Relative Prices, Hysteresis, and the Decline of American Manufacturing

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2013

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April, 2014

JOB MARKET PAPER
Most recent draft here.

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 US fiscal deficits led to a sharp appreciation in the dollar, and to Canada's experience in mid-2000s, when high oil prices and a falling US dollar led to an equally sharp appreciation of the Canadian dollar. I use disaggregated sectoral data and a difference-in-difference methodology, finding that an appreciation in relative unit labor costs for the US lead to disproportionate declines in employment, output, investment, and productivity in relatively more open manufacturing sectors. In addition, I find that the impact of a temporary shock to real exchange rates is surprisingly long-lived. I explain the persistent effects of exchange rate movements on manufacturing using a Melitz model extension with sunk fixed costs, which leads to a dynamic gravity equation whereby shocks to trade have persistent effects that decay over time. 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, F41, N60, L60
Keywords: Exchange Rates, American Manufacturing, Hysteresis, Trade

†Special thanks are in order for the comments I have received in the lively Macro/International brownbag at UC Davis, at the All-UC Economic History Conference at Berkeley, and at seminars at UC Davis, Colby College, Santa Clara, and the New Economic School. I benefitted enormously from feedback from my thesis advisor, Chris Meissner, and from Paul Bergin, Gregory Clark, Robert Feenstra, Martha Olney, Katheryn Russ, Deborah Swenson, Alan Taylor, and Noam Yuchtman. This research depends on the new and much improved version 8.0 of the Penn World Tables, so I am also indebted to Robert Feenstra, Robert Inklaar, and Marcel Timmer. Thanks also to Wayne Gray both for managing the NBER-CES manufacturing page, a wonderful resource, and for replying graciously to my suggested improvements for the NAICS to SIC concordance. This research project benefitted from the time I spent as a Staff Economist on the President's Council of Economic Advisers, and benefitted immensely from conversations I had with Chad Bown, Michael Klein, and Jay Shambaugh. All opinions and errors herein are my own.

American manufacturing employment suddenly collapsed in the early 2000s, falling by three million (17.4%) from 2000 to 2003 (Figure 1) after having declined by just 3% from the late 1960s to 2000. As the economy grew from 2003-2007, the jobs lost did not return. In the aftermath of the financial crisis in 2008, the manufacturing sector lost an additional 2.3 million jobs. Since then, fewer than 600,000 of these jobs have returned, indicating that many of the jobs lost during the recession are likely to be gone permanently.

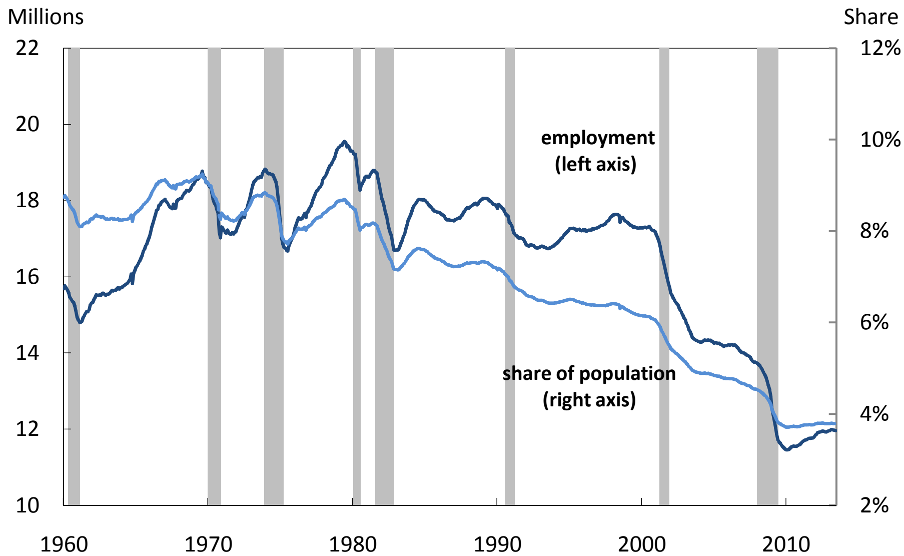


Figure 1: American Manufacturing Employment, 1960-2013.
Source: BEA

What caused the sudden collapse? Economists have generally believed that the public's concern with trade and offshoring as an explanation for the decline of American manufacturing employment is misplaced (Baily and Bosworth, 2014, and Edwards and Lawrence, 2013), and that the real cause is outsized productivity gains in manufacturing and a sectoral shift toward services. If true, this would imply that a decline in manufacturing employment is a sign of progress, and irrelevant due to growing services exports. However, aggregate measured labor productivity growth in manufacturing has been relatively constant over the post-war period, making it a strange explanation for a sudden employment collapse in this sector (Appendix Figure 20(a)).[1] And while the share of services in GDP has long been increasing, the services share of exports has been

[1]Yet, Houseman *et al.* (2010) present evidence that perhaps one-fifth to one-half of the measured growth in value-added per worker from 1997 to 2007 reflects upward bias due to the dramatic increase of imported intermediate inputs. This would make productivity growth a less likely cause of the employment collapse over the same period.

surprisingly constant over the past few decades (Figure 20(b)). In fact, the services trade surplus actually shrank by one-third over the period 1997-2004, while the goods trade deficit ex-manufacturing also worsened. Thus, the decline in manufacturing in the early 2000s was actually part of a broad-based decline in tradable sectors.[2]

These facts give credence to recent research focusing on trade liberalization and the rise of China as explanations for the collapse of US manufacturing. In a seminal paper, 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.* (2013) argue that the "sag" in *overall* U.S. employment in the 2000s – a decade which began with the Federal Reserve nearly missing the zero lower bound and which ended in a liquidity trap – was partly caused by the collateral damage from increasing Chinese manufacturing imports to other sectors via input-output linkages. In another important contribution Pierce and Schott (2012) argue that China's ascension to the WTO removed trade policy uncertainty and led to a large increase in imports from China, reducing US manufacturing employment.[3]

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, see Klein *et al.* 2002 for an overview).[4] Even though the dollar was generally strong in the early 2000s, to my knowledge these two literatures – on the collapse in manufacturing in the early 2000s and the impact of exchange rate movements – do not intersect. This paper is intended to fill the gap by asking how much of the collapse in manufacturing in the early 2000s can be explained by relative prices.

To identify a causal impact 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 mid-2000s, when high oil prices and a falling US dollar led to an equally sharp appreciation of the Canadian dollar. The benefit of these periods is that each contained large RER movements which I argue were likely to be exogenous from the perspective of the manufacturing sector. I

[2]There were also declines in the trade balances of agricultural produce, animal husbandry, forestry and fish according to BEA data. Two notable exceptions were natural gas and metal ores, which were likely affected by supply-side factors.

[3]Ebenstein *et al.* (2012) document a series of facts consistent with the idea that Chinese import competition reduced US manufacturing employment.

[4] Other key papers in this literature are Branson and Love (1986), (1987), and (1988), Gourinchas (1999), Campa and Goldberg (2001), for the U.S. and Berman *et al.*, (2012), Moser *et al.*, (2012), and Belke *et al.* (2013) for Europe. Rose (1991) and McKinnon and Schnabl (2006), by contrast, find no impact of real exchange rate movements on trade and so this question is still not settled.

then use a difference-in-difference research design using substantial variation in lagged openness across disaggregated manufacturing sectors and in real exchange rates over time to identify the impact of currency appreciations on manufacturing sectors with differential exposure to international trade. I find that when relative unit labor costs in manufacturing are high (even when proxied by changes in the structural budget balance in the US case, or by oil prices in the Canadian case), more open sectors experience a relative decline in employment and output. For the US, I find this is due to 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 for a significant impact on inventory, sectoral prices, or on 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.[5] 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 seen 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 plausibly exogenous policy-related movement in real exchange rates in the 1980s. I find that while Japanese industries gained market share in the US when the Yen was weak, after the Yen appreciated sharply vs. the dollar, Japanese industries consolidated their gains but did not make further inroads.

This paper has not already 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, as it was computed as an "index-of-indices," which does not reflect compositional changes in trade toward countries, such as China, with systematically lower price levels (Fahle, Marquez, and Thomas 2008). The Fed's RER index implies that the appreciation in the dollar from 1996 to 2002 was a bit more modest than the dollar appreciation in the 1980s, and yet (ostensibly a paradox) gave

[5] I thank Thomas Wu for this suggestion.

rise to a much larger trade deficit as a share of GDP (plotted ex-oil in Figure 2).[6] By contrast, a simple trade-weighted average of relative prices (WARP) using version 8.0 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: (1) the rising share of trade with countries, such as China, with relatively low price levels, and (2) the multiple benchmarking used in the creation of PWT version 8.0.[7]

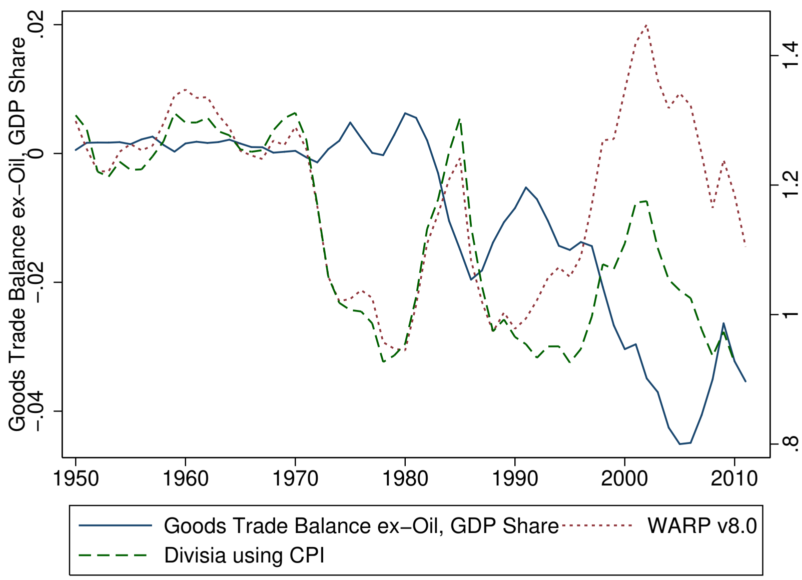


Figure 2: Real Exchange Rate Measures vs. the Current Account
Sources: BEA and Campbell and Pyun (2013)

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 a number of drawbacks (Campbell and Pyun, 2013). One problem is that these measures are also computed as indices-of-indices, and as such do not properly account for compositional changes in trade with countries, such as China, that have systematically lower unit labor costs.[8] Additionally, China and many other developing countries are not even included

[6]The Fed's real exchange rate index is: $I_t^d = I_{t-1} \times \Pi_{j=1}^{N(t)} (\frac{e_{j,t} p_t / p_{j,t}}{e_{j,t-1} p_{t-1} / p_{j,t-1}})^{w_{j,t}}$, 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 countries in the basket, and $w_{j,t}$ is the trade weight of country j at time t. The base year value of the index is arbitrary.

[7]These factors also suggest the superiority of WARP, although both measures could be useful to look at since they provide different information.

[8]These issues are explained in more detail in Campbell and Pyun (2013). Another important problem

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 ICP benchmarks, and which includes developing countries such as China.[9] I find that this index does a remarkably good job of predicting manufacturing employment declines, and in particular does much better than CPI-based real exchange rate indices or the RULC indices created by the Federal Reserve, the IMF and the OECD. 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 Fahle *et al.* (2008) or the Balassa-Samuelson adjusted WARP index created by Campbell and Pyun (2013).[10]

The finding that when US unit labor costs appreciate sharply relative to trading partners, more open sectors are differentially harmed should not be suprising 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 also 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, with the 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 weighing in with multiple contributions. By contrast, in the past 15 years, new trade theory models often omit sunk costs and make scant reference to path-dependence. Nevertheless, Figure 2 shows that the pattern for the 1980s is also apparent in the 2000s. US relative prices have become steadily more competitive since 2002, but while the trade deficit shrank due to declining domestic demand during the recession, as demand began to recover by 2011, the trade deficit worsened, lagging the improvement in relative prices. The chief contribution of this paper lies in documenting the phenomenon of hysteresis at a disaggregated level for 437 SIC manufacturing sectors for both the 1980s and the 2000s.

A second important finding in this paper is that the measured elasticity of manufacturing employment with respect to changes in relative unit labor costs and the magnitude

with the IMF and OECD series is that manufacturing output is deflated using country-specific deflators (constructed idiosyncratically), which can lead to bias over time without the use of multiple benchmarks. This is the same problem that afflicted older vintages (predating version 8.0) of the Penn World Tables.

[9] I am greatly indebted to Professor Paul Bergin for suggesting I apply the Fahle *et al.* (2008) insight to unit labor costs.

[10] The details of the construction of these indices are included in a companion paper, Campbell and Pyun (2013).

of the appreciation in relative prices—Campbell and Pyun (2013) show that the shock to WARP in the 1990s and 2000s was the largest in recorded US relative price history, 1820-2011—are large enough to explain the loss of 1.9 to 2.1 million manufacturing jobs directly in the period 1995-2008.[11] Third, while 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 sharpest impact on the most tradable sectors via relative prices. Fourth, I briefly sketch a variation of the Melitz (2003) model, and show that sunk costs lead to a dynamic gravity equation (also a new result).

In the next section, I first introduce a slight variation of the Melitz (2003) model, similar to Chaney's (2008) modification, in order to motivate the empirical sections which follow.

1 Theoretical Motivation

1.1 The Model

In this section, I motivate the empirics using a slight variation of the Chaney (2008) model with sunk costs as in Melitz (2003). In this model, households in the home country consume from a continuum of goods, ω, from a set of goods in H+1 sectors, Ω_h, determined in equilibrium. There is a freely traded homogenous numeraire good q_0 as in Chaney (2008), with one unit of labor producing w units of the good.

$$U_t = q_{0t}^{\mu_0} \prod_{h=1}^{H} (\int_{\Omega_h} q_h(\omega)_t^{\frac{(\sigma_h - 1)}{\sigma_h}} d\omega)^{\frac{\sigma_h \mu_h}{(\sigma_h - 1)}}, \, \sigma_h > 1 \forall h \,. \tag{1.1}$$

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

$$q_h(\omega)_t = \frac{\mu_h Y_t p_h(\omega)_t^{-\sigma_h}}{P_{ht}^{1-\sigma_h}}. \tag{1.2}$$

Firms maximize profits each period after paying a sunk fixed cost to receive a productivity draw (output per unit of labor φ) and begin producing for the home market, and then choose whether to pay a sunk entry cost to enter the foreign market (for simplicity

[11] In this paper I do not study input-output linkages, but given that every dollar of manufacturing output requires 60 cents of output from other industries used in production seemingly implies that the direct estimates only represent part of the total jobs lost due to relative price movements.

I assume there are only two countries). Profits per period for an existing firm from sales at home are thus[12]

$$\Pi_h(\omega)_t = q_h(\omega)_t p_h(\omega)_t - \frac{q_h(\omega)_t w_t}{\varphi_h(\omega)} - f_{ht} w_t, \quad (1.3)$$

where p is price, q is output sold at home, w is the wage, τ 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 δ, yet otherwise will always choose to stay in a market they have previously entered, as expected profits are strictly positive going forward. Maximizing profits, firms choose prices marked up over marginal cost $p_h(\omega)^*_t$ (denotes the price of exports)

$$p_h(\omega)_t = \frac{\sigma_h}{\sigma_h - 1}\frac{w_t}{\varphi_h(\omega)}, \quad p_h(\omega)^*_t = \frac{\sigma_h}{\sigma_h - 1}\frac{w_t \tau_t}{\varphi_h(\omega)}. \quad (1.4)$$

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.[13]

$$Foreign\,Entry : E_t\Pi(\omega)^*_{PV,t} = E_t\sum_{s=0}^{\infty}(1-\delta)^s\Pi(\omega)^*_{t+s} - f^x_{ht}w_t \geq 0. \quad (1.5)$$

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:

$$L_{ht} = \underbrace{\int\limits_{\omega\in\Omega}\frac{q_h(\omega)_t}{\varphi_h(\omega)_t}}_{\text{Home Production}} + \underbrace{\int\limits_{\omega\in\Omega^*}\frac{q^*_h(\omega)_t}{\varphi_h(\omega)_t}}_{\text{Export Production}} + \underbrace{M^e_{ht}(f^e_{ht} + f^x_{ht}p^x_{ht})}_{\text{Entry}} + \underbrace{\sum_{s=0}^{\infty} M^e_{h,t-s}(1-\delta)^s f_{ht}p_{h,t,-s}}_{\text{Overhead}}. \quad (1.6)$$

Here M^e_{ht} is the mass of potential entrants at time t, $p^x_{ht} = 1 - G(\bar{\varphi}_x)$ is the share of new firms in sector h with productivity greater than the cutoff productivity for exporting, $\bar{\varphi}_x$, and $p_{h,t-s} = 1 - G(\bar{\varphi}_{f,t,-s})$ 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

[12] 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.

[13] 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: $E_t\Pi(\omega)_{tot,PV,t} = E_t[\sum_{s=0}^{\infty}(1-\delta)^s\Pi(\omega)_{t+s} + \Pi(\omega)^*_{PV,t}] - f_{e,ht}w_t \geq 0$.

based on country factors (proportional to output).

The cutoff productivity for entering into the export market at time t can be derived from equation (1.5) 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" draw with probability δ. Thus the cutoff productivity for exporting is

$$\bar{\varphi}_{xht} = \left(\frac{P_{ht}^{*(1-\sigma_h)} w_t^{\sigma_h}}{\mu_h Y_t^*} \lambda_0 \delta f_{h,t}^x \right)^{\frac{1}{\sigma_h - 1}} \tau_t, \tag{1.7}$$

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

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[14]

$$\bar{\varphi}_{fht} = \left(\frac{P_{ht}^{(1-\sigma_h)} w_t^{\sigma_h}}{\mu_h Y_t} \lambda_0 f_{ht} \right)^{\frac{1}{\sigma_h - 1}}. \tag{1.8}$$

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 (1.6) is the total labor re-

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

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

$$\frac{\sum_{s=0}^{\infty} \mu_{h,t} Y_t M^e_{h,t-s} \rho^s w_t^{-\sigma_h} \lambda_1 \bar{\varphi}_{mh,t,-s}^{(\sigma_h - 1 - \gamma_h)}}{\sum_{s=0}^{\infty} \rho^s (M^e_{h,t-s} w_t^{(1-\sigma_h)} \lambda_2 \bar{\varphi}_{mh,t-s}^{\sigma_h - 1 - \gamma_h} + M^{*e}_{h,t-s} (w_t^* \tau_{ht}^*)^{(1-\sigma_h)} \lambda_2 \bar{\varphi}_{mxh,t-s}^{*(\sigma_h - 1 - \gamma_h)})}, \tag{1.9}$$

where λ_1 and λ_2 are parameters[15], $\rho = 1 - \delta$ 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 $\bar{\varphi}^*_{mxh,t,-s}$ 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, τ^*_{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 1.8), 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 (1.6) is analagous, 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 (1.8). If wages, fixed overhead costs (f_{ht}), iceberg trade costs, or more foreign firms enter, the cutoff productivity for making

[15] $\lambda_1 = \frac{(\sigma_h/(\sigma_h-1)^{-\sigma_h}}{\gamma_h - (\sigma_h - 1)}$ and $\lambda_2 = \frac{1}{\gamma_h - (\sigma_h - 1)}$

a profit will rise, and some existing firms will be forced out of the market:

$$\frac{\sum_{s=0}^{\infty}\mu^*_{h,t}Y^*_t M^{*e}_{h,t-s}\rho^s w_t^{*(-\sigma_h)}\tau_t^{1-\sigma_h}\lambda_1\bar{\varphi}_{mh,t,-s}^{\sigma_h-1-\gamma_h}}{\sum_{s=0}^{\infty}\rho^s M^e_{h,t-s}(w_t\tau_{ht})^{(1-\sigma_h)}\lambda_2\bar{\varphi}_{mh,t-s}^{\sigma_h-1-\gamma_h}+\sum_{s=0}^{\infty}\rho^s M^{*e}_{h,t-s}w_t^{*(1-\sigma_h)}\lambda_2\bar{\varphi}_{mh,t-s}^{*(\sigma_h-1-\gamma_h)}}. \tag{1.10}$$

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 denomenated 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 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.

1.2 Implications

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 $\alpha_{ht}Y_t$:

$$X_{ht}=\sum_{s=0}^{\infty}(1-\delta)^s\alpha_h Y_{t-s}\int_{\bar{\varphi}_{t-s}}^{\infty}x_{h,t}(\varphi)\mu(\varphi)d\varphi. \tag{1.11}$$

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:

$$X_{ht}=\frac{\mu_h^*Y_t^*(w_t\tau_t)^{1-\sigma_h}}{P_t^{*(1-\sigma_h)}}\lambda_3\sum_{s=0}^{t}(1-\delta)^s(\alpha_h Y_{t-s})\left(\frac{P_{h,t-s}^{*(1-\sigma)}w_{t-s}^{\sigma_h}}{\mu_{h,t-s}Y_{t-s}^*}\lambda_0\delta f_{h,t-s}^x\tau_{t-s}^{\sigma_h-1}\right)^{\frac{-\gamma_h+\sigma_h-1}{\sigma_h-1}}, \tag{1.12}$$

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 (1.10).

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:

$$X_t = f(\underbrace{Y_t}_{+}, \underbrace{Y_{t-s}}_{+}, \underbrace{Y_t^*}_{+}, \underbrace{Y_{t-s}^*}_{+}, \underbrace{w_t}_{-}, \underbrace{w_{t-s}}_{-}, \underbrace{\tau_t}_{-}, \underbrace{\tau_{t-s}}_{-}, \underbrace{f_{ht}^x}_{-}, \underbrace{f_{h,t-s}^x}_{-}), s > 0. \tag{1.13}$$

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 (not for publication), I prove that similar transition 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 (2011), 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 (1.12). 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), Eichengreen and Irwin (1998), and Head, Mayer and Ries (2010).

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 Meissner and Liu (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 chloropleth 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.

2 RER Movements and US Manufacturing

When estimating the impact of real exchange rate movements on manufacturing, RER movements, in general, cannot simply be assumed to be exogenous. Three salient facts about capital flows and manufacturing trade make the task more manageable: first, capital flows dwarf trade flows by a factor of 300 to 1, meaning that in the short run, exchange rates are largely determined by capital flows, and famously difficult to predict based on fundamentals such as interest rates (Meese and Rogoff, 1983). Second, while endogeneity is still a concern, a collapse in manufacturing output should theoretically lead to a decline in the real exchange rate, potentially leading to, if anything, a downward bias in the magnitude of the estimated impact. If the large estimated negative impact of RER appreciations on manufacturing employment is in fact a floor, it would only increase the salience of the results. Third, trade has long been noticed to respond to exchange rate movements with a lag, mitigating the impact of reverse causality. Yet, there is also the possibility that a third factor, such as high real interest rates, could cause both a RER appreciation and a decline in manufacturing.

To deal with these concerns, the approach in this paper is to study 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. Disaggregated sectoral data and a difference-in-difference research design are then used to test whether more open manufacturing sectors are more sensitive to movements in RERs than sectors which are less exposed to trade. Difference-in-difference research designs can still generate spurious results when researchers fail to identify the relevant external factors (which may be far from obvious).[16] However, spurious results tend not to hold out of sample. Thus this paper adopts a "repeated" difference-in-difference approach, looking at several distinct episodes of currency movements in the US, Canada, and Japan which are arguably exogenous. First, I consider the US case, which for data reasons is the main focus of

[16]This is especially likely in cases in which the findings were not supported *a priori* by strong theoretical or intuitive priors. Alternatively, DID estimators can fail when there is systematic correlation in their error terms.

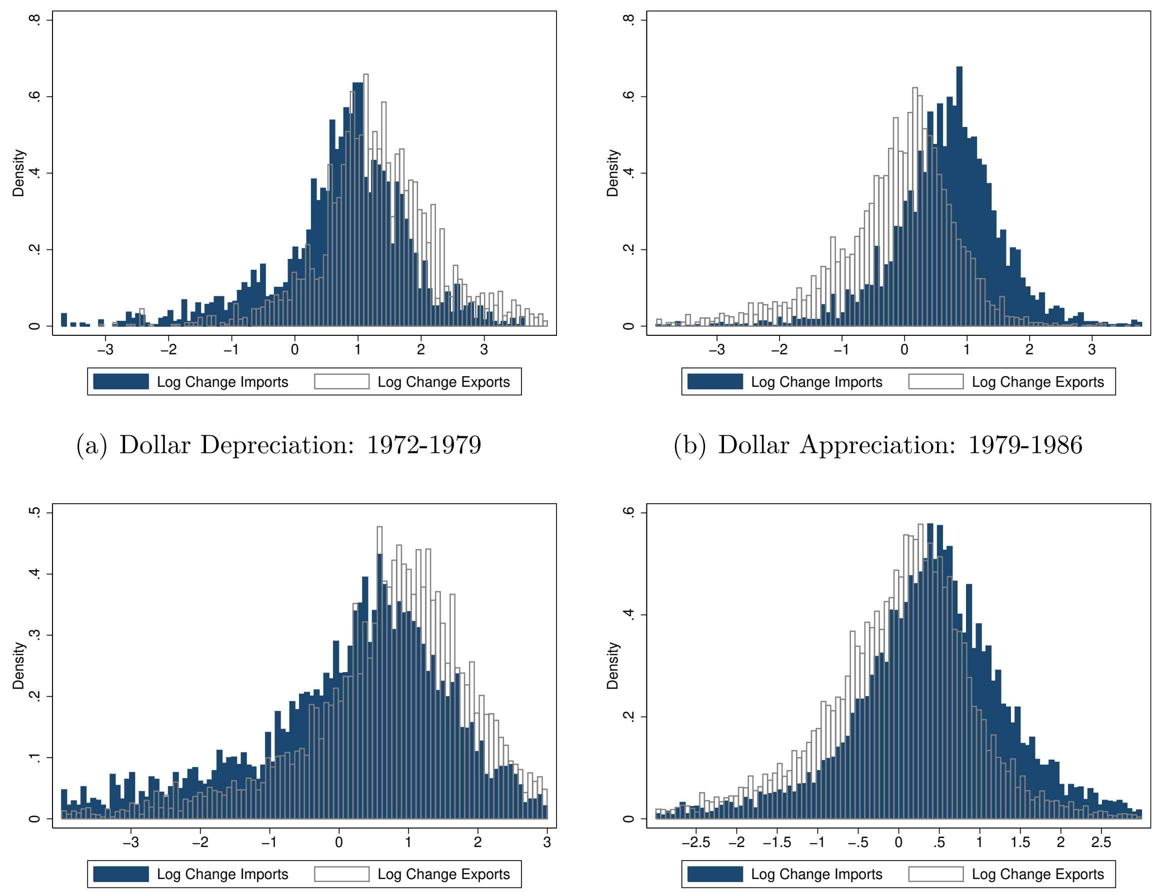
this paper.

In the US case, since the end of Bretton Woods, there have been two distinct periods of dollar appreciation. 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 in which standard theory would suggest (Guajardo *et al.* 2011). While one could certainly make an argument that the collapse in manufacturing employment in the early 2000s was unlikely to have caused the dollar to appreciate in those years, given that the dollar's strength from the late 1990s stems from many different potential factors (including the Asian Financial Crisis, rising US productivity, the tech boom, the Bush tax cuts, and the onset of the Great Reserve Accumulation), the research design for the 2000s era is not nearly as clean as the US experience in the 1980s. Thus it is necessary to compare the US experience in the 2000s with the US experience in the 1980s, which deserves to be the canonical case of sharp, but temporary RER movements having a surprisingly persistent impact on manufacturing.

For exchange rate movements to impact manufacturing employment, a necessary condition is that exchange rates affect trade. Figure 3 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.[17]

Next, using disaggregated sectoral data, I test whether sectors with higher initial levels of openness do worse when the dollar appreciates relative to how the same sectors do when real exchange rates are low. "Openness" is defined using the average of the share of exports in shipments and the share of imports in domestic consumption (where domestic consumption = shipments + imports - exports). The four panels of Figure 4 confirm that during periods of sharp dollar appreciation, sectors with higher initial trade shares experienced disproportionate declines in employment. During periods of dollar depreciation, there was no meaningful difference in performance, but the previous period's losses appeared to be locked in. Openness predicts employment declines over the period 1979-1986, but there is no relationship between openness in 1979 and em-

[17]In the Additional Appendix 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.



(a) Dollar Depreciation: 1972-1979

(b) Dollar Appreciation: 1979-1986

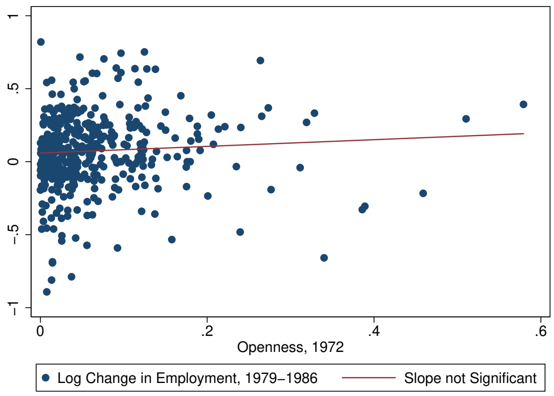
(c) Dollar Depreciation: 1986-1996

(d) Dollar Appreciation: 1996-2005

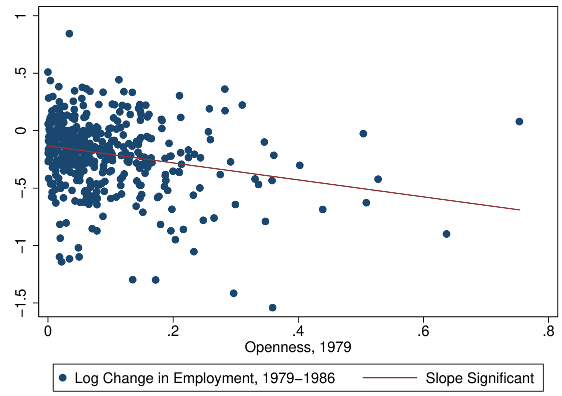
Figure 3: Distribution of Changes in Trade, by Sector and Country
Source: Trade data for 452 SIC sectors and roughly 200 countries are from Comtrade

ployment growth over the period 1986-1996 (Figure 5). Note that these periods all end at roughly similar points in the business cycle, effectively controlling for the fact that some manufacturing sectors are much more cyclical than others. These results become slightly stronger when controlling for domestic sectoral demand growth, productivity growth, lagged capital-per-worker ratios, changes in tariffs, and various other controls.

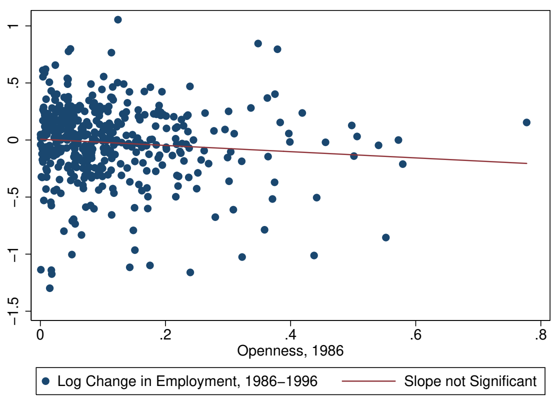
The magnitude of the slope for each period of appreciation is large and economically significant. The slope in the 1979-1986 period is -.79 with a standard error clustered at the 3-digit SIC level of .24, which implies that for every 10% increase in trade an industry had in 1979, it approximately lost an additional 7.9% of manufacturing employment during that period, when the Federal Reserve's broad trade-weighted dollar index appreciated 45.4%. Figure 5 shows that openness in 1979 is uncorrelated with employment growth from 1986 to 1996, suggesting that the losses experienced by the



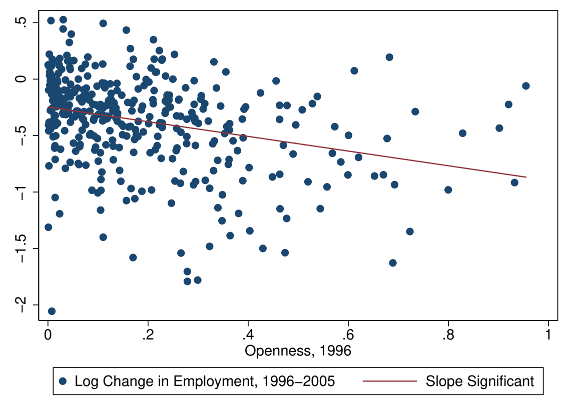
(a) Dollar Depreciation: 1972-1979



(b) Dollar Appreciation: 1979-1986



(c) Dollar Depreciation: 1986-1996



(d) Dollar Appreciation: 1996-2005

Figure 4: Manufacturing Employment vs. Openness

Source: Annual Survey of Manufactures, BEA

more open sectors in the mid-1980s persisted into the 1990s. The slope for the 1996-2005 period is similarly large, at -.65, with a clustered standard error of just .15. However, since the mean amount of trade was much larger in the late 1990s than in the 1980s, the later period accounted for a much larger overall decline in employment.

Figure 6 displays the difference-in-difference research design graphically, plotting the evolution of employment indices by fixed categories of tradability in 1972 vs. Weighted Average Relative Unit Labor Costs (WARULC) for the manufacturing sector. The employment index for each sector is given a base year value of 100 in 1979, and then the changes in the employment indices not due to changes in demand or productivity, or to general movements in all sectors by year, are plotted over time with error bounds. Comparing the top 25% of sectors by openness as of 1972 vs. the bottom 50%, the pretreatment trends are very similar for the 1970s, but when the dollar appreciated in

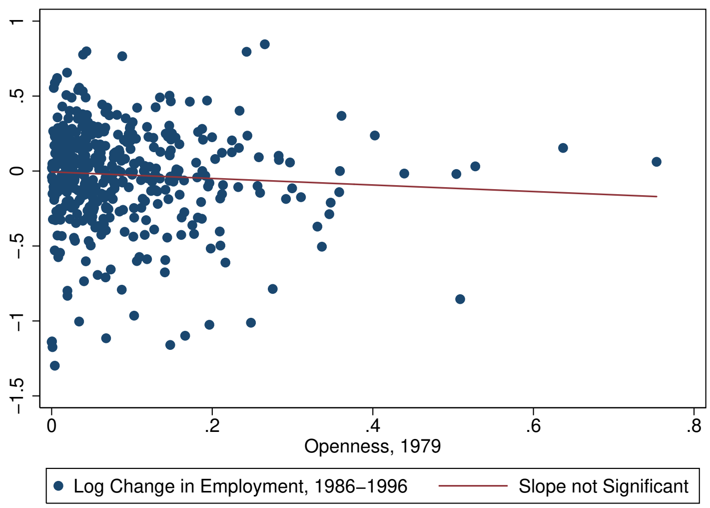


Figure 5: Hysteresis: No Rebound after Collapse
Source: Annual Survey of Manufactures, BEA

the 1980s, the more open sectors lost roughly 10% of their employment relative to less 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, and thus a 50% increase in labor costs relative to trading partners should have left a differential impact on more exposed sectors. Interestingly, after the dollar fell in the late 1980s, this differential impact seems to have decayed very modestly.

The appreciation in the late 1990s and early 2000s (Figure 7) suggests a similar story – steep losses in the early 2000s which then reverted to previous levels only gradually. While the magnitudes appear smaller here, this is in part a function of the fact that both of these categories of industries contain a large variation in their respective degrees of openness. In both periods, the decline in the more open sectors took place at the same time as a decline in aggregate "structurally adjusted" manufacturing employment (Figure 20 in the Appendix).[18]

2.1 Data

Data on employment, shipments, value-added, wages, investment, and capital, and the prices of shipments, materials, and energy are all from the BEA's Annual Survey of

[18]The "structurally adjusted" employment was computed at quarterly intervals by subtracting off 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 Index, used because it has data at quarterly intervals.

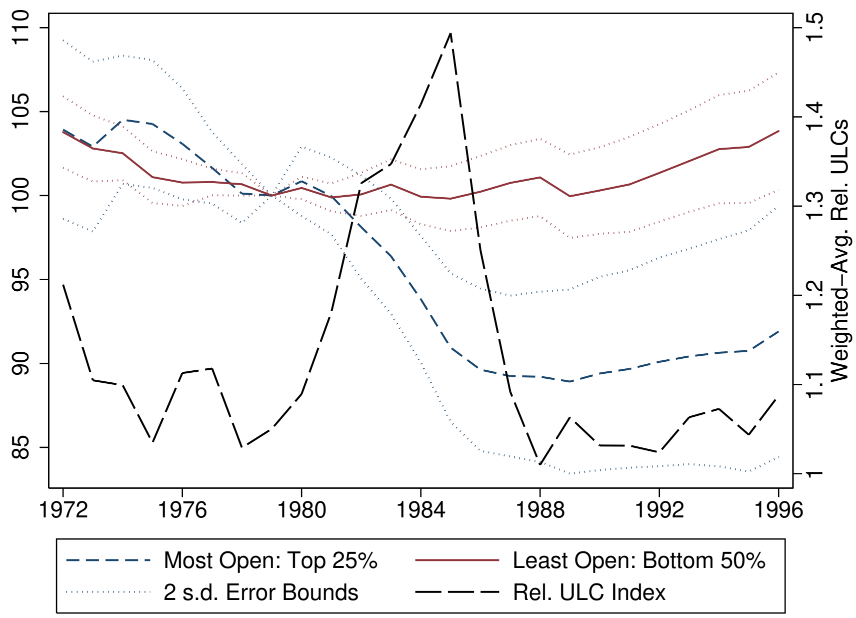


Figure 6: Employment Growth by Degree of Tradability in 1972 (SIC)*

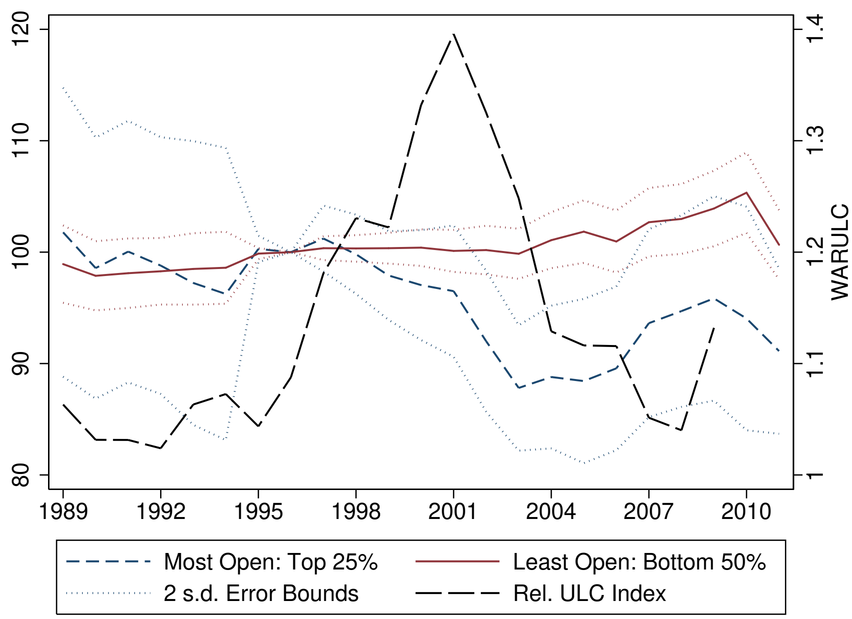


Figure 7: Employment Growth by Degree of Tradability in 1989 (NAICs)*

*Notes: Employment is indexed to 1979 in Figure 6 and to 1996 in Figure 7, and is updated with residuals from a regression controlling for demand, productivity, and year fixed effects. Employment data are from the Annual Survey of Manufactures, and WARULC is from Campbell and Pyun (2013).

Manufactures, via the NBER-CES Manufacturing Industry Database for the 4-digit SIC data from 1958 to 2009, and were taken directly from the BEA 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, 2014). 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).[19]

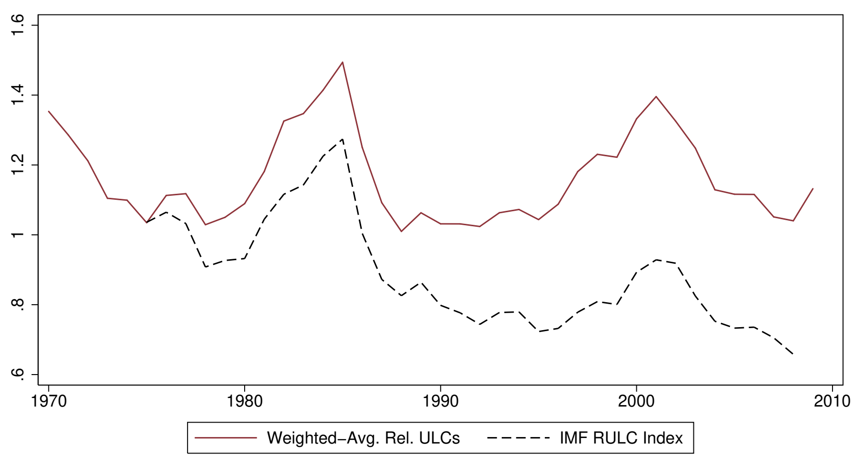


Figure 8: WARULC vs. IMF RULC Index

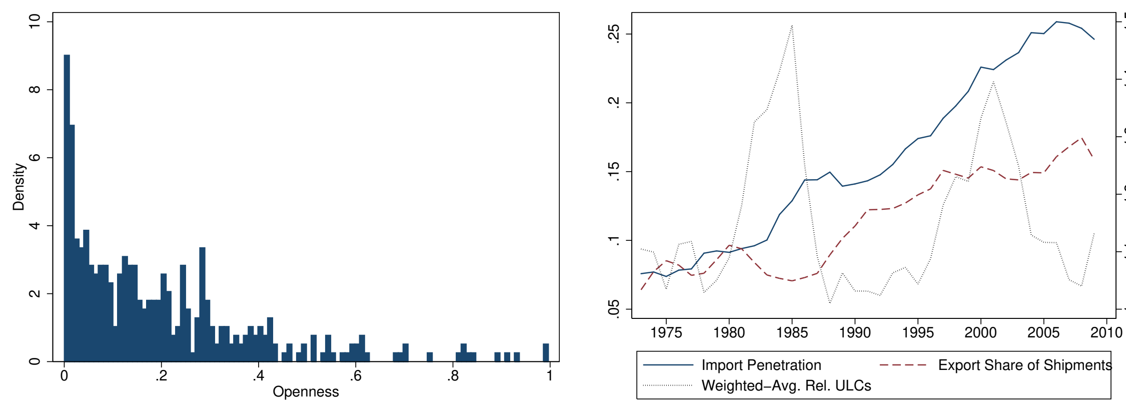
Sources: Campbell and Pyun (2013) and the IMF

The main measure of the real exchange rate used in this paper is the Weighted Average Relative Unit Labor Cost (WARULC) index from Campbell and Pyun (2013), plotted in Figure 8 vs. the IMF's RULC index.[20] The IMF's index suggests a steady depreciation of US unit labor costs over the period, a feature largely corrected by the multiple benchmarking used in the construction of WARULC (in the IMF's measure,

[19]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, 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.

[20]Specifically, the WARULC index from Campbell and Pyun is computed as $I_{US,t}^{WARULC} = \prod_{i=1} \left(\frac{ULC_{US,t}}{ULC_{i,t}}\right)^{\omega_{i,t}}$, where $ULC_{i,t} = \frac{w_{i,t}}{e_{i,t}} / \frac{Y_{i,t}}{PPP_{i,t}}$, 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 value-added is deflated using country-specific deflators alone), and also by the inclusion of China and the change in indexing method (the IMF using a Tornquist index with fixed trade weights whereas WARULC uses a geometric weighted average with time-varying trade weights). Panel (a) of Figure 9 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.



(a) Openness

(b) Trade Growth vs. WARULC

Figure 9: Trade Growth and the Distribution of Openness in 1997

Sources: BEA, Comtrade, and Campbell and Pyun (2013)

The summary statistics for the most relevant variables in select years are reported in Table 1. Openness increased from about 7% in 1972 to 24% in 2001 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%. Chinese import penetration increased from almost nothing in the 1980s to 12.4% by 2005. The average applied tariff was about 8.2% in 1974, and fell to just 2.4% by 2005. By contrast, the cost of insurance and freight was about 9.6% of customs costs in 1974, and was still 9.8% in 2005. The last two entries in Table 1, 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).

2.2 Difference-in-Difference Panel Estimation

My first approach is to compare how employment in relatively more open sectors does when unit labor costs in the US are relatively high compared to when these costs at home

Table 1: Data Summary for Select Years

	(1) 1974	(2) 1979	(3) 1985	(4) 1993	(5) 2001	(6) 2005
Openness	0.0862	0.0981	0.115	0.174	0.238	0.279
	(0.112)	(0.105)	(0.119)	(0.174)	(0.241)	(0.265)
Value Added, Millions	1099.3	1818.0	2273.4	3475.4	4551.3	5443.2
	(1687.9)	(2913.5)	(3429.0)	(5497.0)	(8030.1)	(10989.7)
Hourly Wages, Prod. Workers	4.366	6.464	9.572	11.99	15.10	17.48
	(1.008)	(1.794)	(2.782)	(3.354)	(4.145)	(4.739)
Payroll/Value-Added	0.426	0.413	0.413	0.373	0.364	0.320
	(0.115)	(0.110)	(0.112)	(0.118)	(0.120)	(0.115)
Investment/Value-Added	0.0669	0.0691	0.0750	0.0622	0.0647	0.0502
	(0.0427)	(0.0458)	(0.0752)	(0.0654)	(0.0426)	(0.0298)
Energy Costs/Value-Added	0.0405	0.0579	0.0729	0.0488	0.0491	0.0468
	(0.0596)	(0.0868)	(0.128)	(0.0856)	(0.0689)	(0.0663)
Materials Costs/Value-Added	1.234	1.284	1.327	1.119	1.147	1.118
	(0.954)	(1.011)	(1.408)	(0.716)	(0.700)	(0.678)
Shipments per Worker, (1000s)	61.43	96.91	143.1	197.6	267.6	374.9
	(60.72)	(105.4)	(151.5)	(165.6)	(278.9)	(477.7)
Duties %	0.0831	0.0740	0.0553	0.0505	0.0306	0.0242
	(0.0709)	(0.0643)	(0.0564)	(0.108)	(0.0420)	(0.0317)
Ins., Freight Costs %	0.0747	0.0685	0.0736	0.0969	0.0913	0.0956
	(0.0668)	(0.0576)	(0.0750)	(0.0471)	(0.0494)	(0.0555)
K/L, (1000s)	51.04	59.09	78.01	84.43	115.3	145.3
	(56.95)	(69.55)	(89.27)	(90.95)	(130.7)	(160.8)
5-factor TFP index 1987=1.000	0.974	0.976	0.974	1.018	1.078	1.216
	(0.214)	(0.151)	(0.0818)	(0.131)	(1.444)	(2.585)
Prod. Workers/Total Emp	0.764	0.758	0.731	0.714	0.714	0.700
	(0.0966)	(0.0955)	(0.105)	(0.119)	(0.120)	(0.115)
Chinese Import Penetration	0.000181	0.000468	0.00285	0.0256	0.0808	0.124
	(0.00143)	(0.00206)	(0.00893)	(0.115)	(0.545)	(0.628)
Japanese Import Penetration	0.0130	0.0137	0.0231	0.0292	0.0258	0.0261
	(0.0356)	(0.0324)	(0.0466)	(0.0520)	(0.0503)	(0.0534)
Shipments Deflator	0.541	0.762	0.976	1.160	1.284	1.401
	(0.182)	(0.127)	(0.0582)	(0.121)	(0.246)	(0.317)
Materials Deflator	0.528	0.774	1.001	1.122	1.158	1.324
	(0.122)	(0.0710)	(0.0658)	(0.0797)	(0.197)	(0.272)
Investment Deflator	0.480	0.735	0.938	1.136	1.116	1.162
	(0.0402)	(0.0394)	(0.0174)	(0.0550)	(0.126)	(0.148)
Energy Deflator	0.375	0.760	1.123	1.126	1.386	1.560
	(0.120)	(0.0759)	(0.0526)	(0.0205)	(0.0717)	(0.146)

Mean coefficients; sd in parentheses.

are close to a weighted average of trading partners. Figure 10 displays the results from regressing the log change in employment on lagged relative openness by year, controlling for demand growth and shipments per production worker.[21] The annual coefficients are plotted in blue vs. WARULC, along with two standard deviation upper and lower error bounds (with standard errors clustered at the 3 digit level). The results suggest a strong correlation between the level of relative unit labor costs and the annual coefficient on lagged openness.[22] Note that the annual coefficient becomes significant in 1998, while China was awarded permanent MFN status and joined the WTO in December of 2001. Thus while those events may well have increased imports from China, it is unlikely that they would have had an impact until 2002, when the coefficient on openness becomes larger in magnitude although less-precisely estimated.

Figures 6, 7, and 10 suggest a functional form for the relationship between relative unit labor costs and the evolution of sectoral manufacturing employment. When unit labor costs are higher in the US than they are in US 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 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 lagged relative openness, while including controls from the model (equation 1.6).

$$ln(L_{ht}/L_{h,t-1}) = \alpha_t + \beta_0 R.Openness_{h,t-1} + \beta_1(\varphi(L)ln(RER_{t-1})) * R.Openness_{h,t-1} + \quad (2.1)$$

$$\beta_2 ln(D_{h,t}/D_{h,t-1}) + \beta_3 ln(TFP_{h,t}/TFP_{h,t-1}) + \sum_{i=4}^{n} \beta_i C_{i,t} + \alpha_h + \nu_t + \epsilon_{ht},$$

$$\forall h = 1, ..., 353, \; t = 1973, ..., 2009,$$

where L_{ht} is employment in sector h at time t, $R.Openness_{h,t-1}$ is relative openness in

[21] This regression is $ln(L_{ht}/L_{h,t-1}) = \alpha_t + \beta_0 Rel.Openness_{h,t-1} + \beta_2 ln(D_{h,t}/D_{h,t-1}) + \beta_3 ln((TFP)_{h,t}/(TFP)_{h,t-1} + \epsilon_{ht}$, $h = 1, ..., 353$, $for\, each\, year = 1973, ..., 2009$.

[22] The one period that appears to be slightly anomalous is 2005-2007. One explanation may be that during this period, the WARULC index implies lower relative prices than either WARP or the Balassa-Samuelson adjusted WARP index from Campbell and Pyun (2013), even though the three series are broadly similar and yield similar results on the whole (although WARULC does well predicting the decline in 2002). Nonlinearities in the impact of relative price misalignment are also possible, as large overvaluations relative to China may have trumped mild undervaluation relative to Canada and Europe during this period.

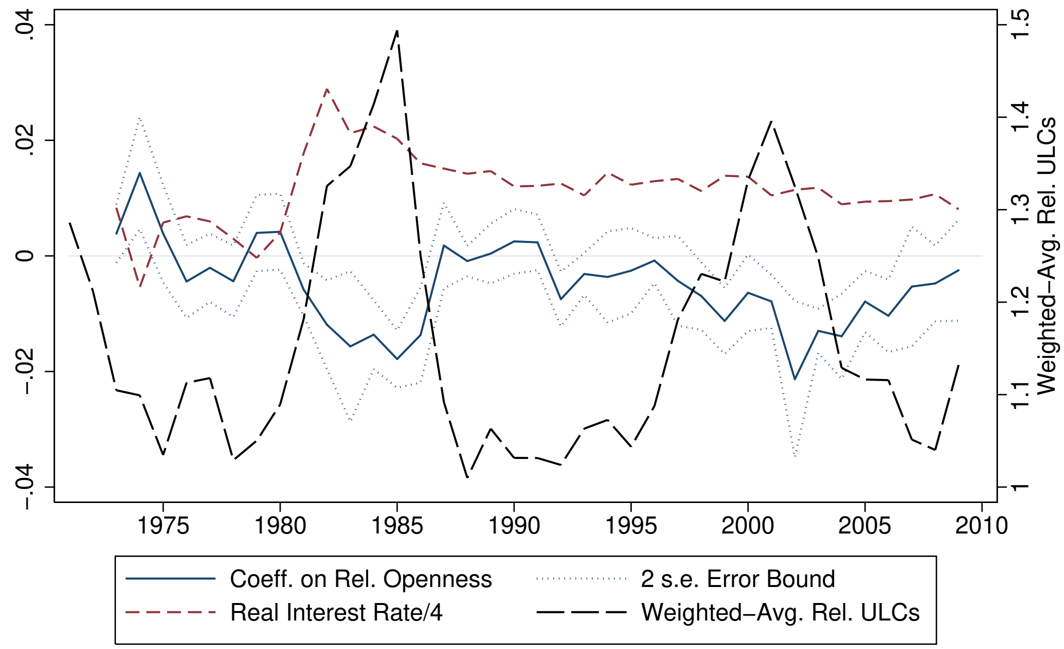


Figure 10: Impact of Relative Openness by Year

Notes: Real interest rate data are from FRED, WARULC is from Campbell and Pyun (2013), and the coefficients on relative openness are from annual regressions of log changes in employment on changes in demand and productivity with standard errors clustered at the 3-digit SIC level.

sector h at time t-1, 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. $\varphi(L)$ 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. Each regression also includes sectoral fixed effects α_h, year fixed effects ν_t, and two-way clustered errors, by both industry and by year, and all regressions are weighted by initial period value-added. The results do not appear to be sensitive to the choice of weights, as qualitatively similar results attain when weighting by average value-added, employment, or shipments, although the key coefficient is the largest when weighting by employment or when not weighting. Additionally, one gets very similar results by simply using openness rather than relative openness, and by clustering at the 3-digit SIC level instead of the SIC level, given the correlation of errors at higher levels of industry aggregation.[23]

[23]These controls, and others, are contained in the Additional Appendix. 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. Additionally, the results are robust to omitting

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 weighted average relative unit labor costs (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 2, column (1) shows that appreciations in relative unit labor costs are associated with a decline in employment for more open sectors, but that depreciations are not. Column (2) uses the log of the level of WARULC instead as a control, 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 appreciation and depreciation variables lose significance. I then use the level of WARULC for the remainder of the paper. Since the level of WARULC impacts the log change, this specification by itself implies hysteresis.[24]

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 consistently significant across specifications. Following Pierce and Schott (2014), I also include a control for the interaction between China's ascension to permanent normal trade relations (PNTR) interacted with a control for the NTR gap by sector. I find that this variable is generally significant,

defense and computer-related sectors, 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.

[24] In addition, that it appears to be the level of real exchange rates which matters for changes in employment rather than changes in real exchange rate, this is another reason to the class of 'WAR' exchange rate indices, in which levels matter, as opposed to divisia-based indexes, which do not consider levels.

supporting the findings of Pierce and Schott (2013). Lastly, to control for the possibility that more open sectors also may be more sensitive to movements in real interest rates, I also include an interaction between openness and the real interest rate, where the real interest rate is 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.

Column (6) includes additional controls for changes in average tariffs by sector and changes in insurance and freight costs (spanning only 1974-2005), neither of which are significant. While some observers may find these results counterintuitive, the reason is likely that there were not any large movements in either variable during this period, as, for example, the average duty was already less than 10% in 1974. Additionally, all of the findings in this table (and others in this paper) are robust to minimizing the sum of absolute deviations, which is less sensitive to outliers (see the Additional Appendix).

The results in this table include 353 sectors with complete, balanced data, and exclude all sectors in the 2-digit SIC category publishing, which is not classified as manufacturing by NAICS. The results are robust to including both publishing and the unbalanced sectors, for a total of 448 industries. The coefficient of -.068 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 an openness twice that of the average industry would have lost an additional 5.3% of employment from 1985-1986 (=exp(-.068*0.4*2)-1) as compared with a completely closed industry, and 2.6% more than an industry with average openness. Over the entire 1982-1986 period, this industry would have lost a cumulative 19% of employment relative to a closed industry, and 9% more than an industry with average openness.

Additionally, in a series of falsification exercises, I find that currency appreciations do not predict differential changes in the prices of materials, energy, or investment inputs for more open sectors at up to five years of lags and up to four years of leads for a total of 30 regressions. Since there is no theoretical reason to believe that a currency appreciation should lead to differential input price changes for more open sectors (since openness here is defined by output rather than by input exposure), this is an indication that my estimation procedure is not prone to yielding spurious results. Additionally, I find that future values of RER movements, at two and three year leads, are not a significant predictor of relative declines in employment for more open sectors.[25]

[25] These results, too, are contained in the Additional Appendix. One year leads are borderline significant at 90% which is not surprising given autocorrelation in the RER index by year.

Table 2: 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.Relative Openness	-0.0096**	-0.0048	-0.0091	-0.0036	-0.0034	-0.00028
	(0.0048)	(0.0041)	(0.0060)	(0.0060)	(0.0058)	(0.0067)
L.Rel.Open*ln Δ WARULC*Pos.	-0.090*		-0.20**	-0.098		
	(0.052)		(0.10)	(0.099)		
L.Rel.Open*ln Δ WARULC*Neg.	-0.0057		0.011	0.0012		
	(0.054)		(0.057)	(0.045)		
L.ln(WARULC)*Rel. Openness		-0.057***		-0.068***	-0.090***	-0.091***
		(0.017)		(0.016)	(0.022)	(0.024)
$ln\Delta$ VA-per-Production Worker			-0.21***	-0.21***		
			(0.036)	(0.036)		
$ln\,\Delta$ Demand			0.44***	0.45***	0.38***	0.39***
			(0.062)	(0.061)	(0.067)	(0.082)
L.(K/L)			0.046	0.047	0.029	0.031
			(0.030)	(0.030)	(0.029)	(0.037)
L.(K/L)*Real Interest Rate			-0.19	-0.31	-1.36***	-1.28**
			(0.30)	(0.29)	(0.50)	(0.52)
L.$ln\,\Delta$ Wages			0.021	0.018	0.021	
			(0.023)	(0.023)	(0.028)	
L.$ln\,\Delta$ Price of Shipments			0.038**	0.036*	0.041**	0.027
			(0.019)	(0.019)	(0.017)	(0.019)
$ln\Delta$ TFP (5 factor)					-0.075	-0.11
					(0.076)	(0.093)
Post-PNTR x NTR *Gap_i*					0.049***	0.049**
					(0.012)	(0.020)
Low Markup*L.ln(WARULC)					0.018	0.0048
					(0.028)	(0.026)
Imported Inputs*L.ln(WARULC)					0.071	0.10
					(0.18)	(0.18)
L.Rel.Openness*RIR					0.0093	0.0087
					(0.0091)	(0.0099)
L.$ln\,\Delta$ PM*(M/S)					-0.16**	-0.12
					(0.081)	(0.090)
L.$ln\,\Delta$ PI*(I/S)					-1.17**	-1.16**
					(0.59)	(0.55)
L.$ln\,\Delta$ PE*(E/S)					-0.27	-0.14
					(0.19)	(0.17)
Change in Tariffs						0.00030
						(0.0090)
Change Ins. & Freight Costs						-0.0044
						(0.0055)
Observations	12963	12963	12963	12963	12507	10113

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 353 SIC industry and year fixed effects over the period 1973-2009. 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.

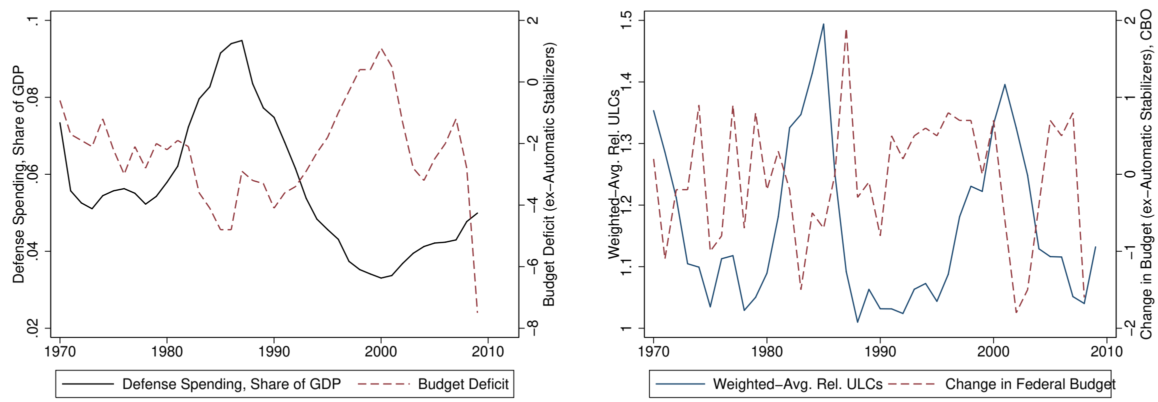
2.3 Proxies and Alternative Measures of RER Indices

In the 1980s, large US fiscal deficits were a likely potential cause of the dollar's strength during that period. Fiscal deficits can affect the tradables sector in at least three 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, 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.* (2011) 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 hinged on the outcomes of presidential elections, and thus are arguably exogenous from the perspective of the subsequent evolution of manufacturing employment in more open sectors.

Figure 11(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 11(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 budget balance are also good for relatively more tradable sectors. These results are not driven by outliers, as they are also robust to minimizing the sum of absolute values (see the Additional Appendix).



(a) Defense Spending vs. Budget Deficit (b) Structural Budget Deficit vs. WARULC

Figure 11: Defense Spending, the Structural Budget Deficit, and RULCs
Sources: FRED and CBO

Next I consider alternative measures of relative prices. Figure 12 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 sounds implausible. I have also plotted an updated version of Fahle *et al.*'s (2008) Weighted Average Relative Prices (WARP) using PWT v8.0, and Balassa-Samuelson Adjusted Weighted Average Relative Prices (BSWARP) introduced in Campbell and Pyun (2013b). 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 major differences, the more negative overall slope of WARULC, 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 (2013b), unit labor cost-based relative price measures are not necessarily *a priori* better measures of competitiveness than Balassa-Samuelson Adjusted Weighted Average Relative Price (BSWARP) indices. This is because manufacturing requires many more inputs, including nontraded inputs, than just labor, as labor costs fell to just 16% of shipment revenue by 2007. Thus broader measures of

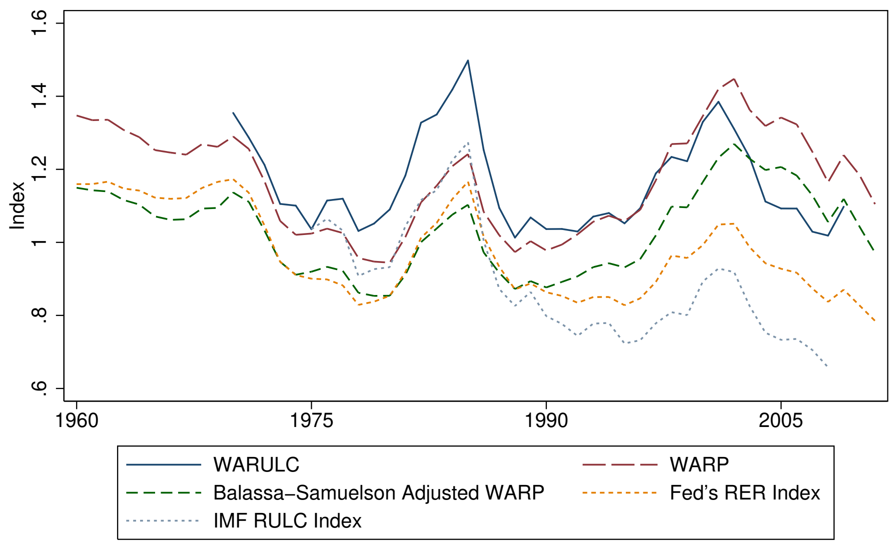


Figure 12: Comparing Various Exchange Rate Measures
Source: Campbell and Pyun, 2013 and the IMF

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 (5), I use the lagged log of the WARP index, and in column (6) I use the log of the BSWARP index (the Balassa-Samuelson adjusted version of WARP). In each case, the results are little-changed.

Additionally, in column (4), I use sector-specific trade weights, with the difference being only that the trade weights are simply 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. 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 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.[26]

[26]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 are reasons why one may 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

Table 3: Using Alternative Measures of Relative Prices, and Proxies for the RER

	(1) $ln\Delta$ L	(2) $ln\Delta$ L	(3) $ln\Delta$ L	(4) $ln\Delta$ L	(5) $ln\Delta$ L	(6) $ln\Delta$ L
L.Relative Openness	-0.013**	-0.011**	-0.014**	-0.011*	-0.019***	-0.0037
	(0.0055)	(0.0053)	(0.0059)	(0.0066)	(0.0067)	(0.0057)
$ln\Delta$ VA-per-Production Worker	-0.22***	-0.22***	-0.21***	-0.22***	-0.22***	-0.22***
	(0.037)	(0.037)	(0.036)	(0.036)	(0.036)	(0.037)
$ln\,\Delta$ Demand	0.46***	0.46***	0.46***	0.46***	0.46***	0.46***
	(0.063)	(0.064)	(0.063)	(0.064)	(0.064)	(0.065)
L.(K/L)	-0.0038	-0.0053	-0.011	-0.0012	0.0010	-0.010
	(0.030)	(0.031)	(0.032)	(0.030)	(0.030)	(0.030)
L.(K/L)*L.Real Interest Rate	-0.27	-0.33	-0.16	-0.27	-0.28	-0.24
	(0.22)	(0.25)	(0.25)	(0.23)	(0.23)	(0.22)
L.$ln\,\Delta$ Price of Shipments	0.036***	0.035***	0.038***	0.028**	0.028**	0.036**
	(0.014)	(0.013)	(0.014)	(0.014)	(0.014)	(0.016)
L.$ln\,\Delta$ Price of Materials	0.13**	0.13**	0.13**	0.11*	0.11*	0.13**
	(0.065)	(0.062)	(0.063)	(0.060)	(0.060)	(0.064)
L. $ln\,\Delta$ Hourly Wages	0.042	0.043*	0.047*	0.047*	0.046*	0.053*
	(0.026)	(0.026)	(0.027)	(0.028)	(0.028)	(0.028)
L.$ln\,\Delta$ Price of Investment	0.27	0.27*	0.32*	0.34*	0.33*	0.30
	(0.17)	(0.16)	(0.18)	(0.18)	(0.18)	(0.18)
L.$ln\,\Delta$ Price of Energy	0.055*	0.054	0.060*	0.058*	0.057*	0.064*
	(0.032)	(0.033)	(0.034)	(0.035)	(0.035)	(0.034)
L.$ln\,\Delta$ PM*(M/S)	-0.19**	-0.19**	-0.19**	-0.16**	-0.16**	-0.18**
	(0.087)	(0.083)	(0.082)	(0.080)	(0.080)	(0.087)
L.$ln\,\Delta$ PI*(I/S)	-1.20**	-1.16**	-1.31**	-1.30**	-1.29**	-0.98*
	(0.54)	(0.53)	(0.53)	(0.53)	(0.52)	(0.57)
L.$ln\,\Delta$ PE*(E/S)	-0.37*	-0.38**	-0.36*	-0.30*	-0.30*	-0.38**
	(0.19)	(0.19)	(0.18)	(0.17)	(0.17)	(0.19)
L.Rel.Openness* $ln\Delta$ (Defense/GDP)	-1.10***					
	(0.27)					
L.Rel.Openness* $ln\Delta$ (Defense/Shipments)		-1.12***				
		(0.20)				
L.Rel.Openness*Δ Structural Budget			0.65**			
			(0.28)			
L.Rel.Openness*ln(WARP)				-0.070***		
				(0.017)		
L.Rel.Openness*ln(BSWARP)					-0.077***	
					(0.018)	
L.ln(Sectoral WARULC)						0.021*
						(0.012)
L.Rel.Openness*ln(Sectoral WARULC)						-0.038***
						(0.010)
Observations	12963	12963	12963	12963	12963	12963

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 353 SIC industry and year fixed effects over the period 1973-2009. The dependent variable is the log change in sectoral manufacturing employment.

2.4 Impact on Output, 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 investment, this would imply that the previous results 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. In this section, I test the impact of relative price movements on a multitude of other variables, and provide additional falsification tests.

In Table 4, I show that production worker hourly wages in more open sectors only decline slightly when relative prices are elevated (I separately found no significant impact on non-production worker wages), and that investment, value-added and shipments all fared worse. 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 movments 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 toward finding spurious results. However, I find that the interaction term on WARULC and openness does not significantly predict the growth of any of these deflators, even for various leads and lags.[27]

In addition, I find an impact of exchange rate movements on job creation, job destruction, and TFP (the regression results for these variables are reported in the Additional Appendix). 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 important "fingerprint" of hysteresis. Nearly four good years of job creation are needed for every

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.

[27] These results are also in the additional appendix. I thank Scott Carrell for suggesting this as a robustness check.

bad year of destruction.

Table 4: Impact on Hours, Investment, Production, Inventory and Prices

	(1) $ln\Delta$ PW hourly	(2) $ln\Delta$ I	(3) $ln\Delta$ VA	(4) $ln\Delta$ TFP	(5) $ln\Delta$ Inventory	(6) $ln\Delta$ Prices
L.Relative Openness	0.00363***	0.00608	-0.00231	0.00124	0.000315	-0.00361
	(0.00120)	(0.0118)	(0.00732)	(0.00290)	(0.00748)	(0.00241)
L.ln(WARULC)*Open.	-0.0166***	-0.148***	-0.0910***	-0.0283***	-0.0121	-0.000368
	(0.00639)	(0.0427)	(0.0243)	(0.00725)	(0.0236)	(0.00858)
ln Δ VA-per-Prod. Worker	0.0589***	-0.0977	0.646***	0.269***	-0.708***	-0.0919***
	(0.00988)	(0.0672)	(0.0477)	(0.0258)	(0.0440)	(0.0313)
$ln\ \Delta$ Demand	0.0103	0.591***	0.460***	0.186***	-0.0552**	-0.0819***
	(0.0117)	(0.101)	(0.0689)	(0.0260)	(0.0281)	(0.0248)
L.K/L	-0.0508**	-0.141	0.0274	0.0261	-0.0554	0.0150
	(0.0253)	(0.164)	(0.0570)	(0.0283)	(0.0804)	(0.0326)
L.(K/L)*Real Interest Rate	-1.107*	-7.045***	-4.144***	0.0366	0.101	-3.749***
	(0.592)	(2.115)	(1.223)	(0.447)	(1.731)	(1.193)
L.$ln\ \Delta$ Price of Shipments	0.0101	0.217***	0.0313	-0.00105	0.0249	
	(0.00846)	(0.0658)	(0.0466)	(0.0168)	(0.0548)	
Observations	12963	12963	12963	12963	12963	14864

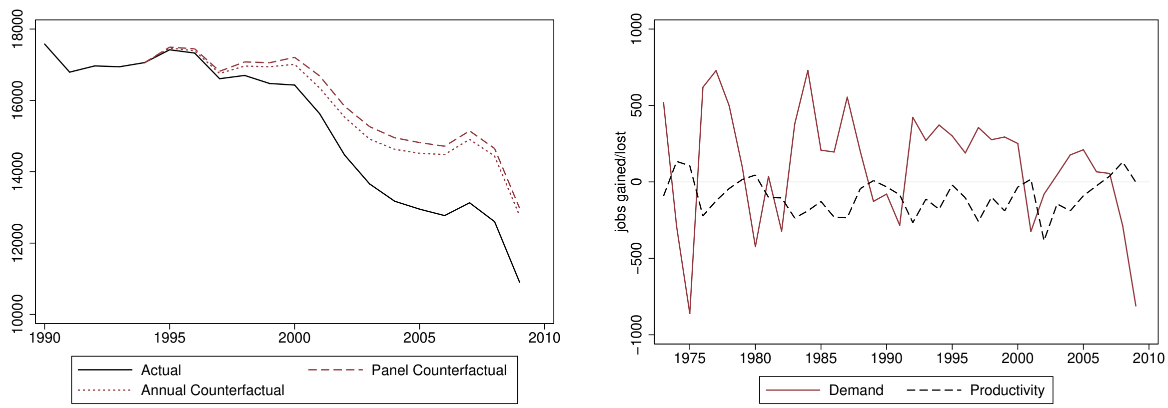
Two-way clustered standard errors in parentheses, clustered by year and industry. *$p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions weighted by initial sectoral value-added, and include 4-digit SIC industry and year fixed effects over the period 1973-2009. The dependent variables are 1) log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

2.5 Accounting for Jobs Lost

Figure 13 presents the results from two counterfactuals which add back the cumulative jobs lost from the dollar's strength in the late 1990s and early 2000s (blue dashes), using the regression coefficients displayed in Figure 10 and a second estimate using the panel regression from Column (5) of Table 2. The estimates of jobs lost are calculated by multiplying the coefficient and actual data on the level of WARULC interacted with relative openness times lagged sectoral employment, and then summing by year to derive an estimate of the total jobs lost due to WARULC appreciation. The estimates using the annual regressions imply that 1.86 million jobs were lost due to trade competition over the period 1995-2008, while the panel estimates suggest 2.07 million jobs were lost. Both of these are substantially *lower* than the 3.9 million jobs lost according to a straightforward accounting approach (Table 7) based on the rise in the manufacturing trade deficit.[28] However, what is clear is that even both of these counterfactuals imply

[28]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.

a substantial fall in manufacturing employment after 2000. What accounts for this decline?



(a) Manufacturing Employment Counterfactuals

(b) Impact of Demand and Productivity

Figure 13: Accounting for Labor Lost

Notes: In Panel (a), the "Panel Estimate" counterfactual is computed using the coefficient on relative openness from the regression in Column (2) of Table 3. The "Annual Estimate" uses regression coefficients plotted in Figure 10. The coefficient on lagged import penetration is multiplied by lagged sectoral employment and then summed by year.

Figure 13(b) details the impact of changes in demand and productivity on changes in manufacturing employment (using the regression coefficients from Column (5) 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. 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. Every dollar of output of apparel manufacturing requires 30 cents of output from textile mills.[29] Every dollar of industrial machinery requires 6.9 cents worth of the output from iron and steel mills. Overall, every dollar of aggregate manufacturing output generally requires about 60 cents worth of additional output from other manufacturing industries. This suggests that it is quite likely that closer to 3 million manufacturing jobs were lost from the dollar's appreciation.[30]

[29]Data come from the BEA's Total Requirements Input-Output table.

[30]This would also not be a complete estimate, as the collapse in manufacturing employment may 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.

3 International Evidence

3.1 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 in the previous section, 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 14 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.[31] This indicates that the job losses in the US in the early 2000s were not simply due to a 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 15).[32] As Canadian unit labor 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 15, Panel (b)).

Thus, we now estimate:

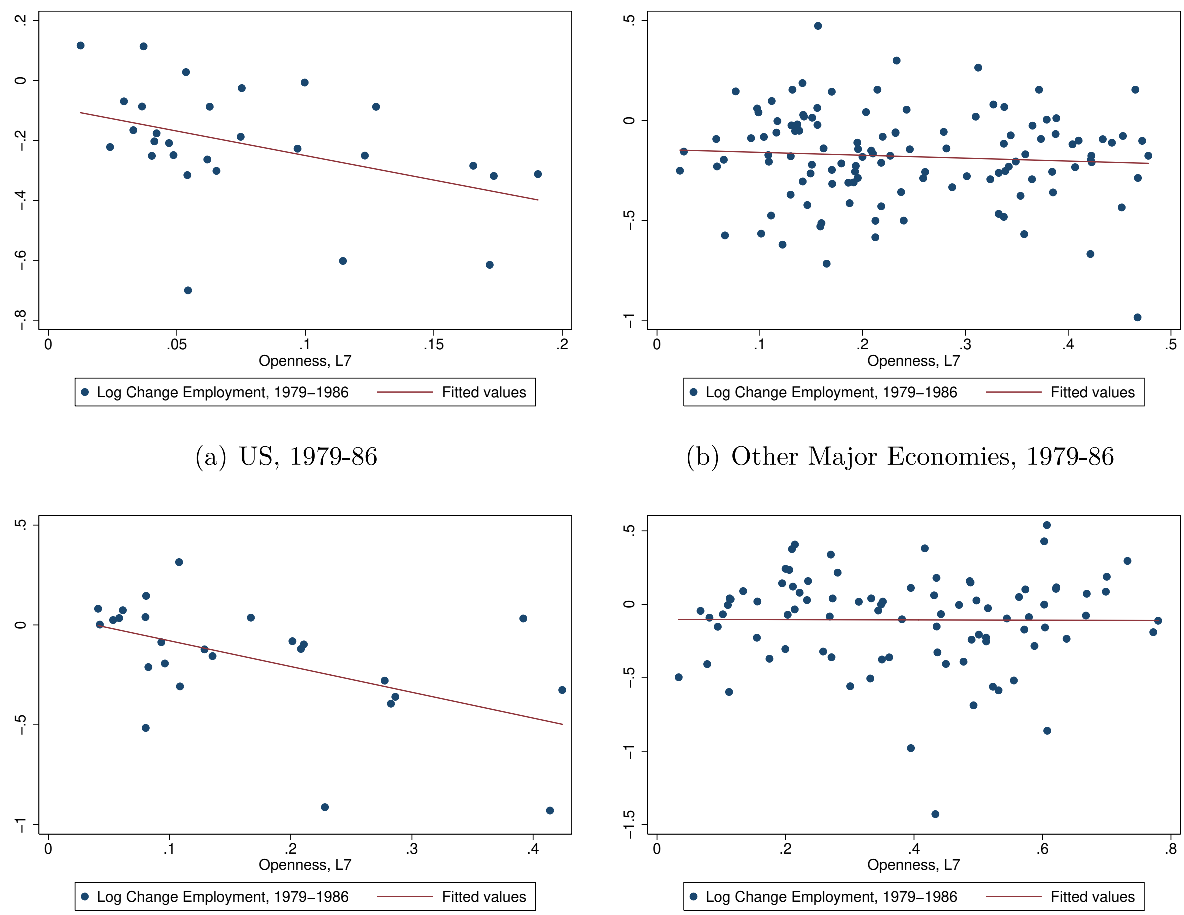
$$ln(\frac{L_{US,h,t}}{L_{US,h,t-1}}) - ln(\frac{L_{G5,h,t}}{L_{G5,h,t-1}}) = \alpha_t + \beta_1((WARULC-1)*Openness)_{h,t-1}+ \quad (3.1)$$

$$\beta_2(ln(\frac{D_{US,h,t}}{D_{US,h,t-1}}) - ln(\frac{D_{G5,h,t}}{D_{G5,h,t-1}})) + \beta_3(ln(\frac{(S/L)_{US,h,t}}{(S/L)_{US,h,t-1}}) - (ln(\frac{(S/L)_{G5,h,t}}{(S/L)_{G5,h,t-1}})) + \alpha_h + \nu_t + \epsilon_{ht},$$

$$\forall h = 1, ..., 29,\ t = 1978, ...1995, 1998, ..., 2003,$$
$$G5 = (Canada, France, Germany, Italy, UK).$$

[31] In the Additional Appendix, I also show that there is no correlation between openness and employment for years when the dollar was weak.

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



(a) US, 1979-86 (b) Other Major Economies, 1979-86

(c) US, 1995-2002 (d) Other Major Economies, 1995-2002

Figure 14: Employment Growth vs. Lagged Openness

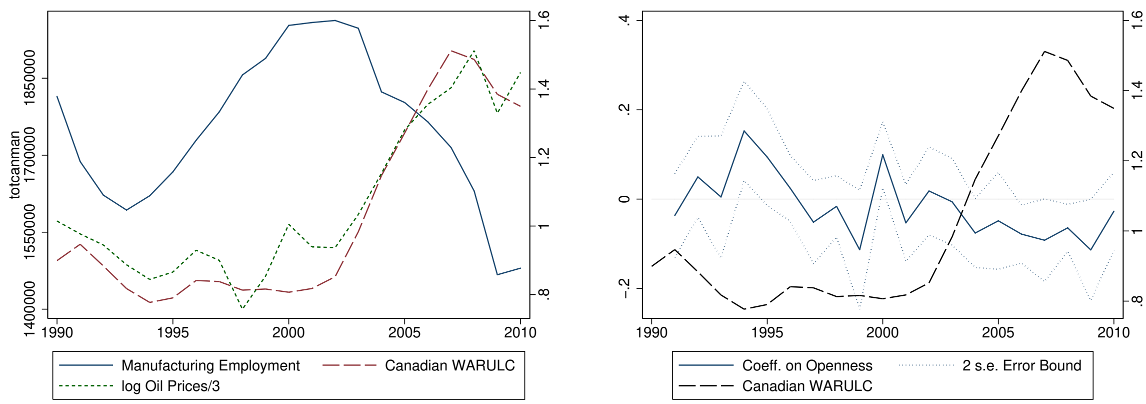
Source: UNIDOs (3-digit ISIC manufacturing sectors). Other major economies include Canada, France, Germany, Italy, and the UK.

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 data are 3-digit ISIC Rev. 2 data from UNIDOs, which does not report data for the US for 1996. 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 (normalized by subtracting one) 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. In the second column, the dependent variable is now the log change in sectoral output, and the key interaction term is once again large and significant.

Table 5: International Evidence

	(1)	(2)	(3)	(4)	(5)	(6)
	ln ΔL	ln ΔY	ln ΔL Rel.	ln ΔY Rel.	ln ΔL Canada	ln ΔL Canada
L.Openness	0.048	0.059***	0.072	-0.027	0.048	0.030
	(0.030)	(0.022)	(0.056)	(0.032)	(0.035)	(0.033)
L.Openness*(WARULC-1)	-0.58***	-0.53***	-0.76***	-0.64***		
	(0.10)	(0.095)	(0.090)	(0.078)		
ln $\Delta(Y/L)$	-0.90***				-0.83***	-0.82***
	(0.041)				(0.041)	(0.042)
ln Δ Demand	0.89***	0.97***			0.82***	0.82***
	(0.040)	(0.040)			(0.064)	(0.066)
ln $\Delta(Y/L)$ (Relative)			-0.52***			
			(0.078)			
ln Δ Demand (Relative)			0.59***	0.91***		
			(0.066)	(0.040)		
L.Openess*(WARULC-.85)					-0.15***	
					(0.042)	
L.Openess*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 sectoral and 3-digit ISIC industry fixed effects. Data for the first four regressions span 1977-1995 and 1998-2003 and 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 third and fourth 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 last column, oil prices are used as a proxy for Canada's RER by taking the log of the price of a barrel of crude oil and subtracting three.



(a) Total Employment vs. WARULC

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

Figure 15: Canadian Manufacturing Employment, WARULC

Sources: UNIDOs, Comtrade, Campbell and Pyun (2014)

In the third column of Table 5, I estimate the relative difference-in-difference regression in equation (3.1), 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 heterogenous effects of exchange rate movements by country dependent on labor market institutions (see, for example, Berman *et. al.* (2009), Pozzolo and Nucci (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.[33] Also, it appears that for Canada, the dividing line between faster vs. slower growth for more open sectors is when WARULC is around .85 instead of 1, so I have subtracted .85 instead of one for Canada.[34] Finally, in the last column, I proxy movements in Canadian relative unit labor costs using the log of oil prices minus three, and again find that when oil prices are high, the more open sectors

[33]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 substantially higher than the same elasticity using SIC (or NAICs) data from the BEA. A comparison of these elasticities is covered in the Not-for-publication Appendix.

[34]This could be due to a country-specific bias in the data collection, tariff policy, or any number of other factors.

in Canada tend to lose ground relative to less open sectors.

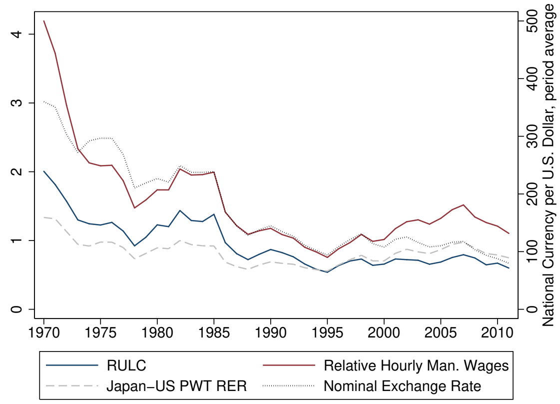
3.2 Japan

Just as China as 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.

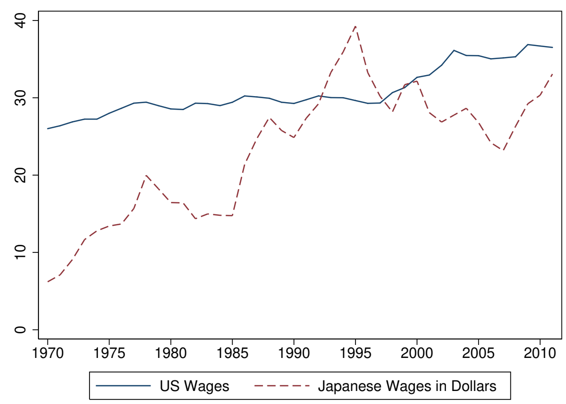
Japan is a particularly good case study since the yen was heavily managed and then appreciated substantially shortly after the full liberalization of Japanese capital markets. The yen was fixed after World War II until the early 1970s, when President Nixon, worried about what were very small trade deficits 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 16, 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.

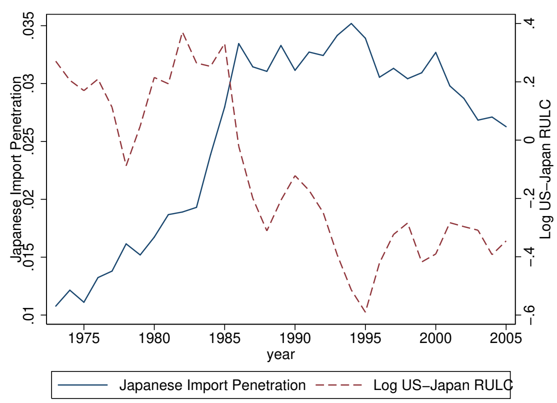
The result of this real appreciation was that as wages in the Japanese manufacturing sector suddenly increased substantially relative to their American counterparts, the meteoric Japanese export growth from 1946 to 1986 suddenly ground to a halt (Figure



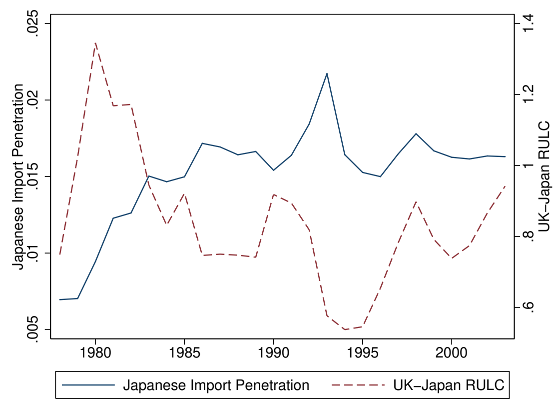
(a) US-Japan Exchange Rates



(b) Manufacturing Wages (2011 Dollars)



(c) US



(d) UK

Figure 16: RULCs and Japanese Import Penetration
(Sources: PWTs, CP 2013, UNIDOs, Comtrade)

16(c)). However, Japan kept the gains in market share it had made even though it did not make further inroads—another validation 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 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, Japanese import penetration decreased. 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 this period, Japanese import penetration fell relative to the period when the Yen was strong. 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 the US initially.

Table 6: Japanese Exports and the Yen

	(1) US	(2) US	(3) UK	(4) US	(5) G6
ln Δ Import Pen.	0.82***	0.80***	0.74***	0.76***	0.87***
	(0.18)	(0.19)	(0.16)	(0.068)	(0.050)
L.ln(RULC)	0.13***		0.25***	0.11***	0.13***
	(0.027)		(0.051)	(0.021)	(0.016)
Post-Plaza Accord Dummy		-0.076***			
		(0.015)			
ln Δ Japan. MP Pen. in UK				0.18***	
				(0.026)	
Observations	606	606	669	606	3544

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. The dependent variable is the log change in sectoral Japanese import penetration. 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, UNIDOs, and Campbell and Pyun (2014).

4 Conclusion

In this paper, I document that when nominal exchange rates move, the nominal rigidity of wages leads to large changes in Weighted Average Relative Unit Labor Costs, a new measure of competitiveness in manufacturing. 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 exchange rates. These exogenous shocks (from the perspective of manufacturing employment) appear to lead to increased imports and decreased exports in the manufacturing sector, and to declines in investment and employment concentrated in relatively more open manufacturing sectors. The impact of a temporary shock to relative prices is persistent, indicating that current economic relationships are historically dependent. The shock to trade in the early 2000s was large enough to explain at least close to two-thirds of the decline in American manufacturing employment in this period, and perhaps substantially more if input-output linkages are taken into account. The job losses were potentially large enough to have had a macroeconomic impact. As the "Lesser Depression" continues, the US experience with Japan in the 1980s provides an example of what presidential leadership might accomplish regarding the ongoing Bretton Woods II system of managed exchange rates, developing country capital controls, and large-scale accumulation of official dollar reserves.[35] And the lesson of hysteresis reminds us that the consequences of continued slow-growth will be diminished economic possibilities for years to come.

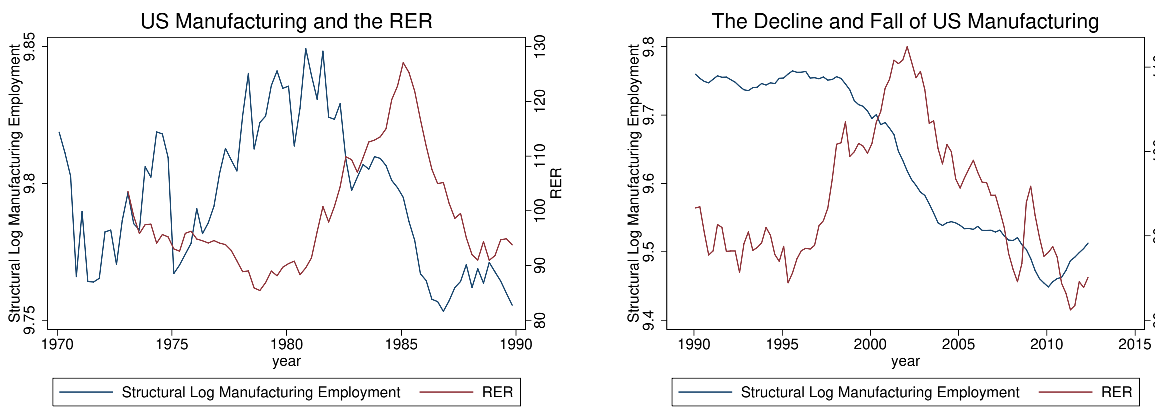
5 Appendix

Table 7: Manufacturing Employment Accounting

Year	Manufacturing Consumption (billions)	Manufacturing Trade Deficit (billions)	Productivity (1 million workers)	Deficit Δ from 1995 over Productivity	Actual Jobs Lost in Man. Since 1995
1995	1340	159	68	0.00	0
1996	1361	152	70	-0.09	-0.01
1997	1432	155	73	-0.05	0.17
1998	1542	215	76	0.75	0.32
1999	1661	293	79	1.70	0.08
2000	1780	364	82	2.50	0.02
2001	1688	344	82	2.26	-0.80
2002	1760	404	89	2.76	-1.99
2003	1822	448	95	3.05	-2.74
2004	2023	540	104	3.68	-2.93
2005	2158	590	110	3.92	-3.02

Source: BEA. Manufacturing "Consumption" is defined as manufacturing GDP plus imports minus exports.

[35]See Dooley *et al.* 2004, 2005, 2007, and 2009.



(a) 1970s and 1980s

(b) 1990s and 2000s

Figure 17: Structural Manufacturing Employment vs. the RER

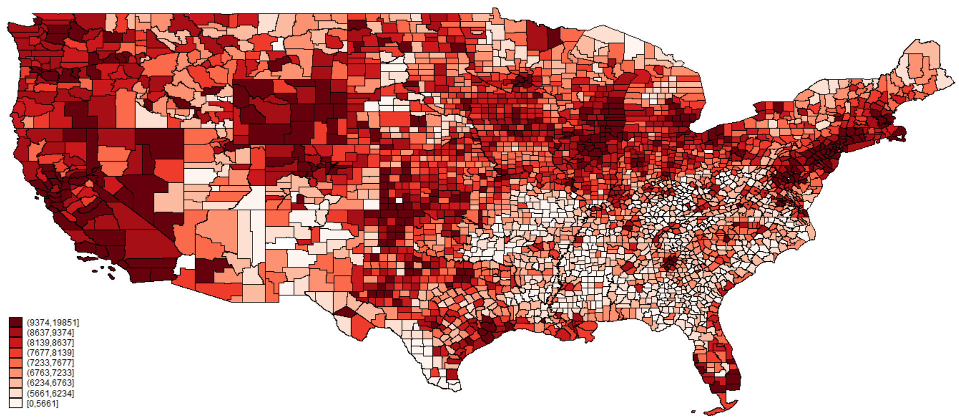


Figure 18: Income per Capita, 1979

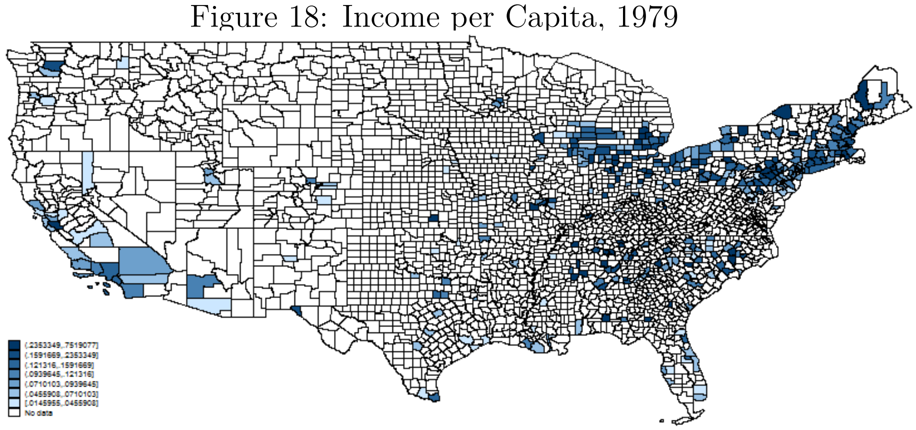
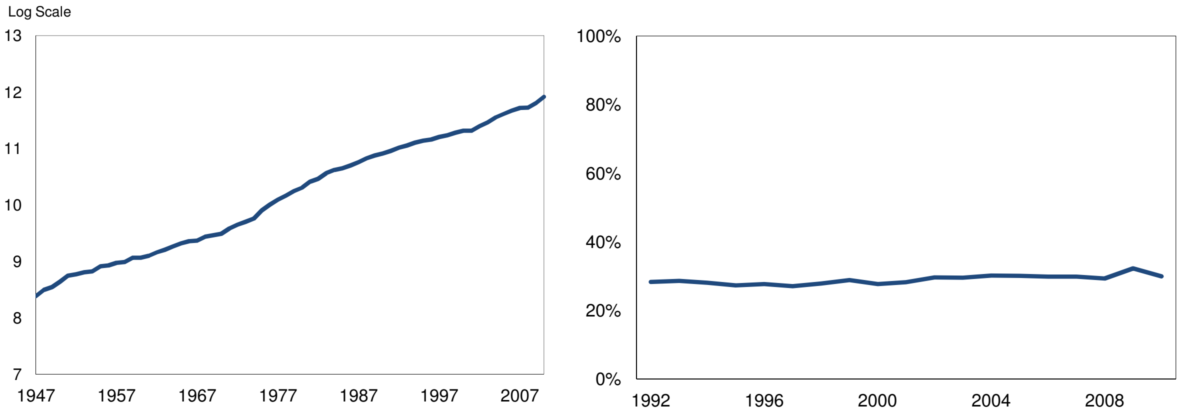


Figure 19: Import-Competing Manufacturing Employment, Share of Total Employment, 1979

Notes: 1,500 worker minimum. Sources: BEA and WITS



(a) Value-Added per Worker

(b) Services Share of Exports

Figure 20: The Usual Suspects: Explanations for the Decline of Manufacturing
Source: BEA

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