvaluation. One of the differences is that the other WAR measures show a slower dollar depreciation in the mid-2000s, which is consistent with the finding that relatively open manufacturing sectors continued to fair poorly in this period (Figure 7). Another difference is the slightly more negative overall slope of WARULC, which is due to the declining share of labor income in manufacturing in the US relative to many other developed countries, which appears to be a broad-based phenomenon in manufacturing not caused by outsized changes in a small number of sectors.

As argued in Campbell (2016), unit labor cost-based relative price measures are not necessarily *a priori* better measures of competitiveness than Penn-Adjusted Weighted

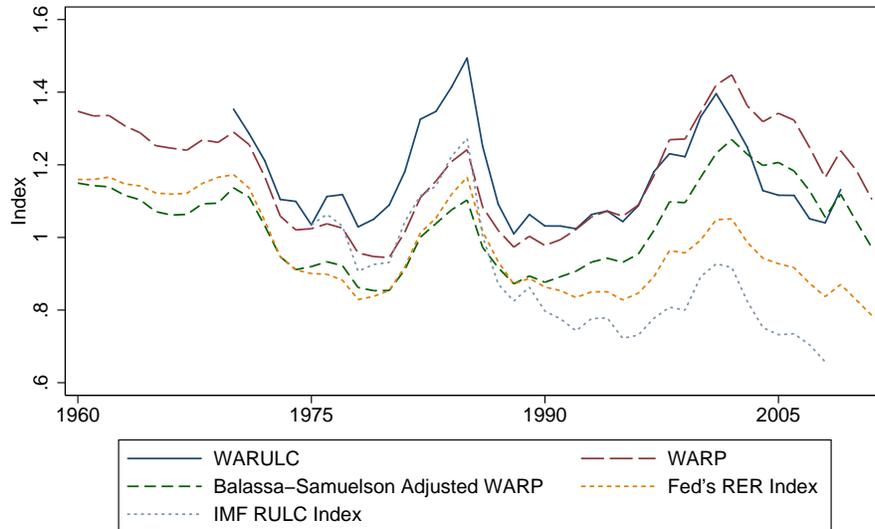


Figure 10: Comparing Various Exchange Rate Measures

Source: Campbell (2016) and the IMF

Average Relative Price (PWARP) indices. This is because manufacturing requires many more inputs, including nontraded inputs, than just labor, as labor costs fell to just 23% of total costs by 2007 (or 32% of value-added). Thus broader measures of prices may be just as appropriate to gauge competitiveness as ULC indices.

In Table 3, I show that the results hold for the other WAR exchange rate indices. In column (4), I use the lagged log of a GDP Weighted Average Relative Price (WARP) index. This is an important robustness check for those who may be concerned that the trade-weights themselves are endogenous and may be driving the result. In column (5) I use the log of the PWARP index (the Penn or Balassa-Samuelsan adjusted version of WARP). In each case, the results are little-changed.

Additionally, in column (6), I use WARULC computed with sector-specific trade weights (following Revenga, 1992). The trade weights are computed as imports plus exports at the sectoral level, as complete unit labor cost data, including for manufacturing PPP, are only available internationally for manufacturing as a whole.<sup>40</sup> Sectoral real exchange rates may *a priori* seem like a vast improvement over using real exchange rates for the manufacturing sector as a whole, and, indeed, the “between” R-squared nearly doubles, while the overall R-squared also increases modestly, providing further evidence that relative prices affect manufacturing employment. However, the magnitude is much

<sup>40</sup>I thank a discussant, Tadashii Ito, for the suggestion to use sectoral producer data collected by Sato *et al.* (2012). However, the Sato *et al.* data covers just 7 years and 26 countries, and does not include relative price levels.

Table 3: RER Proxies and Alternative Measures of Relative Prices

	(1)	(2)	(3)	(4)	(5)	(6)
	$\ln\Delta$ L	$\ln\Delta$ L	$\ln\Delta$ L	$\ln\Delta$ L	$\ln\Delta$ L	$\ln\Delta$ L
L.Avg.Openness* $\ln\Delta$ (Defense/GDP)	-4.52** (1.78)					
L.Avg.Openness* $\ln\Delta$ (Defense/Shipments)		-2.75*** (1.03)				
L.Avg.Openness* $\Delta$ Structural Budget			3.26*** (1.17)			
L.Avg.Openness* $\ln$ (G-WARP)				-0.22** (0.097)		
L.Avg.Openness* $\ln$ (PWARP)					-0.21** (0.11)	
L. $\ln$ (Sectoral WARULC)						0.015 (0.012)
L.Avg.Openness* $\ln$ (Sectoral WARULC)						-0.11*** (0.039)
Observations	12357	12357	12357	12357	12357	12357

Two-way clustered standard errors in parentheses, clustered by year and industry. \* $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . All regressions are weighted by initial sectoral value-added, and include 359 SIC industry and year fixed effects over the period 1975-2009. The dependent variable is the log change in sectoral manufacturing employment. All other controls from Table 2 are suppressed for space. L.Avg.Openness is defined once again as the average of openness lagged 3, 4, 5 and 6 years.

smaller in part because the variance of the sector-specific exchange rate is much higher. Estimating with this index implies more jobs lost in periods when the overall WARULC index is low, but also implies fewer jobs lost when relative prices are high.<sup>41</sup>

## 6 Impact on Investment, and Other Variables

Movements in relative prices impact manufacturing employment, but if they were to only affect manufacturing employment and not other variables such as output and in-

<sup>41</sup>While using either the overall WARULC or the sectoral version yields broadly similar results, there are subtle complications with the sectoral version of WARULC which may lead one to prefer the overall WARULC index. The wider dispersion of sectoral WARULC values, ranging from .52 to 6.35 (over six times higher than trading partners) implies movements in the dollar will lead to proportionally smaller changes in these high-WARULC indices relative to the difference between the high-value WARULC sectors and the low-value WARULC sectors. Thus, the sectoral WARULC index will tend to predict a more constant rate of job losses, while the overall WARULC index will not predict any jobs lost when the overall unit labor costs are the same at home and abroad. The larger sectoral WARULC values also give rise to a multicollinearity issue for some sectors, as the interaction term between lagged relative openness and sectoral WARULC will not vary as much for high-index value sectors compared to lower-index value sectors. Additionally, there is incomplete ULC data for developing countries, which implies that some of the movements in the sectoral WARULC index may be spurious, as China's share of trade increased in certain sectors at the expense of countries, such as Thailand, with missing data. This is much less of a problem for the overall index, which may be why when I control for both in the same regression, I find that most of the action comes from the overall index.

vestment, this would suggest that the apparent impact on employment may be spurious. In addition, if appreciations in the dollar also happened to be correlated with movements in other variables in more open sectors which should not theoretically be affected, such as the price of energy inputs, then this could imply that the estimation method used in this paper is prone to yielding spurious results.<sup>42</sup> In this section, I test the impact of relative price movements on a multitude of other variables, and provide additional falsification tests.

First, for exchange rate movements to impact manufacturing employment, a necessary condition is that exchange rates affect trade. Figure 15 shows that when the dollar fell from 1972 to 1979, the entire distribution of log changes in US exports disaggregated by both sector and destination country is centered around a higher percentage change than the distribution of changes in imports. When the dollar spiked in the mid-1980s, the distribution of log changes in imports then shifted far to the right of the distribution of exports, with the median log change in imports close to one vs. slightly greater than zero for exports, corresponding to a 72% increase in imports relative to exports. The same pattern holds up over the period of dollar weakness from 1986 to 1996, and dollar strength from 1996 to 2005.<sup>43</sup>

In Table 4, I find a modest decline in production worker hourly wages in more open sectors when relative prices are elevated. This result is new, as Ebenstein *et al.* (2014) did not find an effect of globalization on industry wages using the Current Population Survey (although, they did find an impact on the occupations most exposed). I separately found no significant impact on non-production worker wages, and also that investment, value-added and TFP all fared worse. Note that while the theoretical impact on TFP may be ambiguous, one intuitive reason why you might have a negative sign here is that if sectors have substantial overhead costs, then a decline in sales will lead to a decline in measured productivity. There was no significant impact on the log change in prices or on inventory. Since theory does not necessarily provide a strong rationale why inventory should be affected by movements in real exchange rates, this is arguably a falsification exercise. Predicting the changes in the sectoral deflators for investment, materials, and energy are perhaps even stronger candidates for falsification exercises, since any finding that real exchange rate movements lead to disproportionate changes in the costs of more open sectors would likely be spurious, raising doubts as to whether the estimation method in this paper has a tendency to find false positives.

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<sup>42</sup>Note that while energy prices are affected by RER movements, the energy prices faced by sectors which compete internationally should not be impacted relative to sectors who compete domestically.

<sup>43</sup>In an Additional Appendix on my webpage, I present the results from a panel vector error correction model which also indicates that lagged changes in real exchange rates affect the level of trade flows.

However, I find that the interaction term on WARULC and relative openness does not significantly predict the growth of any of these deflators, even for various leads and lags.<sup>44</sup> In addition, multi-year leads and lags of the RER interacted with openness are not significant predictors of differential changes in any of the dependent variables.

Table 4: Impact of RER Movements on Output and Other Variables

	(1)	(2)	(3)	(4)	(5)	(6)
	<i>ln</i> Δ PW Wages	<i>ln</i> Δ I	<i>ln</i> Δ VA	<i>ln</i> Δ TFP	<i>ln</i> Δ Inventory	<i>ln</i> Δ Prices
L.Relative Openness	0.00356*** (0.000993)	0.00630 (0.0109)	-0.00256 (0.00692)	0.00136 (0.00280)	0.000683 (0.00721)	-0.00361 (0.00241)
L. <i>ln</i> (WARULC)*Open.	-0.0163** (0.00641)	-0.148*** (0.0427)	-0.0904*** (0.0228)	-0.0285*** (0.00727)	-0.0121 (0.0234)	-0.000368 (0.00858)
<i>ln</i> Δ VA-per-Prod. Worker	0.0589*** (0.00971)	-0.0998 (0.0648)	0.647*** (0.0464)	0.268*** (0.0256)	-0.706*** (0.0438)	-0.0919*** (0.0313)
<i>ln</i> Δ Demand	0.0106 (0.0116)	0.601*** (0.101)	0.460*** (0.0674)	0.188*** (0.0256)	-0.0536* (0.0281)	-0.0819*** (0.0248)
L.K/L	-0.0515** (0.0224)	-0.150 (0.169)	0.0265 (0.0512)	0.0257 (0.0273)	-0.0562 (0.0808)	0.0150 (0.0326)
L.(K/L)*Real Interest Rate	-1.096* (0.587)	-6.873*** (2.049)	-4.091*** (1.247)	0.0449 (0.448)	0.0928 (1.717)	-3.749*** (1.193)
L. <i>ln</i> Δ Price of Shipments	0.0102 (0.00763)	0.224*** (0.0653)	0.0284 (0.0456)	0.000431 (0.0168)	0.0226 (0.0540)	
Observations	13185	13185	13185	13185	13185	14864

Two-way clustered standard errors in parentheses, clustered by year and industry. \* $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . All regressions weighted by initial sectoral value-added, and include 4-digit SIC industry and year fixed effects over the period 1973-2009. The dependent variables are 1) log changes in production worker hourly wages, 2) investment, 3) value-added, 4) 5-Factor TFP (from NBER-CES), 5) inventories, and 6) prices of shipments.

In addition, I find an impact of exchange rate movements on job creation, job destruction, and shipments.<sup>45</sup> When unit labor costs in the US rise relative to trading partners, there is suppressed job creation, but the impact on job destruction is much larger. Since job creation varies much less than job destruction overall, this asymmetry is an indication of at least persistence if not hysteresis. Nearly four good years of job creation are needed for every bad year of destruction.

<sup>44</sup>These results are also in the additional appendix, Table 9. I thank Scott Carrell for suggesting this as a robustness check.

<sup>45</sup>The regression results for these variables are also reported in an Additional Appendix on my webpage. I put them there because the job creation and destruction variables (provided by Davis, Haltiwanger, and Schuh, 1998), end in 1998, while we probably care a bit more about value-added than shipments, and the results are nevertheless similar.

## 7 Accounting for Jobs Lost

The results so far indicate that RER movements seem to have a statistically significant and large impact on the sectors most exposed, but if the sectors that trade the most are small, then the overall impact on employment might not be very large. To estimate the number of jobs lost due to trade and RER movements over the 1995-2008 period, I used the panel regression results from Column 6, Panel B of Table 2 and the annual regression displayed in Figure 8 to back out the total impact of trade on employment. The approach is to multiply the coefficient on the interaction term, Relative Openness\*ln(WARULC), by the interaction term itself and the lagged level of employment, and then to sum across industries. While any estimates coming from regression results are likely to be approximate, and suggestive rather than conclusive, the results are striking. They suggest that trade was directly responsible for as many as 2.9 million jobs lost from 1995 to 2008, with about 2.1 million jobs stemming directly from the appreciation of US relative prices over this period, and the balance due to China’s WTO accession and the end of the MFA agreement. This complete estimate is more than five times larger than the direct estimate of 560,000 provided by Acemoglu *et al.* (2015). Yet, note that this figure is still substantially lower than the 3.9 million jobs lost I calculated using a straightforward, back-of-the-envelope accounting approach (Table 8), which suggests that 3 million jobs directly due to trade is plausible.<sup>46</sup>

Using the annual regression in Figure 8, we can derive a separate estimate to determine the relative importance of China vs. the dollar’s general strength in the early 2000s, and find very similar results, with total jobs lost due to all four sources at about 2.9 million, with 1.3 million due to the dollar appreciation (not directly related to China, though perhaps indirectly via China’s vast accumulation of dollar reserves).<sup>47</sup> Panel (a) of Figure Figure 11 plots a “counterfactual”, where I add back the jobs lost due to the dollar appreciation ex-China, and a second exercise where I also add back the jobs lost from all three China-related factors. However, what is clear is that this counterfactual exercise still implies a substantial fall in manufacturing employment after 2000. What accounts for this decline?

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<sup>46</sup>This table “accounts” for manufacturing jobs lost due to trade by dividing the increase in the manufacturing trade deficit after 1995 by observed labor productivity as a crude estimate of jobs lost due to increases in the deficit.

<sup>47</sup>This time, I multiplied Import Penetration (ex-China) by the variable itself and the lagged level of employment, and also did the same for Chinese import penetration, the Post-PNTR\*NTR Gap variable (from Pierce and Schott, 2015) and the MFA Exposure variable. Thus, the total jobs lost is calculated as  $Total = \sum_h L_{h,t-1}(\beta_0 * MPPen.exChina_{h,t-1} + \beta_1 * ChineseMPPen_{h,t-1} + \beta_4 * PostPNTR * NTRGap_h + \beta_5 * MFAExposure_{ht})$  from the regression listed in the notes of Figure 8.

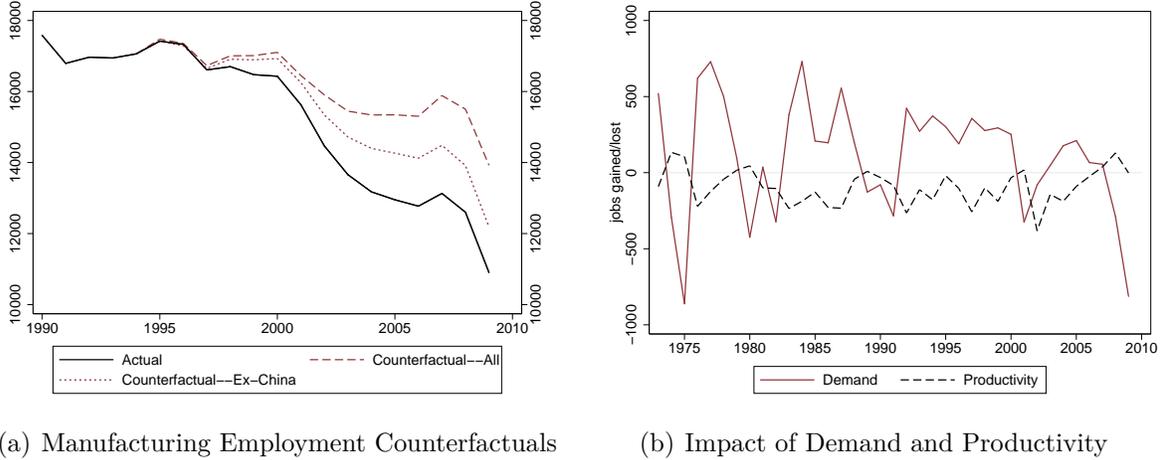


Figure 11: Accounting for Labor Lost

Notes: In Panel (a), the “Counterfactual–All” is computed from all four trade-related coefficients in the annual regression in Figure 8, and yields slightly more conservative estimates than does the panel regression in Column (5) of Table 1. The “Annual Estimate” uses regression coefficients plotted in Figure 7. The Counterfactual–Ex-China adds back the job losses only from the RER appreciation excluding the impact of China.

Figure 11(b) details the impact of changes in demand and productivity on changes in manufacturing employment (using the regression coefficients from Column (6), Panel B of Table 2 multiplied by the actual changes in demand and labor productivity for each sector). While the jobs lost due to productivity gains after 2000 look unimpressive, demand growth stands out as being particularly sluggish in this period.<sup>48</sup> While this may have been the result of an exogenous sectoral shift in consumption patterns toward services, another possibility is that the decline in demand was itself caused by trade via input-output linkages. For example, every dollar of output of apparel manufacturing requires 30 cents of output from textile mills.<sup>49</sup> Overall, every dollar of aggregate manufacturing output generally requires about 60 cents worth of additional output from other manufacturing industries (I get a similar estimate using detailed IO data, as did Acemoglu *et al.*, 2015). This would suggest that the direct and indirect impact of trade might be as high as 5 million manufacturing jobs.<sup>50</sup> Acemoglu *et al.* (2015) estimate the

<sup>48</sup>Note that while one interpretation of this is could be a “sectoral shift” hypothesis, note that the poor overall employment growth from 2000 to 2007 despite a housing bubble also is inconsistent with the theory that the decline in manufacturing employment is really about the rise of services, or about measuring manufacturing workers vs. “factoryless goods producing” (FGP) firms (Bernard and Fort, 2013). Even if we consider all the FGPs in Bernard and Fort as manufacturing firms using their upper bound estimate, then the collapse in manufacturing employment in the early 2000s would still have been 2.4 million, still a large sudden contraction by historical standards.

<sup>49</sup>Data from the BEA.

<sup>50</sup>This would also not be a complete estimate, as the collapse in manufacturing employment may

input-output multiplier for the full economy, including services and local-labor market effects, and get a full multiplier close to four. If correct, this would imply a stunning toll of 12 million jobs, easily large enough to lend credibility to the Bernanke hypothesis that trade and the savings glut are the fundamental cause of the low nominal interest rates, the US's slide into a liquidity trap, and the apparent "secular stagnation" experienced in the US since 2000.<sup>51</sup> Of course, these are micro estimates, and do not factor in the jobs gained from the Fed's low interest rates in the mid-2000s and the ensuing housing bubble. Yet, neither do they count the employment impact of the collapse of the housing bubble or the slide into a liquidity trap in 2008. Thus, a full consideration of the macro impacts could well inflate the impact.

## 8 International Evidence

### 8.1 Difference-in-Difference-in-Difference

An additional empirical approach is to use international data to create a third dimension to the difference-in-difference estimation, and ask whether more open manufacturing sectors in the US tend to lose more jobs when the currency appreciates relative to the same sectors in other large manufacturing countries. Figure 12 displays the idea graphically. From 1979 to 1986 and from 1995 to 2002, the 3-digit ISIC sectors which were more open tended to experience larger declines in employment in the US, but there was no such relation in other major economies.<sup>52</sup> This indicates that the job losses in the US in the early 2000s were not simply due to a general flood of Chinese exports, which also went to other major economies, but rather must be something specific to the US in that period. From the perspective of economic geography, Canada should have been just as exposed to Chinese import competition as the US. But from the mid-1990s to 2003, a period when the Canadian dollar was weak relative to its American counterpart, Canadian manufacturing employment actually *increased* even as American manufacturing employment collapsed (Panel (a) of Figure 13).<sup>53</sup> As Canadian unit labor

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have led to the "secular stagnation" since 2000 resulting with the US falling into a liquidity trap in the fall of 2008, with resulting slow growth.

<sup>51</sup>Bernanke (2005) first raised this idea in a speech while Fed Chair, and followed this up with a series of blog posts in 2015, including here: <http://www.brookings.edu/blogs/ben-bernanke/posts/2015/04/01-why-interest-rates-low-global-savings-glut>.

<sup>52</sup>In the Additional Appendix, I also show that there is no correlation between openness and employment for years when the dollar was weak.

<sup>53</sup>Canadian manufacturing employment also increased over the 1990-2004 period, suggesting that Canada was not more exposed to trade competition with China despite the lack of a threat of returning to Smoot-Hawley level tariffs as there was in the US. In addition, when the Canadian dollar appreciated

costs have increased sharply relative to trading partners (including the US) since 2003, Canadian manufacturing has lost more than twice as many manufacturing jobs as the US as a share of 2003 employment, with the losses concentrated in the more open Canadian manufacturing sectors (Figure 13, Panel (b)).

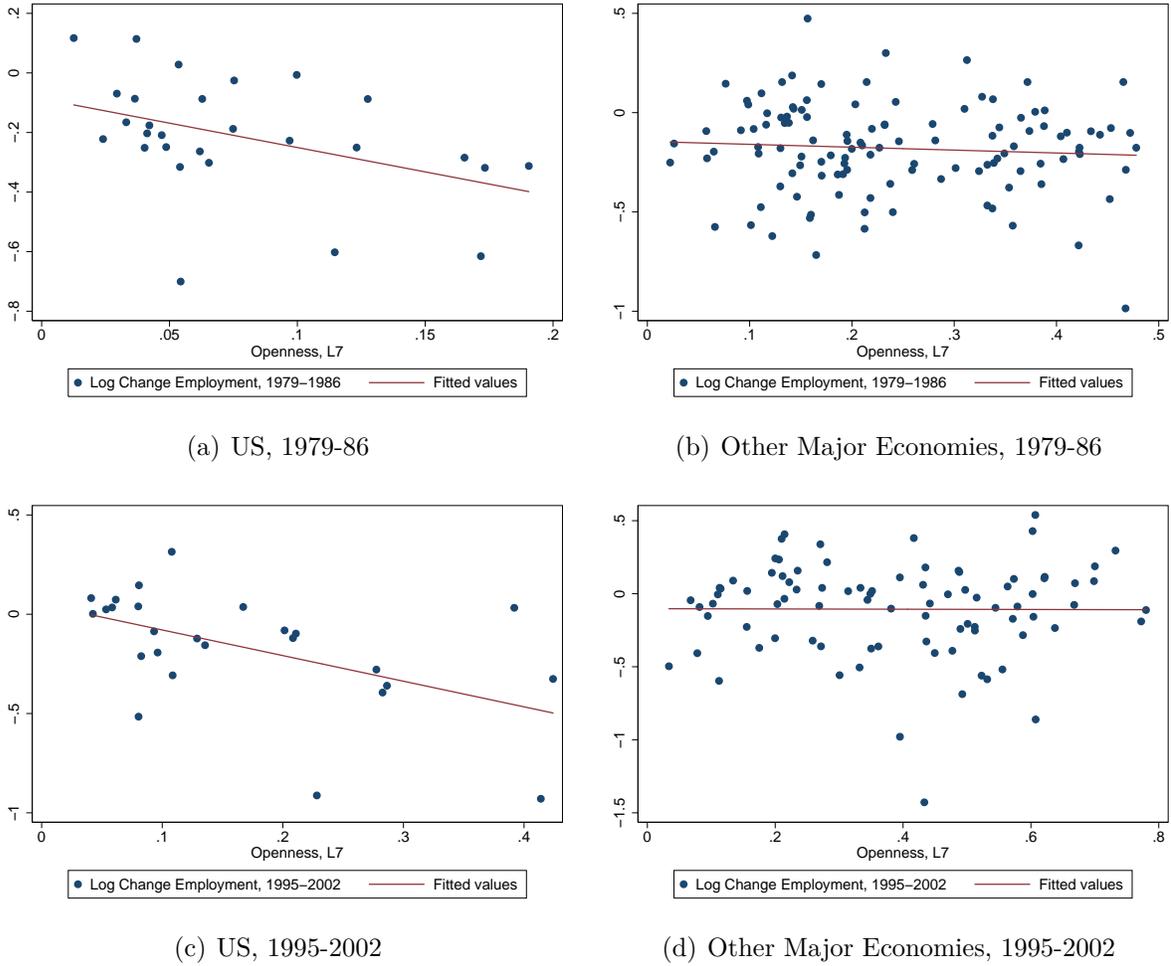


Figure 12: Employment Growth vs. Lagged Openness

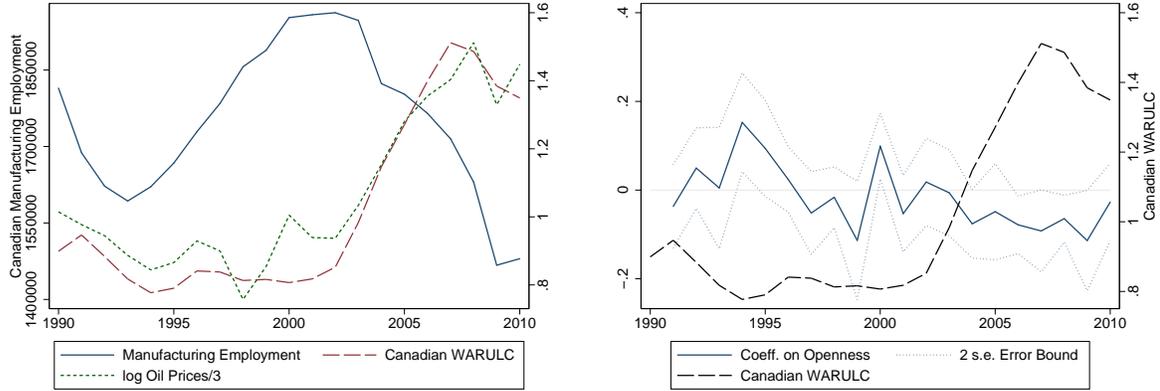
Source: UNIDOs (3-digit ISIC manufacturing sectors). Other major economies include Canada, France, Germany, Italy, and the UK.

Thus, we now estimate:

$$\ln\Delta L_{US,h,t} - \ln\Delta L_{G5,h,t} = \alpha_t + \beta_1 \ln(WARULC) * Openness_{h,t-1} + \quad (8.1)$$

$$\beta_2 (\ln\Delta D_{US,h,t} - \ln\Delta D_{G5,h,t}) + \beta_3 (\ln\Delta(S/L)_{US,h,t} - \ln\Delta(S/L)_{G5,h,t}) + \alpha_h + \nu_t + \epsilon_{ht}$$

later in the 2000s, there was also a correlation between openness and employment declines.



(a) Total Employment vs. WARULC

(b) Impact of Openness on Employment Growth vs. WARULC

Figure 13: Canadian Manufacturing Employment, WARULC

Sources: UNIDOs, Comtrade, Campbell (2016). Notes: Panel (b) shows the results of an annual regression of demand growth, productivity growth, and openness by sector on employment growth. The negative correlation between openness and employment growth begins once WARULC appreciates.

$$\forall h = 1, \dots, 29, t = 1978, \dots, 1995, 1998, \dots, 2003,$$

$$G5 = (\text{Canada}, \text{France}, \text{Germany}, \text{Italy}, \text{UK}).$$

The dependent variable is now the log change in sectoral US employment minus the average log change in employment in Canada, France, Germany, Italy and the UK. The manufacturing data are 3-digit ISIC Rev. 2 data from UNIDOs, which does not report data for the US for the year 1996. I include only a single lag instead of the four year moving average lagged three years because there is missing data, and since I have shown that using a one year lag instead makes little qualitative difference with the ASM data. The first column in Table 5 runs the difference-in-difference regression using US data as in previous tables in a quantile regression with errors clustered at the ISIC 3 industry level and includes industry and year dummies. The key interaction term between openness and WARULC is large and highly significant, indicating that more open sectors tend to lose employment when unit labor costs are high relative to less open sectors compared with when WARULC is close to unity.<sup>54</sup> In the second column, the dependent variable is now the log change in sectoral output, and the key interaction

<sup>54</sup>I subtract one in the US case rather than taking the log (which is approximately the same), because each country may need a slightly different normalizations, and Canada appears to lose employment in manufacturing as its WARULC goes above .85. Since the WARULC measures here exclude factors such as tariffs, fiscal policy, and various other factors, the break-even point for competitiveness need not be exactly one.

term is once again large and significant.<sup>55</sup> The magnitudes suggest that as a sector goes from no openness to 50% openness, employment will decline by an additional 11.1% in a year when WARULC is 1.5 ( $\exp(-.58*.5*\ln(1.5))-1$ ). In column 3, the coefficient of -.76 tells us that for a sector with an additional 50% openness, it will lose ( $\exp(-.76*.5*\ln(1.5))-1$ ) = 14.3% of its total employment when WARULC is 1.5 relative to the employment change of the same sector in other major economies. These numbers are a bit larger than those implied by running a directly comparable regression using the ASM data (a quantile regression on with otherwise the same setup as in Column 6, Panel B of Table 2), as the coefficient of -.58 can be compared with a coefficient of -.33. The caveat here is that there are only 31 sectors with the ISIC data, and thus is more likely to provide a noisy estimate.

Table 5: International Evidence

	(1)	(2)	(3)	(4)	(5)	(6)
	ln $\Delta L$	ln $\Delta Y$	ln $\Delta L$ Rel.	ln $\Delta Y$ Rel.	ln $\Delta L$ Canada	ln $\Delta L$ Canada
L.Openness	0.048 (0.031)	0.059*** (0.021)	0.072 (0.054)	-0.027 (0.027)	0.048 (0.038)	0.030 (0.033)
L.Openness*ln(WARULC)	-0.58*** (0.11)	-0.53*** (0.099)	-0.76*** (0.11)	-0.64*** (0.10)		
ln $\Delta(Y/L)$	-0.90*** (0.041)				-0.83*** (0.040)	-0.82*** (0.042)
ln $\Delta$ Demand	0.89*** (0.040)	0.97*** (0.039)			0.82*** (0.060)	0.82*** (0.068)
ln $\Delta(Y/L)$ (Relative)			-0.52*** (0.075)			
ln $\Delta$ Demand (Relative)			0.59*** (0.065)	0.91*** (0.041)		
L.Openness*ln(WARULC Canada)					-0.15*** (0.042)	
L.Openness*Oil Prices (norm.)						-0.050*** (0.017)
Observations	606	606	606	606	1720	1720

Standard errors clustered by sector in parentheses. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . Each column is a quantile regression including year and 3-digit ISIC industry fixed effects. Data for the first four regressions span from 1977 to 1995 and 1998-2003 for 31 sectors, and the last two regressions span 1991-2010 for 104 sectors. The dependent variables in the first two columns are the log change in sectoral manufacturing employment and output. In the 3rd and 4th columns, the dependent variables are the log change in manufacturing employment (and output) relative to the average log change in employment (and output) in the same sectors in other major economies. Data in the last two columns are for Canada. In the 5th column, I normalized WARULC by adding .15. In the last column, oil prices are used as a proxy for Canada's RER. To normalize oil prices, I took the log and of the price of a barrel of crude oil and subtracted three.

<sup>55</sup>In this paper, I do not focus on Europe, in part because it has been done, and in part because it would be deserving of a separate paper. Chen *et al.* (2013) finds that Euro zone countries with relative price appreciations after the formation of the Euro also experienced worsening trade balances. Ekholm *et al.* (2012) adopt a similar methodology and finds that oil price appreciations adversely affected the Norwegian manufacturing sector.

In the third column of Table 5, I estimate the relative difference-in-difference regression in equation (8.1), and find that the magnitude of the results increases compared to column (1), although the estimate also becomes less precise. Given that the previous literature has found heterogeneous effects of exchange rate movements by country dependent on labor market institutions (see, for example, Berman *et al.* (2009), Nucci and Pozzolo (2008), and Belke *et al.* (2013)), it is important to show in column (4) that the relative difference-in-difference results hold for output as well as employment. In column (5), I estimate the difference-in-difference estimation as in column (1) for Canada instead of the US, and also find that when Canadian Weighted Average Relative Unit Labor Costs are high, the more open Canadian manufacturing sectors lose employment relative to less open sectors.<sup>56</sup> Note that for Canada, it appears that the dividing line between faster vs. slower growth for more open sectors is when WARULC is around .85 instead of 1, so I have normalized the Canadian index by adding .15 instead of one for Canada (the results are little changed if one adds .1 instead).<sup>57</sup> Finally, in the last column, I proxy movements in Canadian relative unit labor costs using the log of oil prices minus three,<sup>58</sup> and again find that when oil prices are high, the more open sectors in Canada tend to lose ground relative to less open sectors.

## 8.2 Japan

Just as China has become the center of focus for those wishing to explain the decline of US manufacturing today, similarly, in the 1980s many Americans blamed manufacturing job losses on Japan's rise. During this period it was widely thought that Japan's dominance owed to superior Japanese business practices such as *Kaizen* costing and *Kanban* scheduling, support from MITI, and innate features of Japanese culture. While these and other factors may have been important, it turns out that relative prices alone can largely explain Japan's ascent and then stagnation in the US market.

Japan is a particularly good case study since the yen was heavily managed and then

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<sup>56</sup>This result also holds up for Canadian output. The coefficient for Canada is much smaller than for the US. This may in part be due to the fact that WARP and BSWARP for Canada do not show as sharp of an appreciation in the 2000s, so estimating with these alternative (yet also appropriate) RER indices would yield a higher elasticity for Canada relative to the US. Secondly, the key coefficient for the US using these 31 sectors from UNIDOs happens to be higher than the same elasticity using SIC (or NAICs) data from the ASM.

<sup>57</sup>This could be due to a country-specific bias in the data collection, tariff policy, or any number of other factors.

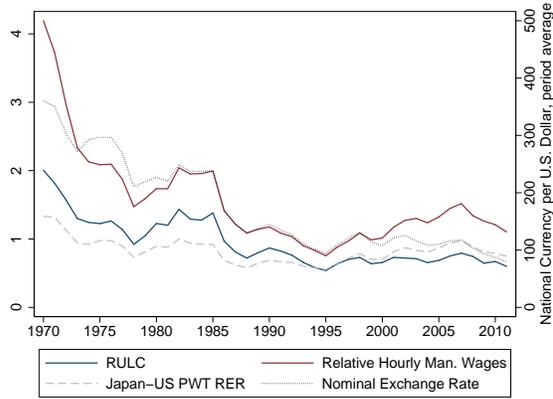
<sup>58</sup>Once again, any measure of the RER or proxy for it have to be transformed somehow so that they vary between zero and positive or negative numbers, otherwise the interaction with openness will be collinear with openness itself.

appreciated substantially shortly after the full liberalization of Japanese capital markets. The yen was fixed after World War II until the early 1970s, when President Nixon, worried about what were very small trade deficits by recent standards, imposed a 10% tariff to force other countries, namely Japan and Germany, to revalue their currencies (Irwin, 2013). In the 1970s, the yen continued to be managed in a dirty float, with most controls on capital lifted in 1980. At that point the dollar began its appreciation for reasons unrelated to Japan. In 1984 Japan, under intense pressure from the US Treasury, added substantial additional liberalization measures in the Yen-Dollar Agreement (Frankel, 1990). As the dollar continued to soar in 1985, the Reagan Administration responded with the Plaza Accord, an agreement among major nations to reduce fiscal imbalances and intervene in the currency markets to weaken the dollar, and the 1985 Gramm-Rudman-Hollings Deficit Control Act.

Figure 14, panel (a) and (b) demonstrate that the combination of the end of capital controls, the move toward fiscal balance in the US in late 1985, and the Plaza Accord had a major impact on relative prices between the US and Japan. US manufacturing workers went from enjoying hourly wages twice that of their Japanese counterparts in 1985 to earning wages that were close to parity three years later. US unit labor costs relative to Japan fell 47% and the real exchange rate using PPP from the Penn World Tables, v8.0, implies an appreciation of Japanese relative prices of 37%. Thus the case of Japan yields a relatively clean quasi-natural experiment for the impact of currency undervaluation and large exchange rate adjustments.

The result of this real appreciation was that as wages in the Japanese manufacturing sector suddenly increased relative to their American counterparts, the meteoric Japanese export growth from 1946 to 1986 suddenly ground to a halt (Figure 14(c)). However, Japan kept the gains in market share it had made even though it did not make further inroads—another indication of hysteresis. Japan’s gains through 1986 were also not purely due to domestic factors in Japan, such as government encouragement to increase market share in export markets, since the same trends are not evident in other markets. In the UK case, Japanese exports grew very quickly in the early 1980s, when the yen was weak relative to the pound, but Japanese import penetration into the UK market did not grow at all from 1983 to 1985, when Japanese unit labor costs were higher than UK unit labor costs. Hence, on balance Krugman (1986) appears to have been correct in guessing that the yen’s appreciation in that year meant that “the Japan problem was over.”

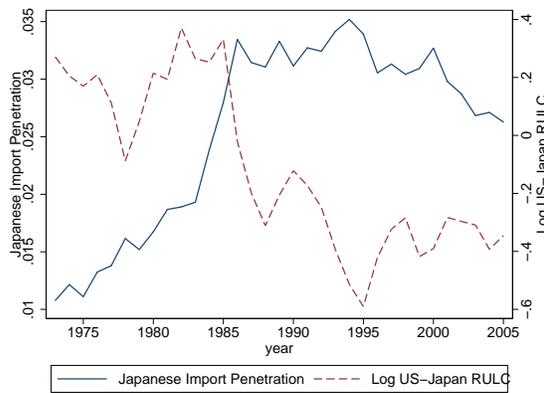
The first column of Table 6 regresses the log change in Japanese import penetration (imports divided by domestic demand) in the US on the lagged log of bilateral relative



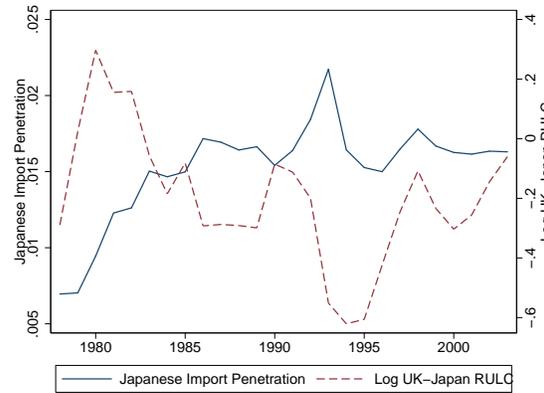
(a) US-Japan Exchange Rates



(b) Manufacturing Wages (2011 Dollars)



(c) US



(d) UK

Figure 14: RULCs and Japanese Import Penetration

Sources: PWTs, CP 2013, UNIDOs, Comtrade. Notes: RULCs = Relative Unit Labor Costs. Import penetration = imports/(imports + shipments - exports).

unit labor costs for the manufacturing sector between the US and Japan, while controlling for changes in overall US import penetration. The coefficient indicates that when ULCs were relatively higher in the US, Japanese sectors gained market share in the US, and when US ULCs were relatively lower, the growth in Japanese import penetration decreased (in fact it became stagnant). In column (2), I include a dummy variable for the period after the Plaza Accord – after the end of capital controls and the strong dollar – and find that after 1985, Japanese import penetration fell relative to the period when the Yen was weaker. In column (3), I use UK data, and find that when unit labor costs in the UK are high relative to Japan, Japanese industries increased their market share in the UK. In column (4), I rerun the regression in column (1), and control for Japanese changes in import penetration in the UK. In column (5), I stack data for each of the G6 countries, and find a similar elasticity as to the US initially.

Thus, the example of Japan would appear to provide another confirmation that relative prices matter and that hysteresis is a quantitatively important aspect of the economic landscape, using quasi-experimental evidence which is effectively out-of-sample.

Table 6: Japanese Exports and the Yen

	(1) US	(2) US	(3) UK	(4) US	(5) G6
ln $\Delta$ Import Pen.	0.82*** (0.18)	0.80*** (0.22)	0.74*** (0.16)	0.76*** (0.081)	0.87*** (0.050)
L.ln(RULC)	0.13*** (0.027)		0.25*** (0.050)	0.11*** (0.022)	0.13*** (0.017)
Post-Plaza Accord Dummy		-0.076*** (0.015)			
ln $\Delta$ Japan. MP Pen. in UK				0.18*** (0.026)	
Observations	606	606	669	606	3544

The dependent variable is the log change in sectoral Japanese import penetration. Errors clustered for 29 ISIC industries in parentheses. \* $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . All regressions include 3-digit ISIC Rev.2 industry fixed effects over the period 1978-2003. Columns (1), (2), and (4) use US data, column (3) uses UK data, and column (5) includes stacked observations from the US, the UK, Canada, Germany, Japan, France, and Italy. The data come from Comtrade, UNIDO, and Campbell (2016).

## 9 Conclusion

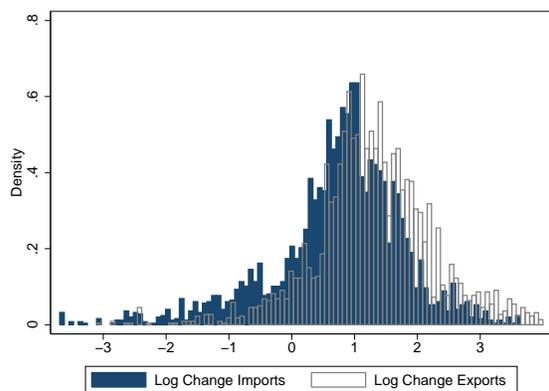
When nominal exchange rates move, the nominal rigidity of wages leads to large changes in Weighted Average Relative Unit Labor Costs (WARULC), a new measure of competitiveness for the manufacturing sector created specifically for this research. I examine periods, such as the US and Japan in the 1980s, and Canada in the 2000s, when identifiable exogenous factors were likely to have driven movements in relative price levels. Exogenous shocks (from the perspective of manufacturing employment) which lead to overvalued relative unit labor costs appear to lead to increased imports and decreased manufacturing exports, and to declines in investment and employment concentrated in relatively more open manufacturing industries. The impact of a temporary shock to relative prices is persistent, indicating that current economic relationships are historically dependent, an insight of obvious importance to the field of development economics. The shock to trade in the early 2000s was large enough to directly explain the loss of perhaps 3 million American manufacturing jobs in this period, and substantially more if input-output linkages are taken into account. These job losses were large enough to have had a macroeconomic impact. As the “Lesser Depression” continues, and as the

Federal Reserve lowers its long-run growth forecasts while the debate over “secular stagnation” rages, understanding the fundamental cause of the slow growth performance in the 2000s is more important than ever. The thesis here is that one would do well to start by studying the recent history of relative prices, and by dusting off the 1980s literature on hysteresis.<sup>59</sup>

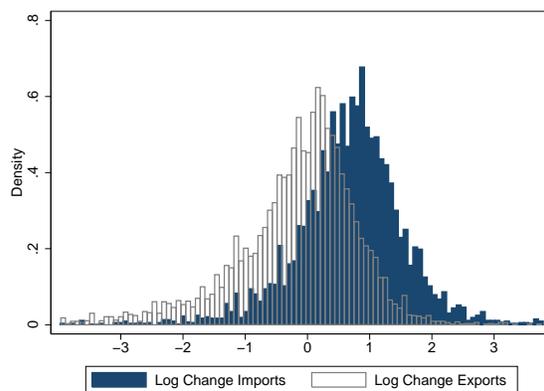
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<sup>59</sup>Note that this is in line with the Bernanke (2005) thesis, which he has written more about recently on his blog, including here: <http://www.brookings.edu/blogs/ben-bernanke/posts/2015/04/01-why-interest-rates-low-global-savings-glut>. Dooley *et al.* 2004, 2005, 2007, and 2009 are also relevant.

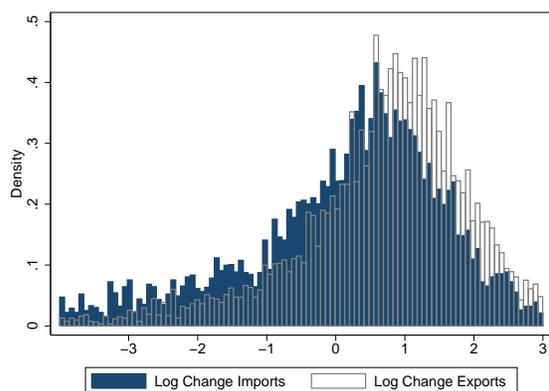
## 10 Appendix



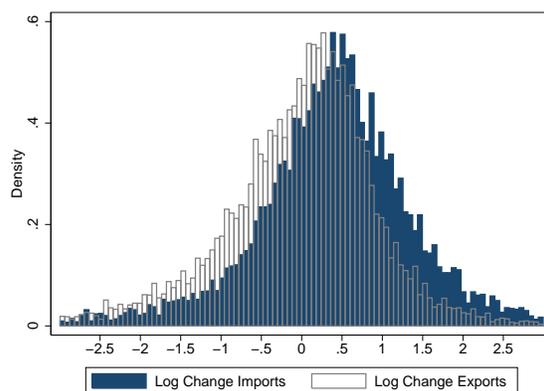
(a) Dollar Depreciation: 1972-1979



(b) Dollar Appreciation: 1979-1986



(c) Dollar Depreciation: 1986-1996



(d) Dollar Appreciation: 1996-2005

Figure 15: Distribution of Changes in Trade, by Sector and Country  
Source: Trade data for 452 SIC sectors and roughly 200 countries are from Comtrade

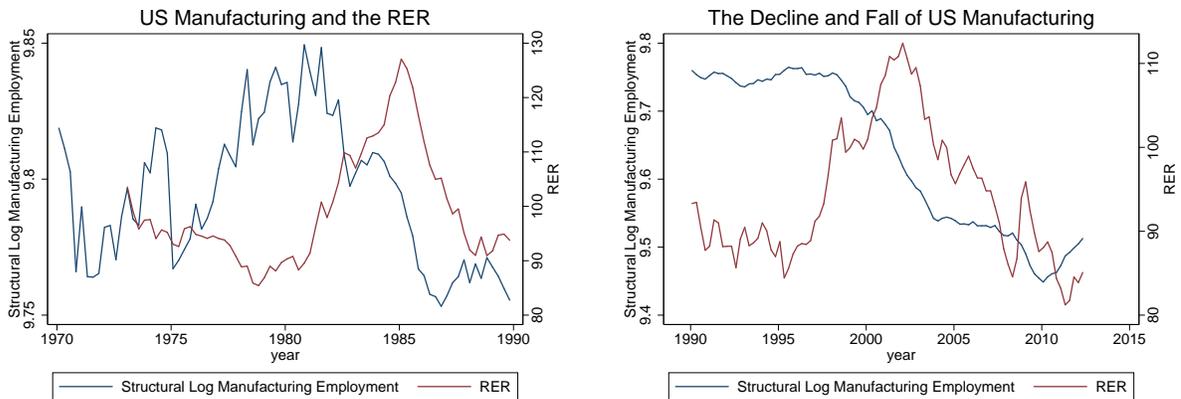
Table 7: Data Summary for Select Years

	(1)	(2)	(3)	(4)	(5)	(6)
	1974	1979	1985	1993	2001	2005
Openness	0.0857 (0.111)	0.0973 (0.104)	0.113 (0.118)	0.173 (0.173)	0.235 (0.240)	0.276 (0.265)
Value Added, Millions	1095.9 (1678.6)	1806.4 (2893.1)	2258.8 (3405.8)	3467.9 (5470.4)	4551.0 (7972.2)	5450.7 (10903.5)
Hourly Wages, Prod. Workers	4.366 (1.003)	6.462 (1.781)	9.571 (2.762)	12.00 (3.337)	15.11 (4.115)	17.50 (4.705)
Payroll/Value-Added	0.425 (0.116)	0.412 (0.110)	0.412 (0.112)	0.373 (0.119)	0.364 (0.121)	0.319 (0.116)
Investment/Value-Added	0.0670 (0.0426)	0.0692 (0.0455)	0.0755 (0.0749)	0.0623 (0.0651)	0.0649 (0.0429)	0.0502 (0.0297)
Energy Costs/Value-Added	0.0405 (0.0593)	0.0581 (0.0863)	0.0733 (0.128)	0.0490 (0.0853)	0.0492 (0.0686)	0.0467 (0.0659)
Materials Costs/Value-Added	1.263 (1.064)	1.315 (1.098)	1.362 (1.503)	1.134 (0.769)	1.153 (0.709)	1.121 (0.682)
Shipments per Worker, (1000s)	63.45 (70.48)	99.47 (113.8)	146.2 (161.4)	201.2 (179.8)	270.7 (286.0)	379.8 (486.9)
Duties %	0.0839 (0.0712)	0.0751 (0.0650)	0.0566 (0.0576)	0.0510 (0.108)	0.0306 (0.0421)	0.0242 (0.0321)
Ins., Freight Costs %	0.0748 (0.0665)	0.0688 (0.0576)	0.0746 (0.0767)	0.0971 (0.0472)	0.0916 (0.0493)	0.0958 (0.0551)
K/L, (1000s)	51.18 (56.88)	59.44 (69.46)	78.43 (89.41)	84.87 (91.02)	115.4 (130.5)	145.0 (160.1)
5-factor TFP index 1987=1.000	0.973 (0.213)	0.974 (0.151)	0.973 (0.0814)	1.018 (0.131)	1.078 (1.432)	1.216 (2.564)
Prod. Workers/Total Emp	0.763 (0.0961)	0.757 (0.0952)	0.730 (0.105)	0.714 (0.118)	0.714 (0.119)	0.700 (0.114)
Chinese Import Penetration	0.000179 (0.00142)	0.000461 (0.00205)	0.00281 (0.00887)	0.0254 (0.115)	0.0795 (0.541)	0.122 (0.623)
Japanese Import Penetration	0.0128 (0.0354)	0.0136 (0.0322)	0.0229 (0.0463)	0.0289 (0.0518)	0.0254 (0.0500)	0.0257 (0.0530)
Shipments Deflator	0.544 (0.186)	0.765 (0.131)	0.977 (0.0580)	1.160 (0.120)	1.284 (0.245)	1.402 (0.315)
Materials Deflator	0.531 (0.130)	0.775 (0.0733)	1.001 (0.0653)	1.122 (0.0793)	1.159 (0.195)	1.326 (0.270)
Investment Deflator	0.479 (0.0401)	0.734 (0.0394)	0.938 (0.0174)	1.137 (0.0550)	1.117 (0.126)	1.163 (0.148)
Energy Deflator	0.375 (0.119)	0.761 (0.0761)	1.123 (0.0525)	1.126 (0.0205)	1.386 (0.0720)	1.560 (0.146)

Mean coefficients; sd in parentheses. All variables have 357 observations for each year, except for duties and freight costs, which have just 308 observations in the 1970s and 1980s.

Table 8: Manufacturing Employment Accounting

Year	Manufacturing Consumption (billions)	Manufacturing Consumption (Share of GDP)	Manufacturing Trade Deficit (billions)	Productivity (thousands per worker)	Deficit $\Delta$ from 1995 over Productivity	Lost in Man. Since 1995
1995	1340	18.1%	159	68	0.00	0
1996	1361	17.4%	152	70	-0.09	-0.01
1997	1432	17.2%	155	73	-0.05	0.17
1998	1542	17.5%	215	76	0.75	0.32
1999	1661	17.8%	293	79	1.70	0.08
2000	1780	17.9%	364	82	2.50	0.02
2001	1688	16.4%	344	82	2.26	-0.80
2002	1760	16.5%	404	89	2.76	-1.99
2003	1822	16.4%	448	95	3.05	-2.74
2004	2023	17.0%	540	104	3.68	-2.93
2005	2158	17.1%	590	110	3.92	-3.02



(a) 1970s and 1980s

(b) 1990s and 2000s

Figure 16: Structural Manufacturing Employment vs. the RER

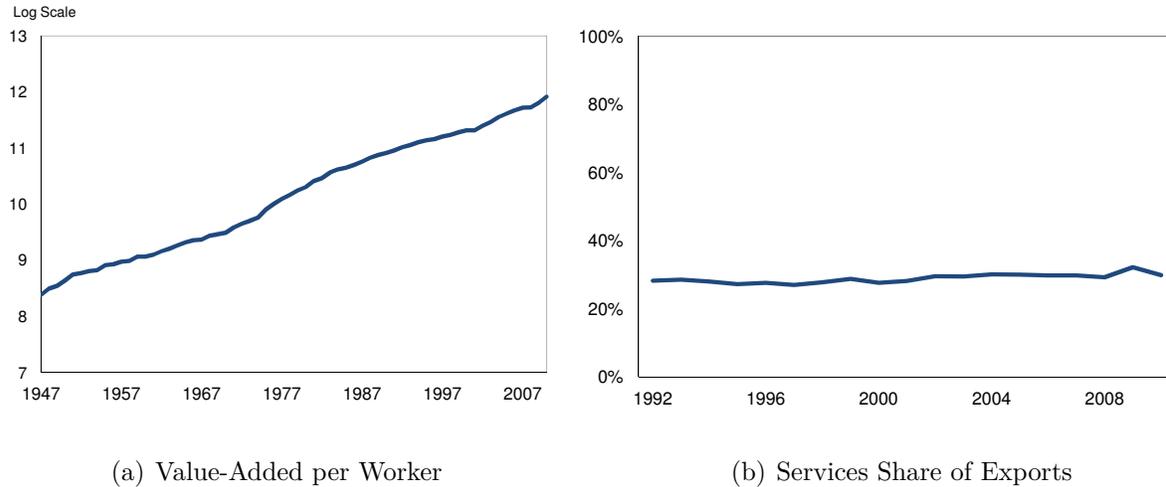


Figure 17: The Usual Suspects: Explanations for the Decline of Manufacturing  
Source: BEA, Census

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# 11 Online Appendix

## 11.1 Theoretical Model

In this section, I motivate the empirics using a slight variation of the Chaney (2008) model with sunk costs as in Melitz (2003). I use this approach because I can show analytically that sectoral labor demand depends on the past history of prices (and I can derive an analytical solution for a dynamic gravity equation), and also partly due to the popularity of the Melitz model.

In this model, households in the home country consume from a continuum of goods,  $\omega$ , from a set of goods in  $H+1$  sectors,  $\Omega_h$ , determined in equilibrium. There is a freely traded homogeneous numeraire good  $q_0$  as in Chaney (2008), with one unit of labor producing  $w$  units of the good.

$$U_t = q_{0t}^{\mu_0} \prod_{h=1}^H \left( \int_{\Omega_h} q_h(\omega)_t^{\frac{(\sigma_h-1)}{\sigma_h}} d\omega \right)^{\frac{\sigma_h \mu_h}{(\sigma_h-1)}}, \sigma_h > 1 \forall h. \quad (11.1)$$

Each period this leads to the solution for variety  $\omega$ , with total income in the home country,  $Y_t$ , and the CES price index  $P_{ht} = \left( \int_{\omega \in \Omega_h} p_h(\omega)_t^{(1-\sigma_h)} d\omega \right)^{\frac{1}{(\sigma_h-1)}}$ :

$$q_h(\omega)_t = \frac{\mu_h Y_t p_h(\omega)_t^{-\sigma_h}}{P_{ht}^{1-\sigma_h}}. \quad (11.2)$$

Firms maximize profits each period after paying a sunk fixed cost to receive a productivity draw (output per unit of labor  $\varphi$ ) and begin producing for the home market, and then choose whether to pay a sunk entry cost to enter the foreign market (for simplicity I assume there are only two countries). Profits per period for an existing firm from sales at home are thus<sup>60</sup>

$$\Pi_h(\omega)_t = q_h(\omega)_t p_h(\omega)_t - \frac{q_h(\omega)_t w_t}{\varphi_h(\omega)} - f_{ht} w_t, \quad (11.3)$$

where  $p$  is price,  $q$  is output sold at home,  $w$  is the wage,  $\tau$  is an iceberg trade cost,  $f$  is the per-period overhead cost and  $\varphi_h(\omega)$  is the output per unit of labor, supplied inelastically by households. Firms have an exogenous probability of death  $\delta$ , yet otherwise will always choose to stay in a market they have previously entered, as expected profits are strictly

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<sup>60</sup>And similarly for exports:  $\Pi_h(\omega)_t^* = q_h(\omega)_t^* p_h(\omega)_t^* - \frac{q_h(\omega)_t^* w_t \tau_t}{\varphi_h(\omega)}$ , where  $q^*$  and  $p^*$  denote quantities and prices of goods produced at home and sold abroad.

positive going forward. Maximizing profits, firms choose prices marked up over marginal cost  $p_h(\omega)_t^*$  (denotes the price of exports)

$$p_h(\omega)_t = \frac{\sigma_h}{\sigma_h - 1} \frac{w_t}{\varphi_h(\omega)}, \quad p_h(\omega)_t^* = \frac{\sigma_h}{\sigma_h - 1} \frac{w_t \tau_t}{\varphi_h(\omega)}. \quad (11.4)$$

A home firm which has previously paid to receive a productivity draw will pay a sunk fixed cost to export,  $f^x$ , if it is less than the expected discounted present value of future profits.<sup>61</sup>

$$\text{Foreign Entry : } E_t \Pi(\omega)_{PV,t}^* = E_t \sum_{s=0}^{\infty} (1 - \delta)^s \Pi(\omega)_{t+s}^* - f_{ht}^x w_t \geq 0. \quad (11.5)$$

The baseline empirical approach in the next section will be to use relative price indices to explain the behavior of sectoral manufacturing employment. Thus, we can write sectoral labor demand as:

$$L_{ht} = \underbrace{\int_{\omega \in \Omega} \frac{q_h(\omega)_t}{\varphi_h(\omega)_t}}_{\text{Home Production}} + \underbrace{\int_{\omega \in \Omega^*} \frac{q_h^*(\omega)_t}{\varphi_h(\omega)_t}}_{\text{Export Production}} + \underbrace{M_{ht}^e (f_{ht}^e + f_{ht}^x p_{ht}^x)}_{\text{Entry}} + \underbrace{\sum_{s=0}^{\infty} M_{h,t-s}^e (1 - \delta)^s f_{ht} \varrho_{h,t,s}}_{\text{Overhead}}. \quad (11.6)$$

Here  $M_{ht}^e$  is the mass of potential entrants at time t,  $\varrho_{ht}^x = 1 - G(\bar{\varphi}_x)$  is the share of new firms in sector h with productivity greater than the cutoff productivity for exporting,  $\bar{\varphi}_x$ , and  $\varrho_{h,t,s} = 1 - G(\bar{\varphi}_{f,t,s})$  is the share of continuing firms with productivity greater than the maximum cutoff for continuing to produce for the home market,  $\bar{\varphi}_{f,t,s}$ , in between years t-s and t. The mass of entrants in Chaney (2008) is assumed to be exogenous, and based on country factors (proportional to output).

The cutoff productivity for entering into the export market at time t can be derived from equation (11.5) assuming that firms know the productivity distribution when they decide to invest to receive a productivity draw, and then have perfect foresight of market conditions for the upcoming period when they decide to invest. However, firms make their investment decisions using rules-of-thumb, taking the form of simple expectations about a future they believe will be like today, conditioned on not receiving a “death”

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<sup>61</sup>Firms will pay a fixed cost to receive a productivity draw and enter the domestic market if the expected profits, home and abroad, are greater than the fixed cost of entry:  $E_t \Pi(\omega)_{tot,PV,t} = E_t [\sum_{s=0}^{\infty} (1 - \delta)^s \Pi(\omega)_{t+s} + \Pi(\omega)_{PV,t}^*] - f_{e,ht} w_t \geq 0$ .

draw with probability  $\delta$ . Thus the cutoff productivity for exporting is

$$\bar{\varphi}_{xht} = \left( \frac{P_{ht}^{*(1-\sigma_h)} w_t^{\sigma_h}}{\mu_h Y_t^*} \lambda_0 \delta f_{h,t}^x \right)^{\frac{1}{\sigma_h-1}} \tau_t, \quad (11.7)$$

where  $\lambda_0 = \frac{\sigma_h}{(\sigma_h-1)\sigma_h-1}$ .

When wages, trade costs, or the sunk fixed costs of exporting rise, or the foreign market either becomes more competitive or experiences an exogenous reduction in demand in sector  $h$ , the cutoff productivity for exporting will rise, meaning that fewer firms will enter.

Additionally, existing firms will exit and stop producing if revenue fails to cover per-period fixed costs. The cutoff productivity for staying in business for purely domestic firms is<sup>62</sup>

$$\bar{\varphi}_{fht} = \left( \frac{P_{ht}^{(1-\sigma_h)} w_t^{\sigma_h}}{\mu_h Y_t} \lambda_0 f_{ht} \right)^{\frac{1}{\sigma_h-1}}. \quad (11.8)$$

This equation tells us that when labor costs or fixed costs rise, or when the domestic market becomes more competitive or domestic demand in sector  $h$  shrinks, fewer firms will be around to employ labor in overhead activities. To the extent that it is the case that more productive firms export (as it is in this model), relative price appreciations, denoted by a rise in wages, or a rise in domestic vs. foreign GDP, would imply that import-competing industries might be more adversely affected than relatively export-intensive industries along the extensive margin, since industries with many firms that do not export may have a more difficult time covering the fixed overhead costs.

The first term in the sectoral labor demand equation (11.6) is the total labor requirement for home production. Plugging in the solutions from above and integrating assuming Pareto-distributed productivity with parameter  $\gamma_h$  (the Pareto distribution is  $G(\varphi) = 1 - \varphi^{-\gamma_h}$ , where I assume  $\gamma_h > \sigma_h - 1$ ), the first term becomes

$$\frac{\sum_{s=0}^{\infty} \mu_{h,t} Y_t M_{h,t-s}^e \rho^s w_t^{-\sigma_h} \lambda_1 \bar{\varphi}_{mh,t,s}^{(\sigma_h-1-\gamma_h)}}{\sum_{s=0}^{\infty} \rho^s (M_{h,t-s}^e w_t^{(1-\sigma_h)} \lambda_2 \bar{\varphi}_{mh,t,s}^{\sigma_h-1-\gamma_h} + M_{h,t,s}^{*e} (w_t^* \tau_{ht}^*)^{(1-\sigma_h)} \lambda_2 \bar{\varphi}_{m,xh,t,s}^{*(\sigma_h-1-\gamma_h)})}, \quad (11.9)$$

<sup>62</sup>The constraint for staying in business for firms which also export is  $\bar{\varphi}_{fxt} = \left( \frac{\mu_h Y_t}{P_{ht}^{(1-\sigma_h)}} + \frac{\mu_h^* Y_t^* \tau_t}{P_{ht}^{*(1-\sigma_h)}} \right)^{\frac{-1}{\sigma_h-1}} (\lambda_0 w_t^{\sigma_h} f_{ht})^{\frac{1}{\sigma_h-1}}$ .

where  $\lambda_1$  and  $\lambda_2$  are parameters<sup>63</sup>,  $\rho = 1 - \delta$  for brevity,  $\bar{\varphi}_{mh,t,s}$  is the maximum cutoff productivity to remain in the market for a firm that entered  $s$  periods previously in the intervening years, and variables with an asterisk denote foreign variables. Thus  $\bar{\varphi}_{m^*h,t,s}^*$  is the maximum cutoff productivity for a foreign firm that entered  $s$  periods previously to export and remain producing during the intervening years, and variables with an asterisk denote foreign variables. The denominator of this equation is the solution to  $P_{ht}^{1-\sigma_h}$ . Thus, along the intensive margin, labor demand for domestic production depends positively on domestic sectoral demand ( $\mu_{ht}Y_t$ ), negatively on domestic wages, and positively on importing trade costs,  $\tau_{ht}^*$ . The extensive margin operates via current and lagged cutoff productivities, which negatively impact home sectoral labor demand. Higher home wages, a more competitive home market, higher fixed costs or smaller domestic demand will all potentially trigger firm exits (via equation 11.8), which will not necessarily be reversed immediately when these variables return to previous levels. The sole discordant note is that, due to the CES preferences, which serve as a modeling convenience rather than as a statement about the way the world operates, growing productivity in a sector will not imply decreased labor demand as both intuition and data would suggest.

The second term on the right-hand side of equation (11.6) is analogous, as labor devoted to production for exports will be a positive function of foreign demand along the intensive margin, and a negative function of home wages and trade costs for exporting. Additionally, there can be movements along the extensive margin, which will depend on the cutoff productivity for existing firms, equation (11.8). If wages, fixed overhead costs ( $f_{ht}$ ), iceberg trade costs, or more foreign firms enter, the cutoff productivity for making a profit will rise, and some existing firms will be forced out of the market:

$$\frac{\sum_{s=0}^{\infty} \mu_{h,t}^* Y_t^* M_{h,t-s}^{*e} \rho^s w_t^{*(-\sigma_h)} \tau_t^{1-\sigma_h} \lambda_1 \bar{\varphi}_{mh,t,s}^{\sigma_h-1-\gamma_h}}{\sum_{s=0}^{\infty} \rho^s M_{h,t-s}^e (w_t \tau_{ht})^{(1-\sigma_h)} \lambda_2 \bar{\varphi}_{mh,t-s}^{\sigma_h-1-\gamma_h} + \sum_{s=0}^{\infty} \rho^s M_{h,t-s}^{*e} w_t^{*(1-\sigma_h)} \lambda_2 \bar{\varphi}_{mh,t-s}^{*(\sigma_h-1-\gamma_h)}}. \quad (11.10)$$

While there is no explicit “exchange rate” in this model, one could proxy it in several ways. One is to stipulate that both wages and output are denominated in local dollars, and to then treat an exchange rate appreciation as local wages and output rising relative to foreign. A second approach, used by Eichengreen *et al.* (2011), is to proxy exchange rate movements using the iceberg trade costs. Either would yield the needed result. Also note that since either of these methods imply a constant elasticity of changes

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<sup>63</sup>  $\lambda_1 = \frac{(\sigma_h/(\sigma_h-1))^{-\sigma_h}}{\gamma_h - (\sigma_h-1)}$  and  $\lambda_2 = \frac{1}{\gamma_h - (\sigma_h-1)}$

in employment in exporting or given movements in wages or iceberg trade costs, that sectors with higher shares of either imports or exports in production will theoretically be impacted more by movements in exchange rates. This intuitive theoretical result will be used to identify the impact of relative price movements on manufacturing employment.

## 11.2 Implications (Online Appendix)

*Proposition: Trade is a Function of History*

To simplify matters, the fixed overhead costs will now be set to 0. Total exports in industry  $h$  at time  $t$  are the sum of exports of each cohort of past entrants, where I borrow Chaney's assumption that the mass of entrants in industry  $h$  at time  $t$  is  $\alpha_{ht}Y_t$ :

$$X_{ht} = \sum_{s=0}^{\infty} (1-\delta)^s \alpha_h Y_{t-s} \int_{\bar{\varphi}_{t-s}}^{\infty} x_{h,t}(\varphi) \mu(\varphi) d\varphi. \quad (11.11)$$

Substituting in the solutions for  $x = pq$ , plugging in the pricing rules, assuming Pareto-distributed productivity and integrating, I arrive at a dynamic gravity equation:

$$X_{ht} = \frac{\mu_h^* Y_t^* (w_t \tau_t)^{1-\sigma_h}}{P_t^{*(1-\sigma_h)}} \lambda_3 \sum_{s=0}^t (1-\delta)^s (\alpha_h Y_{t-s}) \left( \frac{P_{h,t-s}^{*(1-\sigma)} w_{t-s}^{\sigma_h}}{\mu_{h,t-s} Y_{t-s}^*} \lambda_0 \delta f_{h,t-s}^x \tau_{t-s}^{\sigma_h-1} \right)^{\frac{-\gamma_h + \sigma_h - 1}{\sigma_h - 1}}, \quad (11.12)$$

where  $\lambda_3 = \frac{\gamma_h}{\gamma_h - \sigma_h + 1} \frac{\sigma_h^{1-\sigma_h}}{(\sigma_h - 1)^{1-\sigma_h}}$ , and where  $P_t^{1-\sigma}$  is the denominator of equation (11.10).

The key underlying insight of this equation is that trade today depends on the history of trade costs, both entry and iceberg, in addition to market sizes and contemporaneous variables. Even with the simplifying assumptions, this equation is still fairly complex, so for purposes of clarity, I have summarized the sign of the impact of key variables on exports (foreign variables denoted by an  $*$ ) at time  $t$ :

$$X_t = f(\underbrace{Y_t}_{+}, \underbrace{Y_{t-s}}_{+}, \underbrace{Y_t^*}_{+}, \underbrace{Y_{t-s}^*}_{+}, \underbrace{w_t}_{-}, \underbrace{w_{t-s}}_{-}, \underbrace{\tau_t}_{-}, \underbrace{\tau_{t-s}}_{-}, \underbrace{f_{ht}^x}_{-}, \underbrace{f_{h,t-s}^x}_{-}), s > 0. \quad (11.13)$$

Note that if we were in a one-period world, then, as in Chaney (2008), the elasticity of substitution would not magnify the impact of iceberg trade costs, but that with multiple periods of firm entry, this result would no longer follow. How general is this dynamic gravity formulation? In the Additional Appendix, I prove that similar tran-

sition dynamics arise when moving from autarky to free trade for assumptions similar to those for key models in the new trade theory canon, including Krugman (1980) and Melitz (2003). Recent related research includes Burstein and Melitz (2013), who provide impulse response functions for shocks to trade costs, and Bergin and Lin (2012), who focus on the dynamic impact of future shocks. The large aforementioned literature on hysteresis from the 1980s carried the same core insight, that trade shocks can have lagged effects, as in equation (11.12). This paper is the first to show that the logic of sunk entry costs naturally leads to a “dynamic gravity” equation which can be derived explicitly.

Empirically, incumbent firms dominate most sectors in terms of market share, which means that the current trade relationship could be determined, in part, by historical factors as emphasized by Campbell (2010, 2013), Eichengreen and Irwin (1998), and Head, Mayer and Ries (2010).<sup>64</sup>

*Corollary: The Real Wage is a Function of Historical Market Access*

A key insight from New Trade Theory is that the real wage is a function of market access. Krugman (1992) argues that new trade theory can help explain higher wages in the northern manufacturing belt of the US, Redding and Venables (2004) argue that market access can explain cross-country variation in per capita income, and Liu and Meissner (2012) show that market access can help explain high living standards in northwest Europe in the early 20th century. An important corollary is that sunk costs imply that the real wage is also a function of historical market access. This follows from the dynamic gravity equation, as utility is increasing in the number of varieties and the extensive margin increases over time after a decline in trade costs. Figure 18 in the Appendix is a choropleth map of per capita income by county, which can be compared to the distribution of import-competing manufacturing in Figure 19. It is immediately obvious that both are highly correlated with access to sea-navigable waterways – and that the US north was still much richer than the south in 1979. I posit that this owes more to the past history of trade costs than it does to low shipping costs on Lake Erie today.

### 11.3 Figures and Graphs (Online Appendix)

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<sup>64</sup>Edwards (2015) makes a similar argument based on a search model of trade.

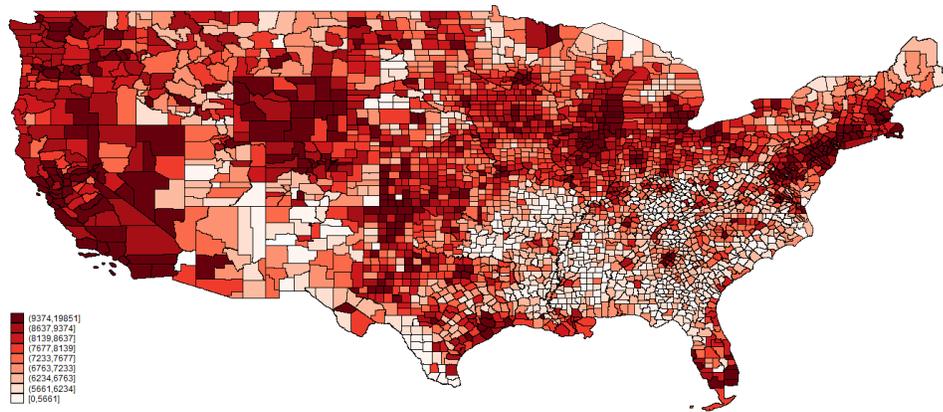


Figure 18: Income per Capita, 1979

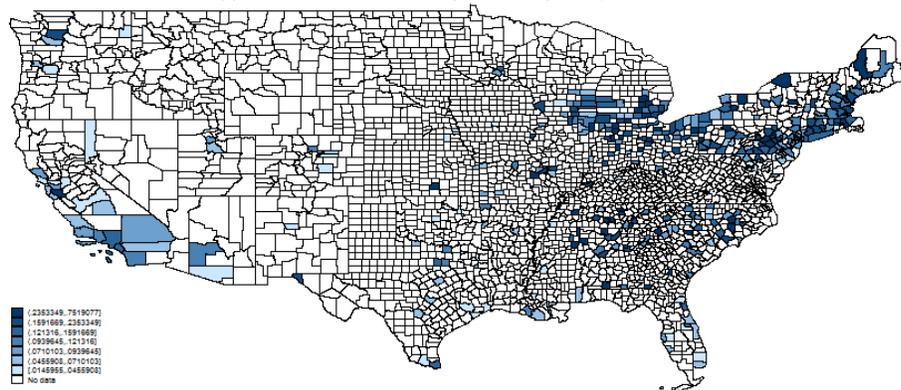


Figure 19: Import-Competing Manufacturing Employment, Share of Total Employment, 1979

Notes: 1,500 worker minimum. Sources: Census Bureau and WITS

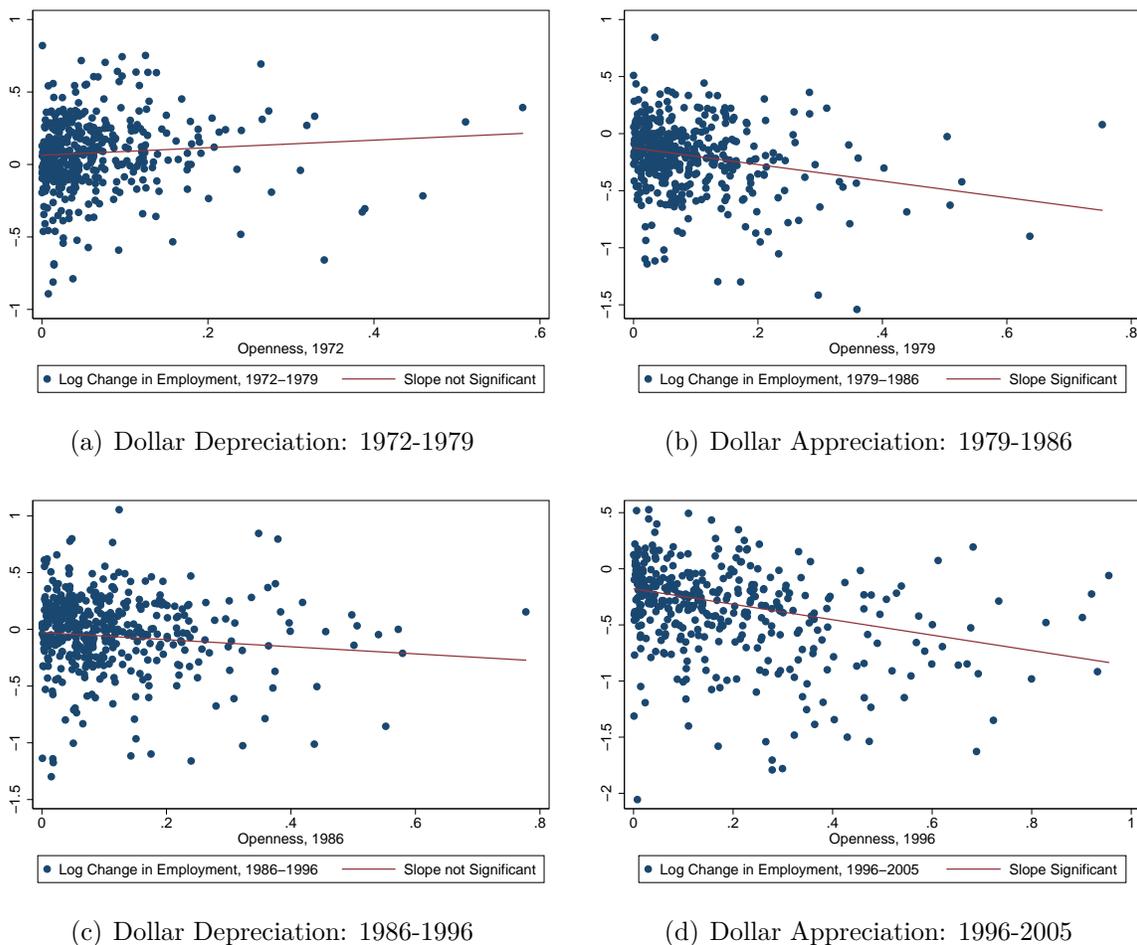


Figure 20: Manufacturing Employment vs. Openness

Notes: In the right panels, when the US price level is relatively high, more open sectors experience statistically significant and economically meaningful declines in employment. When the US price level is close to that of trading partners, there is no relationship. All regression lines weighted by initial year value-added. Source: Annual Survey of Manufactures, Census Bureau

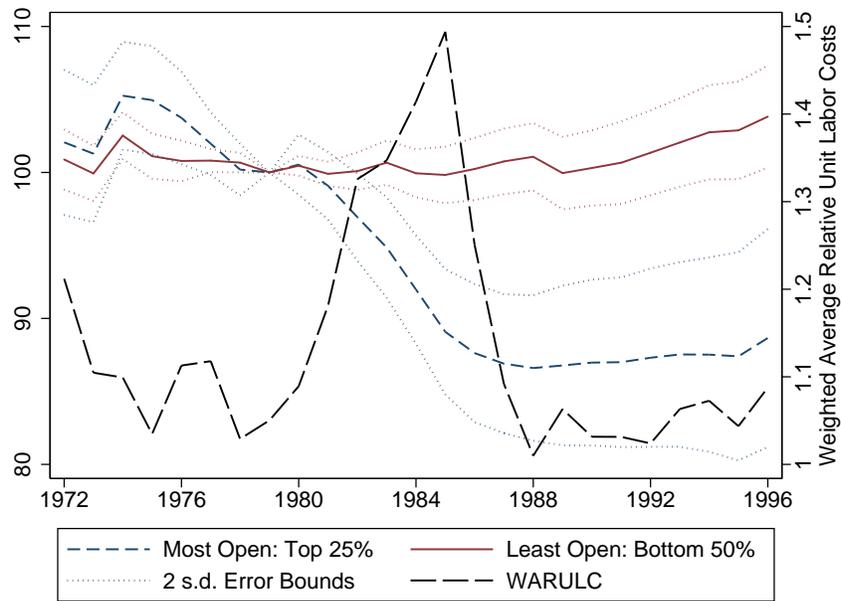


Figure 21: Employment Growth by Degree of Openness in 1972 (SIC)\*

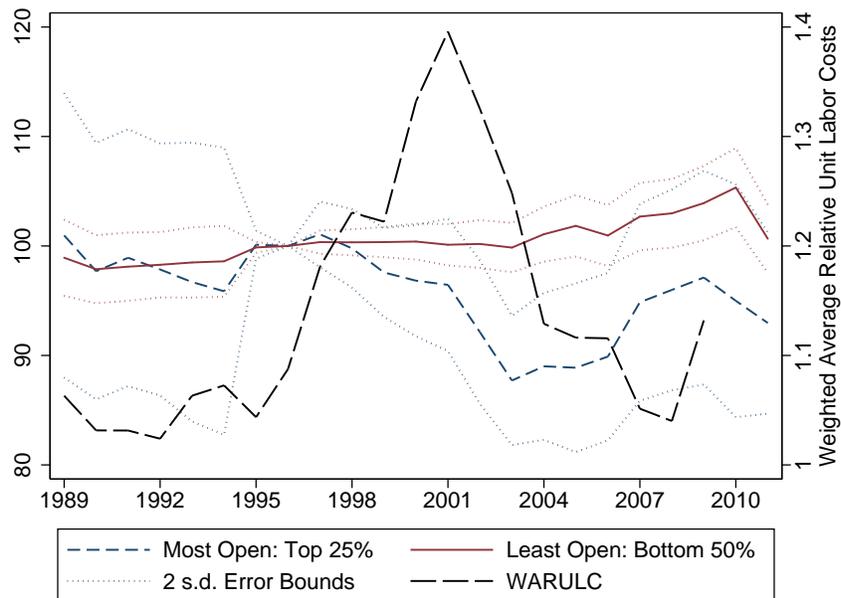


Figure 22: Employment Growth by Degree of Openness in 1989 (NAICs)\*

\*Notes:  $Openness = m * imports / (imports + shipments - exports) + (1 - m) * (exports / shipments)$ , where  $m = imports / (imports + exports)$ . Employment is indexed to 1979 in Figure 3, which uses SIC data, and to 1996 in Figure 4, which uses NAICs data, and is updated with residuals from a regression controlling for demand, productivity, and year fixed effects. Thus the blue dashed lines in the figures tell us how employment in more open sectors evolved after controlling for other key factors. The cutoff for the non-open sectors was 3.8% in 1972 and 9.7% in 1989, and the lower bound for the open sectors was 8.3% in 1972 and 20.9% in 1989.

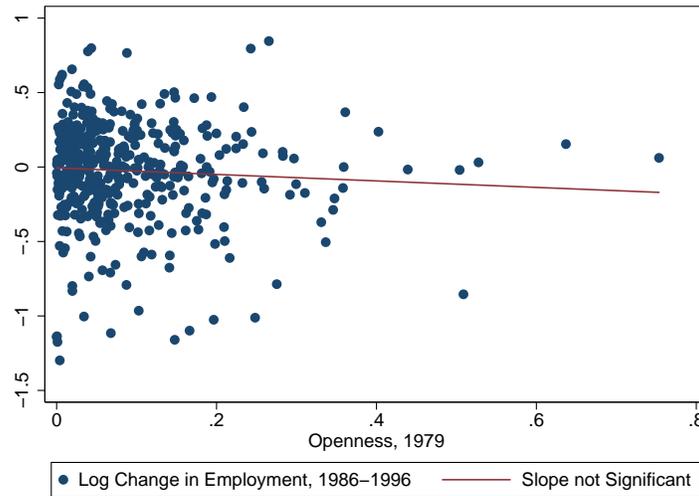


Figure 23: Hysteresis: No Rebound after Collapse

Note: This figure demonstrates hysteresis, as more open sectors which did relatively worse during the downturn did not necessarily do better once US relative prices returned to unity. Sources: Annual Survey of Manufactures, Census Bureau

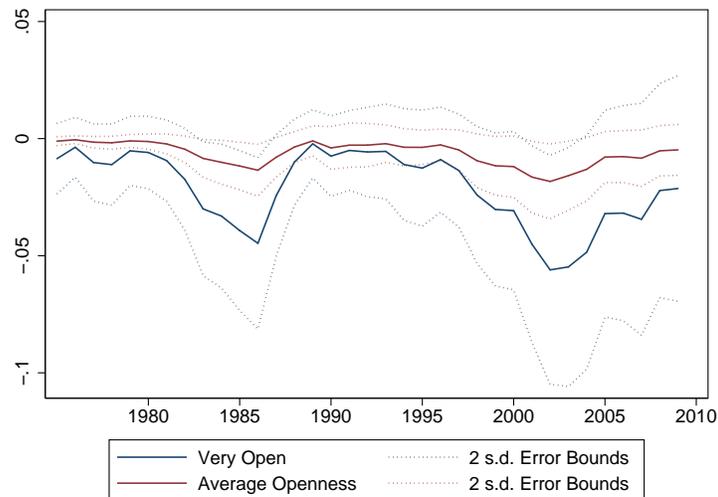


Figure 24: Implied Job Losses for Two Sectors

Note: This figure estimates the linear combination of  $\beta_0 Avg.Openness_{h,t-3,t-6} + \beta_1 (\ln(WARULC_{t-1})) * Avg.Openness_{h,t-3,t-6}$  from the benchmark regression in Column 5 in Table 1 for two sectors. One sector has average openness and the other is one of the most open sectors in the economy (with an average openness of 50% in the early 1980s). The y-axis is thus the log change in sectoral employment.

Table 9: Falsification Exercises: Input Prices and Employment at Various Lags

	$\ln\Delta L$	$\ln\Delta MaterialsPrices$	$\ln\Delta EnergyPrices$	$\ln\Delta InvestmentPrices$
L3.ln(WARULC)*Rel. Openness	-0.0077 (0.018)	-0.0044 (0.0085)	-0.0057 (0.0053)	0.0013 (0.0022)
L2.ln(WARULC)*Rel. Openness	-0.043*** (0.016)	-0.0077 (0.011)	-0.0048 (0.0047)	-0.00059 (0.0025)
L.ln(WARULC)*Rel. Openness	-0.061*** (0.022)	0.019* (0.010)	0.018 (0.011)	0.0032 (0.0034)
ln(WARULC)*Rel. Openness	-0.068** (0.027)	0.0022 (0.0085)	-0.0077 (0.0065)	0.0015 (0.0026)
F.ln(WARULC)*Rel. Openness	-0.038* (0.021)	0.000042 (0.011)	-0.00094 (0.0039)	0.0022 (0.0027)
F2.ln(WARULC)*Rel. Openness	-0.014 (0.025)	-0.010 (0.012)	-0.0036 (0.0043)	0.0014 (0.0026)
F3.ln(WARULC)*Rel. Openness	0.0039 (0.022)	-0.0093 (0.0095)	-0.00045 (0.0049)	0.0023 (0.0017)

Two-way Clustered standard errors in parenthesis, clustered by year and 4-digit SIC sectors. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . Each cell is a separate regression, with 28 regressions total, and with other controls from the benchmark regression suppressed. In addition, each regression controls for relative openness at the same number of leads and lags as the reported interaction term. The dependent variable in the first column is the log change in sectoral manufacturing employment. These results demonstrate that this estimation strategy is not generally prone to yielding spurious results.

Table 10: Appendix Robustness: Dynamics and Other Controls

	$\ln\Delta L$					
A. Adding Dynamics and Other Controls						
L.ln(WARULC)*L.Rel.Openness	-0.087*** (0.020)	-0.087*** (0.020)	-0.089*** (0.027)			-0.094*** (0.021)
L.ln $\Delta L$	0.062*** (0.020)	0.063*** (0.021)				
L2.ln $\Delta L$		-0.0087 (0.027)				
L.ln(WARULC)*L.Openness				-0.48*** (0.12)		
L.(WARULC-1)*L.Openness					-0.40*** (0.096)	
Duties						0.025* (0.014)
Ins., Freight Costs						-0.0038 (0.0082)
B. Longer Lags of Rel. Openness						
L1.ln(WARULC)*L1.RO	-0.090*** (0.021)					
L1.ln(WARULC)*L2.RO		-0.075*** (0.021)				
L1.ln(WARULC)*L3.RO			-0.074*** (0.021)			
L1.ln(WARULC)*L4.RO				-0.070*** (0.018)		
L1.ln(WARULC)*L5.RO					-0.070*** (0.020)	
L1.ln(WARULC)*(RO in 1972)						-0.019*** (0.0059)

Two-way clustered standard errors in parentheses, clustered by year and by 4-digit SIC industry. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . All regressions are weighted by initial sectoral value-added, and include 359 SIC industry and year fixed effects over the period 1973-2009. The dependent variable is the log change in sectoral manufacturing employment. In Panel A the first two columns add lagged dependent variables. Note that given  $T=37$ , Nickell Bias will be relatively small. The third column includes sector trends, which control for second-derivative trends in employment. The fourth column uses openness interacted with  $\ln(\text{WARULC})$  instead of relative openness as the regressor of interest, and the fifth column uses  $\text{WARULC}-1$  in place of  $\ln(\text{WARULC})$ , and the last column includes controls for the cost of insurance and freight. In Panel B, the key regressor is the lagged log of  $\text{WARULC}$  interacted with longer and longer lags of relative openness (RO). The last column interacts the lag of log  $\text{WARULC}$  Value-Added in 1972. The other controls from the baseline regression in Table I are suppressed.

Table 11: Appendix Robustness: Was it Just China?

	$\ln\Delta L$					
L.ln(WARULC)*Rel.Openness	-0.090*** (0.021)	-0.067*** (0.026)	-0.071*** (0.025)	-0.093*** (0.021)	-0.078*** (0.022)	-0.083*** (0.022)
L.Chinese Import Penetration	-0.042* (0.021)		-0.037 (0.049)	-0.13*** (0.020)		-0.11*** (0.028)
L.Chinese Import Pen.*ln(RULC)		-0.046 (0.038)			-0.086*** (0.018)	
Industry FE	Yes	Yes	Yes	No	No	No
Time Period	1972-2009	1990-2009	1990-2009	1972-2009	1990-2009	1990-2009

Two-way Clustered standard errors in parenthesis, clustered by year and 4-digit SIC sectors. \* $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ . The first three of the six regressions include industry FEs, and the 2nd, 3rd, 5th, and 6th columns include data from the period of the rise of China, 1990-2009. The dependent variable is the log change in sectoral manufacturing employment, for 359 four digit SIC sectors. Other controls from [Table 1](#) are omitted for space.