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Comparing Advantages : US Trade with the Rest of the World, 1968~2008

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Abstract

Calibrating a stylized version of the Dornbusch-Fischer-Samuelson model, this paper finds that relative to a cohort of 97 trading partners, the US capital stock, labor force, and nominal GDP per capita decreased, while the level of technology embodied in its output increased. These observed dynamics suggest a shift in comparative advantage that, coupled with increased production at the extensive and intensive margins, yields an expectation of labor market churning. Grouping trading partners by World Bank income classifications reveals that observed changes for low and lower middle income cohorts resulted in more pronounced shifts in comparative advantage. Examining employment and earnings in US manufacturing industries, a dynamic regression model reveals that increased import penetration has significant negative effects on production worker employment and wages, while increases in exports has significant positive effects on production worker employment. Variation in labor market outcomes is found across income classifications, as well as industries categorized by trade orientation.

JEL Classifications: F11, F14, F16
Keywords: Comparative Advantage, Dornbusch-Fischer-Samuelson Model, Exports, Imports, Manufacturing

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I. Introduction

The basis for mutually-beneficial exchange, illustrated by Ricardo (1817), is intuitive when one considers how people conduct their daily lives. They rarely produce the items that they consume, instead exploiting their individual comparative advantages by specializing in the production of a narrow range of goods and/or services for which they are most productive. They then use their resulting compensation to acquire those goods and services that they are relatively less adept at producing. Similarly, Ricardo's example concludes with Britain producing and exporting cloth to Portugal in exchange for port wine. The result of the countries' specialization in production and subsequent exchange is that both can consume more cloth and more port wine than the case when they chose to not trade.

Ricardo's example neither explicitly accounts for capital nor technology, but the two-good, two-country, one productive factor structure he posited is sufficient for making the point that trade carries the potential for increased consumption and, therefore, higher welfare. Heckscher (1919) and Ohlin (1933) extend the basic Ricardian model to include both labor and capital as factors of production and, thus, to provide differences in relative factor endowments as a basis for comparative advantage. While the Heckscher-Ohlin model provides a clear prediction of the pattern of trade, both the basic Ricardian framework and the Heckscher-Ohlin model are limiting if one seeks to consider the simultaneous effects of changing the levels of labor, capital, and technology on the good(s) for which comparative advantage is held.

Not surprisingly, between 1968 and 2008, the United States experienced increases in the size of its labor force, its capital stock, and the level of technology embodied in its output. During this same period, the rest of the world also, collectively, realized growth in its labor force and its capital stock, and it experienced technology gains. By comparison, labor supplies and capital stocks in the rest of the world increased at faster rates than did those of the US while technological advancement in the US outpaced corresponding advances in the rest of the world. These dynamics have implications for factor input usage and factor returns. Accordingly, there are corresponding implications for the range of products for which the US and the rest of the world hold comparative advantage.

To present these stylized facts and make them relevant to this paper's discussion of the effects of trade on domestic labor, this study employs the Dornbusch-Fischer-

Samuelson (DFS) model (Dornbusch *et al*. 1977). The DFS model allows for the inclusion of capital stocks, technologies, and labor supplies, which may vary across potential trading partners. While the model extends the factor endowments approach to comparative advantage determination that was introduced by Ricardo and extended by Heckscher and Ohlin, it also facilitates technology as a productive factor. Emphasizing the contribution of Dornbusch, Fisher, and Samuelson, Krugman (2008) describes the model as "160 years of international economics in one paper."

Heuristically, this paper evaluates the US relative to all other countries by aggregating these economies to form the rest of the world or, more plainly stated, "foreign". Specifically, calibration of the DFS model permits us to consider the impacts, for both the US and foreign countries, of changes in relative labor supplies, advances in technology, and changes in capital stocks either in isolation or collectively. This paper also explores the US-foreign comparative advantage relationship in greater detail by disaggregating foreign into several cohorts based on World Bank income classifications and then performing a calibration exercise for each cohort. This paper presents only the most basic version of the model here as that is sufficient for the purpose of motivating an empirical examination of the influences of trade on employment and wages in the US manufacturing industries during the reference period.

The choice of the US as the focus of this study is two-fold. First, the effects of international trade on wages and employment continue to be an important issue in the US political arena. Accordingly, US trade policy is directly affected by the links between imports, exports, employment, and wages. This includes a wide range of policies, including previously signed trade agreements, future trade agreements such as the Transatlantic Trade and Investment Partnership (TTIP), and the Trans-Pacific Partnership (TPP), recent export initiatives, and perhaps most importantly, Trade Adjustment Assistance (TAA). Additionally, the availability of industry-level data from the US over a long period of time allows for a more robust analysis than what is possible in other countries.

Employing data for 459 4-digit Standard Industrial Classification (SIC) manufacturing industries that span over 1972~2005 (Becker *et al*. 2013) in conjunction with corresponding industry-level trade data (Schott 2008), the influences of changes in industry-level exports and import penetration on average annual wages and the employment of both production and non-production workers are examined. Results obtained from the estimation of a series of dynamic regression models suggest that increased import competition is negatively related to both employment levels and the average annual wages of production workers. Results also show that increased exports are positively related to production worker employment. Examining the effects of increased import penetration across cohorts of trading partners that have been classified based on average income levels reveals variation. Likewise, the effects of import penetration are found to vary based on industry trade orientation.

It is in combining these two aspects of trade – the comparative advantages revealed in the DFS setting and the effects of these changes in comparative advantage on labor and wages – where this paper contributes most substantially to the literature. Using the DFS model, the comparative advantage enjoyed by the US in 1968, which has evolved due to relative changes in labor, capital, and technology, is shown, along with the effects that these changes, contributing to shifts in US export and import volumes, have influenced domestic labor.

The study proceeds as follows. Section II introduces the DFS model. In Section III, calibration process is detailed and predicted shifts in comparative advantage are gleaned. Section IV presents the findings from the empirical analysis of the influences of exports and import penetration on industry-level wages and employment. Section V concludes.

II. DFS Model

Considering all countries other than the US as the rest of the world, i.e., foreign, denoted by *, this study begins with the assumption that each country is able to both produce and consume a large number of goods. Goods are identified by the variable z and are located along a continuum (Z) that is indexed from zero to one. Next, $a(z)$ is defined as the home country's unit labor requirement for the z^{th} good and $a^*(z)$ as the unit labor requirement, for the same good, in the foreign country. This paper defines the ratio of foreign-to-home unit labor requirements, $\frac{a^*(z)}{a(z)}$, as $A(z)$ and ranks all goods along the (0,1) continuum in descending order of the home country's comparative advantage; that is, $\frac{a^*(\alpha)}{a(\alpha)} > \frac{a^*(\beta)}{a(\beta)} > \ldots > \frac{a^*(\zeta)}{a(\zeta)}$. In Figure 1, the $A(z)$ schedule against Z, our index of goods, is plotted.

To determine which goods will be produced in each country, the ratio of the home country's nominal wages to the nominal wages of the foreign country, $\frac{w}{w^*}$, is considered. As defined by the DFS model, this ratio is labeled ω and is measured along the vertical axis. Because the DFS model is a long-run model, full-employment and perfect competition are assumed. As the static changes are illustrated in comparative advantage and the associated labor market adjustment is inferred, this full-employment assumption is largely, though admittedly not entirely, innocuous. The dynamics implied by the static adjustment in the model is of direct relevance to the topic of study. For now, with the goal of motivating this empirical analysis in mind, this limitation is set aside.

With perfectly competitive markets, the cost of producing a given good z in the home country is $p(z) = wa(z)$. Likewise, the cost of producing the same good in the foreign country is $p^*(z) = w^*a^*(z)$. Therefore, good z will be cheaper to produce in the home country if $p(z) < p^*(z)$ or, equivalently, if $\frac{w}{w^*} < \frac{a^*(z)}{a(z)}$. This is to say that good z will be cheaper to produce at home if $\omega = A(z)$. Thus, for a given $A(z)$ schedule, the ratio of the home and foreign real wage rates establishes the pattern of comparative advantage and, hence, international specialization.

In Figure 1, $\hat{z}$ represents the marginal good for which $\omega = A(z)$ and that both countries produce. All goods to the left of $\hat{z}$ along the continuum are produced by the home country because $\omega < A(z)$, and all goods to the right of $\hat{z}$ are produced by the foreign country because $\omega > A(z)$. Specifically, the range of the continuum for which the home country holds comparative advantage (given as $\hat{z} \rightarrow 0$) includes those goods for which $\frac{w}{w^*} < \frac{a^*(z)}{a(z)}$. Thus, home holds comparative advantage since $w\text{a}(z) < w^*\text{a}^*(z)$, which is to say that $p(z) < p^*(z)$. A similar explanation applies for the range of the continuum for which foreign holds comparative advantage in production: $\hat{z} \rightarrow 1$. Over this range of the continuum, $\omega > A(z)$. This implies that $\frac{w}{w^*} > \frac{a^*(z)}{a(z)}$, and it follows that $w\text{a}(z) > w^*\text{a}^*(z)$ and $p(z) > p^*(z)$.

The $B(z)$ schedule, which illustrates z values that result in balanced trade between the countries given the corresponding $\frac{w}{w^*}$ values, is introduced. To establish an equilibrium value for ω, a simplifying assumption that all consumers spend a constant fraction of their income on each z good is invoked. This restricts movement of the $B(z)$ schedule to represent only changes in relative labor supplies. $G(z)$ is then defined as the fraction of world income spent on home country-produced goods: $G(z) = b(\alpha) + b(\beta) + ... +$

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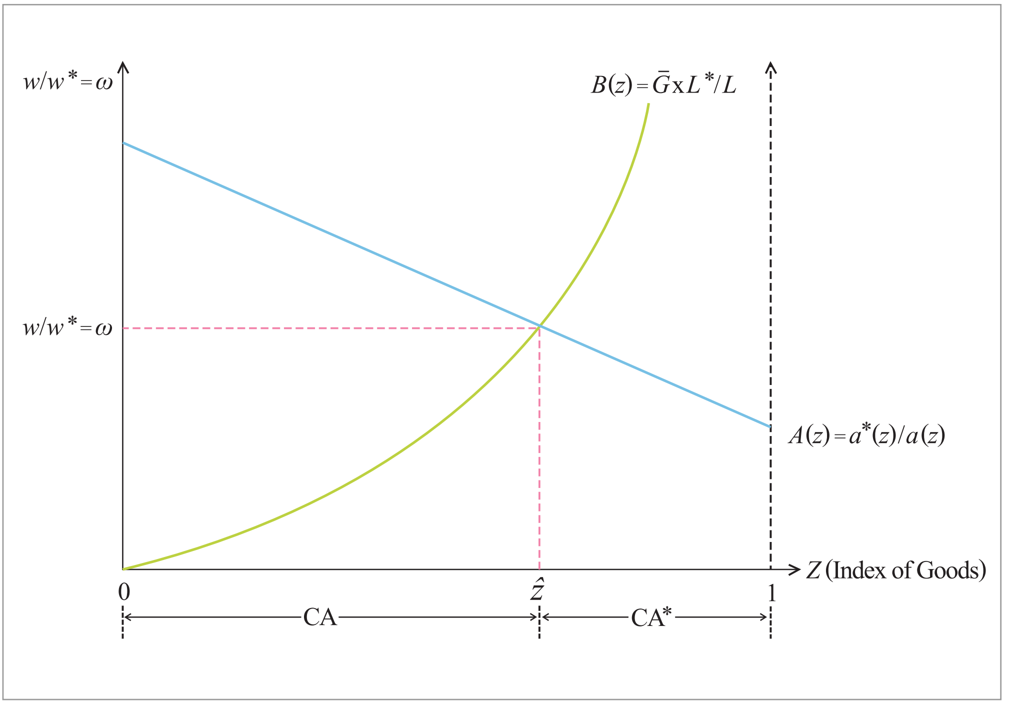
$b(\hat{z})$, where the expenditure shares, b, are assumed to remain constant. To determine the total value of spending on home country production, which is equal to the product of the nominal wage rate in the home country and the domestic labor supply, $G(z)$ is multiplied by world income. Since world income is the sum of incomes in the home and foreign countries, the expression may be written as $wL = G(z)(wL+w^*L^*)$. Solving for $\frac{w}{w^*}$ results in $\frac{w}{w^*} = \frac{G(z)}{1-G(z)} \cdot \frac{L^*}{L}$. Thus, the expression for the $B(z)$ schedule is $B(z) = \overline{G} \cdot \frac{L^*}{L}$ where $\overline{G}$ is the constant ratio of expenditure shares. This provides us with the $B(z)$ schedule illustrated in Figure 1.

The intersection of the $A(z)$ and $B(z)$ curves in Figure 1 determines an initial equilibrium value for ω and a threshold good $\hat{z}$. At a wage ratio of ω, the home country produces and potentially exports all goods over the range from $0 \rightarrow \hat{z}$ and potentially imports all goods from $\hat{z} \rightarrow 1$. The foreign country potentially imports all goods from $0 \rightarrow \hat{z}$ while producing and potentially exports all goods from $\hat{z} \rightarrow 1$.

Figure 1. Illustrating the DFS framework



Admittedly, this is a minimalist derivation of the DFS model. It is, however, sufficiently detailed to allow for the depiction of the comparative statics associated with relative changes in the US and foreign country labor supplies, capital stocks, and technology levels. Thus, it is only as complicated as necessary to allow for the motivation of this study. In that regard, this simple DFS set-up is considered to be elegant. For this paper's purposes, it is only necessary to detail the DFS model in its simpler form. However, the model has been adapted to address a number of issues in international trade, and it is important to note the model's continued importance in trade literature with examples such as Eaton and Kortum (2002) and, more recently, Costinot *et al*. (2010).

III. Calibration of the DFS Model

A. Variable construction

The calibration of the DFS model was completed using data from the Penn World Table 7.0 (Heston *et al*. 2011). In the model, the $A(z)$ schedule represents the ratio, foreign-to-home, of unit labor requirements. The unit labor requirements are determined by the available capital and technology. The $B(z)$ schedule, given the assumption of constant expenditure shares noted earlier, represents the foreign-to-home ratio of labor supplies. Thus, to consider comparative statics over the reference period, data for the capital stocks, technologies, and labor supplies for both foreign and home are necessary. Further, considering that the ratio, home-to-foreign, of nominal wage rates are depicted on the vertical axis of the DFS diagram, a measure of relative wages is also needed.

At this point, it is appropriate to again note that the model has been calibrated for the US relative to foreign and for five cohorts of countries. Specifically, the calibration is performed for the US as compared to (i) all countries and, separately, to those countries classified as (ii) high income, (iii) middle income, (iv) upper middle income, (v) lower middle income, and (vi) low income. The categorization of countries was made based on the 1990 World Bank income classification listing.[1]

[1] The appendix lists the countries in the data set by income cohort. 1990 was used to determine the classifications as it is the year

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The capital stock series was constructed following the methodology employed in Hummels and Levinsohn (1995). For the US and for all cohorts represented as *i*, the 1960 capital stock value is assumed to equal 2.5 times real GDP. In all subsequent years, the capital stock is estimated as the sum of capital stock estimate for the prior year less 13.33% depreciation plus new investment: $K_{it}=[K_{it-1}\times(1-0.1333)]+INVEST_{it}$. Following this methodology, the entire initial capital stock has depreciated by 1968 and the capital stock estimates employed in our analysis are based solely on the timing and the levels of capital investment. Labor supply values are recovered from the Penn World Table data using the real GDP and real GDP per worker series.

Solow (1957) residuals were estimated to represent the levels of technology embodied in the output of the US and each cohort. Employing annual data over the 1968~2008 period for the 97 countries in this study's data, a two-factor (capital and labor) Cobb-Douglas production function was estimated. Due to the presence of panel-level heteroskedasticity and first-order serial correlation, the Feasible Generalized Least Squares technique was employed. The resulting coefficients were then employed in conjunction with US and cohort-specific annual estimates of *L* and *K* to produce estimates of the corresponding levels of embodied technology. Specifically, $T_{it}=\left(\frac{real\ GDP}{L^{0.1364}\times K^{0.8706}}\right)_{\mathrm{it}}$.

Finally, nominal GDP per capita values are employed as a proxy for nominal wages. Average nominal wage values are simply not widely available and, although GDP per capita neither captures wage income solely nor does it represent variation in wages within an economy, it is a measure of average income. In the absence of a better alternative measure, its use would seem an acceptable substitute.

Using the series described above, annual values for foreign-to-home technology ratios (T^*/T), labor supplies (L^*/L), and capital stocks (K^*/K) were produced. Also, the home-to-foreign ratio of nominal GDP per capita (w/w^*) was produced. These ratios were constructed for the US (as the home country) and for each foreign cohort. Table 1 presents descriptive statistics.

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nearest the middle of the reference period for which classifications are available for the included countries. Additionally, the classification is static since countries are categorized throughout the reference period to reduce variation caused by countries moving in/out of cohorts. Classifications are available at: http://siteresources.worldbank.org/DATASTATISTICS/Resources/OGHIST.xls.

Table 1. Descriptive statistics

	Labor: *L* (*or L**)	Capital: *K* (*or K**)	Technology: *T* (*or T**)	GDP per capita: *w*
US	119,713,264 (22,924,971)	9,607,399,804 (4,048,101,260)	3.2836 (0.1698)	30,698 (7,341)
All (excluding US)	1,799,056,529 (443,565,370)	41,260,690,241 (20,393,686,179)	1.7866 (0.0703)	5,111 (1,229)
High Income	222,051,057 (25,908,714)	16,636,524,569 (5,425,075,364)	2.7030 (0.1371)	23,738 (6070)
Middle Income	337,122,295 (104,281,909)	8,576,627,975 (3,701,981,621)	2.2656 (0.1328)	6,352 (1,231)
Upper Middle Income	136,856,395 (45,449,594)	4,452,015,491 (1,909,994,345)	2.4613 (0.1518)	8,536 (1,853)
Lower Middle Income	200,265,901 (58,868,750)	4,124,612,484 (1,816,594,494)	2.1097 (0.1622)	4,883 (882)
Low Income	1,239,883,177 (313,652,568)	16,047,537,696 (11,506,747,489)	0.8677 (0.1040)	1,549 (875)

(Note) N = 41 for all variables/cohorts. Standard deviations in parentheses. Capital stock values are in thousands of US dollars. All mean values, with the exception of GDP per capita for the Lower Middle Income cohort, are significantly different from the overall mean value at the 1% level.

During the reference period, the average value of the US labor supply is just below 120 million. For the rest of the world (that is, the 97 countries for which complete data are available), the corresponding value is nearly 1.8 billion. More than 1.2 billion workers are in low-income countries, and 337 million and 222 million workers are in middle and high income countries, respectively. The average level of the capital stock in the US is about 9.6 trillion US dollars compared to 16.6 trillion US dollars for high income partners, 8.6 trillion US dollars for middle income partners, and 16 trillion US dollars for low income partners, which total approximately 41.2 trillion US dollars for the non-US countries in the data set. The average level of technology for the US over the period is 3.28. For the rest of the world, the average level is 1.79. Across cohorts, average values of 2.70, 2.23, and 0.87 are seen for high, middle, and low income partners, respectively. Finally, the average GDP per capita values over the period are 30,698 US dollars while the US, 23,738 US dollars for high income countries, 6,352 US dollars for middle income countries, and 1,549 US dollars for low-income countries.

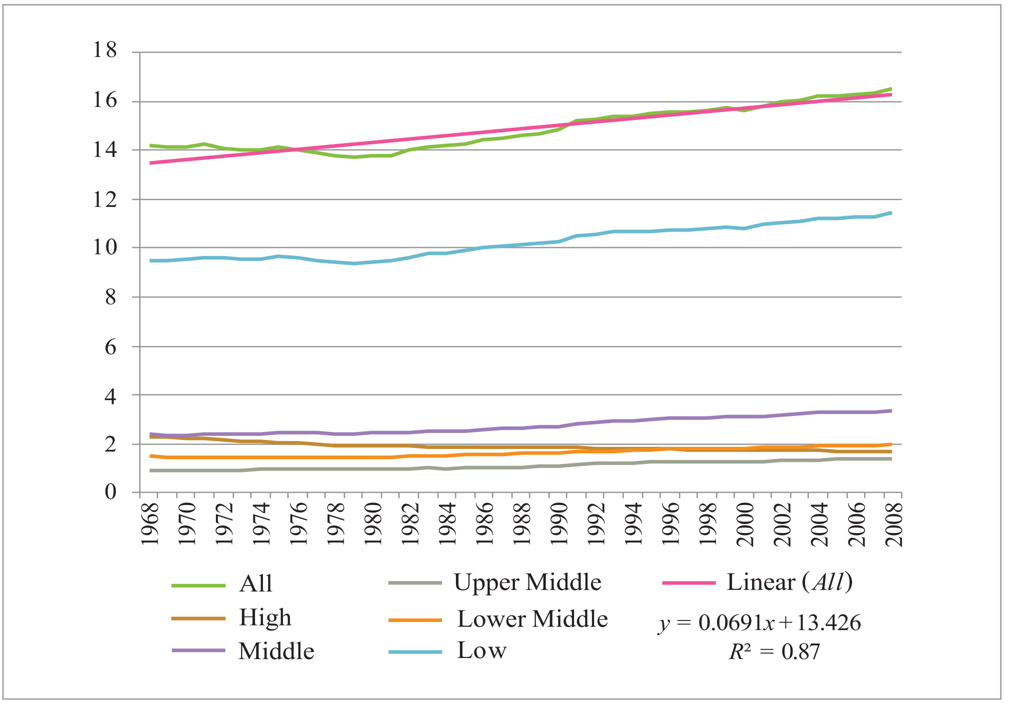
B. Calibration results by cohort

Figure 2 depicts the ratios for each of the four variables of interest over the reference period. The corresponding values, spaced in 10-year intervals, are presented in Table 2. Focusing on the cohort of 97 trading partners (that is, the cohort labeled *All*), the ratio of foreign-to-US labor supplies (L^*/L) increasing 16.6% from 14.18 to 16.53 during the reference period can be seen. Similarly, the ratio of foreign-to-US capital stocks (K^*/K) increased 84.1% from 2.76 to 5.08 during the period. That the ratio of foreign-to-US technology (T^*/T) decreases from 0.63 to 0.55, a decline of 12.7%, can also be seen. Finally, the US-to-foreign ratio of nominal GDP per capita (w/w^*) decreased 14.5% from 6.36 to 5.44.

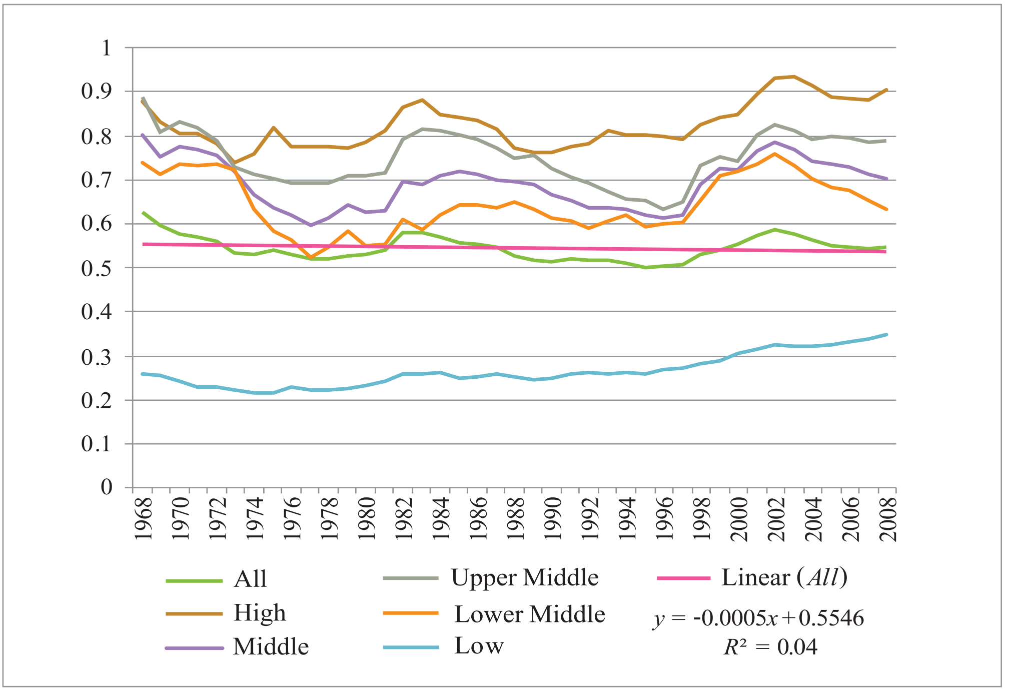
Considering the changes noted above for the *All* cohort, the increase in L^*/L causes an upward pivot of the $B(z)$ schedule in the DFS diagram. The increase in K^*/K shifts the $A(z)$ schedule downward since a greater amount of capital per worker would lower the unit labor requirement for the foreign cohort more so than for the US. That being said, the decrease in T^*/T represents a greater improvement in US technology relative to foreign technology and, thus, has an opposing influence on the $A(z)$ schedule. To determine which effect dominates, the ratio of US-to-foreign values of nominal GDP per capita is looked into. Since the $B(z)$ schedule has pivoted upward and the w/w^* value has decreased, the influence of the increase in K^*/K dominates the influence of the decrease in T^*/T, and the $A(z)$ schedule shifts downward. This loss of comparative advantage, described as a country exporting a smaller portion of the Z continuum and importing a greater portion of goods, is indicated in the rightmost column of Table 2.

Figure 2. Relative changes in factor endowments and nominal wages

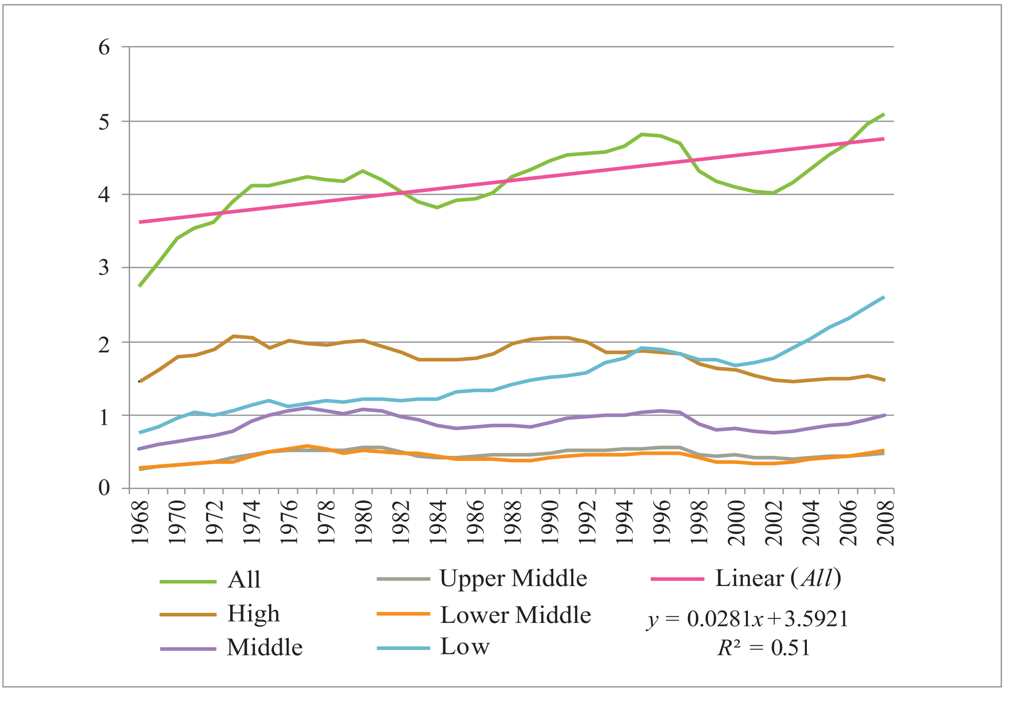
Panel A: Relative Labor Supplies (L^*/L) (1968~2008)



Panel B: Relative Technology (T^*/T)



Panel C: Relative Capital Stocks (K^*/K)



Panel D: Relative Nominal Wages (w^*/w)

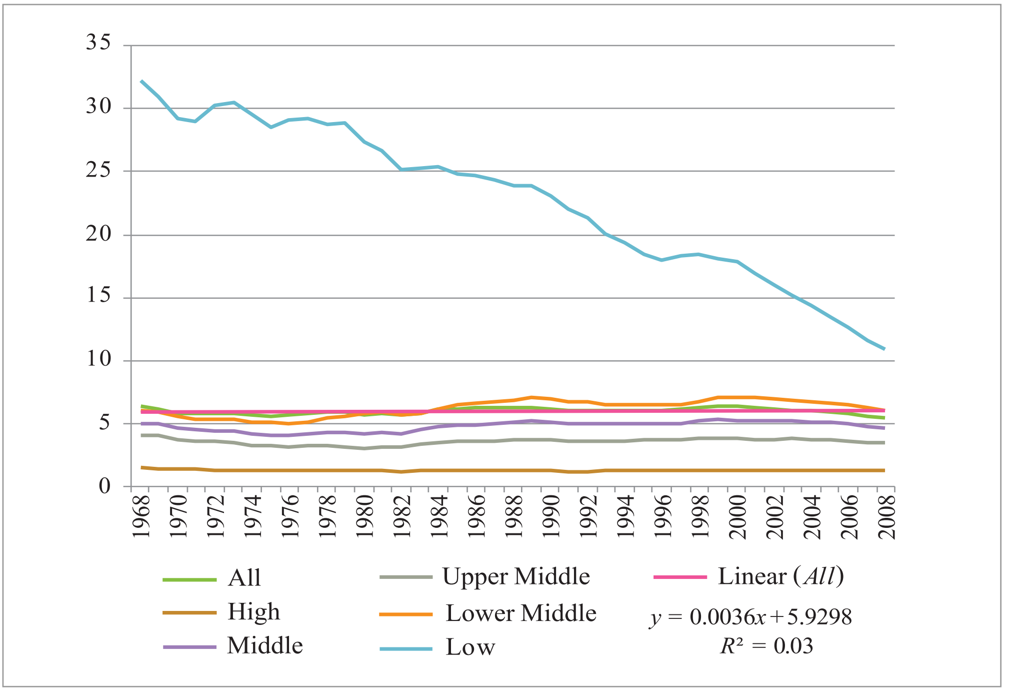


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Table 2. Observed factor changes, and corresponding changes in US comparative advantage

Panel A: All trading partners

Year	L^*/L	% Δ $B(z)$	$B(z)$ pivot	T^*/T	% Δ T^*/T	K^*/K	% Δ K^*/K	$A(z)$ shift	ω	% Δ ω	Δ ω	Δ US Comparative Advantage
1968	14.18	.	.	0.63	.	2.76	.	.	6.36	.	.	.
1978	13.77	-2.89%	–	0.52	-17.46%	4.20	52.17%	unknown	5.91	-7.08%	–	Indeterminable[c]
1988	14.63	3.17%	+	0.53	-15.87%	4.23	53.26%	–[a]	6.26	-1.57%	–	Loss
1998	15.65	10.37%	+	0.53	-15.87%	4.32	56.52%	–[a]	6.32	-0.63%	–	Loss
2008	16.53	16.57%	+	0.55	-12.70%	5.08	84.06%	–[a]	5.44	-14.47%	–	Loss

Panel B: Income classification cohorts

High Income trading partners

Year	L^*/L	% Δ $B(z)$	$B(z)$ pivot	T^*/T	% Δ T^*/T	K^*/K	% Δ K^*/K	$A(z)$ shift	ω	% Δ ω	Δ ω	Δ US Comparative Advantage
1968	2.29			0.88		1.45			1.52			.
1978	1.94	-15.28%	–	0.78	-11.36%	1.95	34.48%	unknown	1.34	-11.84%	–	Indeterminable[c]
1988	1.84	-19.65%	–	0.77	-12.50%	1.97	35.86%	unknown	1.29	-15.13%	–	Indeterminable[c]
1998	1.75	-23.58%	–	0.82	-6.82%	1.70	17.24%	unknown	1.29	-15.13%	–	Indeterminable[c]
2008	1.71	-25.33%	–	0.90	2.27%	1.48	2.07%	–[a]	1.28	-15.79%	–	Indeterminable[b]

Middle Income trading partners												
Year	L^*/L	% Δ $B(z)$	$B(z)$ pivot	T^*/T	% Δ T^*/T	K^*/K	% Δ K^*/K	$A(z)$ shift	ω	% Δ ω	Δ ω	Δ US Comparative Advantage
1968	2.38			0.80		0.55			5.06			.
1978	2.43	2.10%	+	0.61	-23.75%	1.06	92.73%	–[a]	4.28	-15.42%	–	Loss
1988	2.65	11.34%	+	0.70	-12.50%	0.85	54.55%	unknown	5.12	1.19%	+	Indeterminable[c]
1998	3.08	29.41%	+	0.69	-13.75%	0.88	60.00%	unknown	5.21	2.96%	+	Indeterminable[c]
2008	3.37	41.60%	+	0.70	-12.50%	0.99	80.00%	–[a]	4.68	-7.51%	–	Loss

Upper Middle Income trading partners												
Year	L^*/L	% Δ $B(z)$	$B(z)$ pivot	T^*/T	% Δ T^*/T	K^*/K	% Δ K^*/K	$A(z)$ shift	ω	% Δ ω	Δ ω	Δ US Comparative Advantage
1968	0.89			0.89		0.26			4.11			.
1978	0.97	8.99%	+	0.69	-22.47%	0.52	100.00%	–[a]	3.27	-20.44%	–	Loss
1988	1.05	17.98%	+	0.75	-15.73%	0.46	76.92%	unknown	3.72	-9.49%	+	Indeterminable[c]
1998	1.27	42.70%	+	0.73	-17.98%	0.46	76.92%	unknown	3.86	-6.08%	+	Indeterminable[c]
2008	1.41	58.43%	+	0.79	-11.24%	0.48	84.62%	–[a]	3.46	-15.82%	–	Loss

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Year	L^*/L	% Δ $B(z)$	$B(z)$ pivot	T^*/T	% Δ T^*/T	K^*/K	% Δ K^*/K	$A(z)$ shift	ω	% Δ ω	Δ ω	Δ US Comparative Advantage
Lower Middle Income trading partners												
1968	1.49			0.74		0.28			6.06			.
1978	1.44	-3.36%	–	0.55	-25.68%	0.54	92.86%	unknown	5.45	-10.07%	–	Indeterminable[c]
1988	1.60	7.38%	+	0.65	-12.16%	0.39	39.29%	unknown	6.88	13.53%	+	Indeterminable[c]
1998	1.81	21.48%	+	0.65	-12.16%	0.42	50.00%	–[a]	6.77	11.72%	–	Loss
2008	1.96	31.54%	+	0.63	-14.86%	0.52	85.71%	–[a]	6.04	-0.33%	–	Loss
Low Income trading partners												
Year	L^*/L	% Δ $B(z)$	$B(z)$ pivot	T^*/T	% Δ T^*/T	K^*/K	% Δ K^*/K	$A(z)$ shift	ω	% Δ ω	Δ ω	Δ US Comparative Advantage
1968	9.51			0.26		0.76			32.46			.
1978	9.41	-1.05%	–	0.22	-15.38%	1.20	57.89%	–[a]	28.97	-10.75%	–	Indeterminable[b]
1988	10.14	6.62%	+	0.25	-3.85%	1.42	86.84%	–	24.08	-25.82%	–	Loss
1998	10.81	13.67%	+	0.28	7.69%	1.74	128.95%	–	18.72	-42.33%	–	Loss
2008	11.45	20.40%	+	0.35	34.62%	2.61	243.42%	–	11.11	-65.77%	–	Loss

(Notes) (i) Given the upward pivot of the $B(z)$ schedule and the decrease in theta, it follows that increases in K^* values relative to K values shift the $A(z)$ schedule inward moreso than the increases in T values relative to T^* values would shift the $A(z)$ schedule outward.

(ii) The outcome, with respect to comparative advantage, is dependent on the relative magnitudes of the shifts in the $A(z)$ and $B(z)$ schedules.

(iii) The change in US comparative advantage is dependent on the shift in the $A(z)$ schedule and, thus, on the relative magnitudes of changes in K*/K and T*/T .

Figure 3 illustrates the corresponding comparative statics within the DFS framework. The loss of comparative advantage is intuitive. The increase in L^*/L would, *ceteris paribus*, lead to an increase in w/w^*; however, the increase in K^*/K that outweighs the decrease in T^*/T would increase the relative productivity of foreign workers vis-*à*-vis US workers, thus the predicted loss of comparative advantage for the US and the gain of comparative advantage for the foreign cohort.

For all income classification cohorts except the high income trading partners where the outcome is ambiguous, it can be seen that the US is predicted to have lost comparative advantage over the reference period. Revisiting Figure 2 and Table 2, it can be found that the changes relating to the low income cohort are the most striking. The increase in the L^*/L series of 20.4%, which would cause the $B(z)$ schedule to pivot upward, coupled with increases in T^*/T (of 34.6%) and in K^*/K (of 243.4%), which would cause the $A(z)$ schedule to shift down, corresponds with the observed decrease in the w/w^* series.

In Table 2, it can be seen that, relative to 1968, changes in series values were so slight until 1988 that it would be difficult to say that the US had lost comparative advantage relative to the low income cohort. For the lower middle income cohort, it was not until 1998 that enough had changed to say that the US had lost comparative advantage. For upper middle income countries (and for middle income countries collectively), the changes observed between 1968 and 1978 suggest a loss of US comparative advantage; however, this effect disappears by 1988 and it is not until 2008 that evidence of a loss of US comparative advantage reemerged. Finally, for the high income cohort, there is no suggested loss of US comparative advantage.

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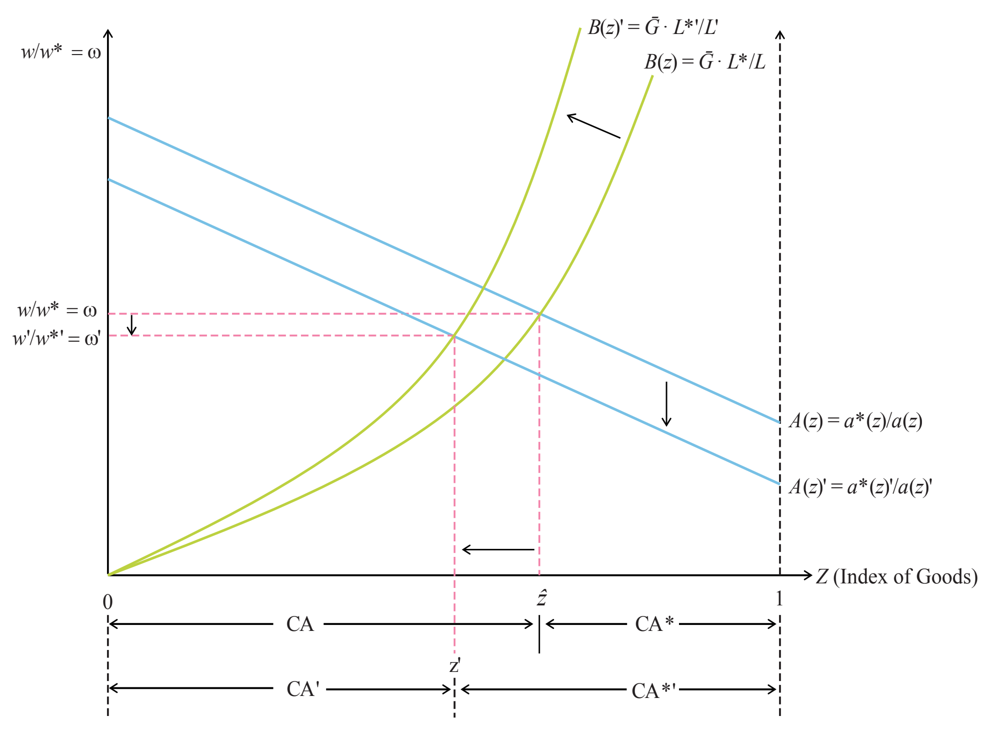
Figure 3. Predicted loss in US comparative advantage

(1968~2008)



From the decade-by-decade review of cohort-specific values three things can be said. First, as predicted by standard trade theory, comparative advantage is a short-run state. Changes in relative factor endowments result in shifts in comparative advantage. Second, the observed shifts in comparative advantage appear to transpire over relatively lengthy time periods. Finally, it can be seen that the pace of observed shifts in comparative advantage appear to have been faster for cohorts that were more dissimilar to the US in terms of their factor endowments at the beginning of the reference period.

In the next section, regression analysis and industry-level data are employed to see if increased trade corresponds with lower average industry wages and/or declines in industry employment. These effects are analyzed for production and non-production workers separately. Further, as variation in observed factor endowment changes have been documented across income classification cohorts, cohort-specific effects of trade on wages and employment are examined.

IV. Estimating the Influences of Trade on Industry-level Wages and Employment

A. Estimation model

The effects of the loss of comparative advantage that has been illustrated for the US over this paper's reference period is demonstrated next. This loss of comparative advantage, especially relative to some cohorts, demonstrates a relative reduction in exports and/or increase in imports. The potential labor market consequences of these changes in comparative advantage are addressed empirically. In a similar manner, other recent approaches to empirically measure the role of imports on changes in domestic labor include Autor *et al*. (2013), Pierce and Schott (2012), Uysal and Yotov (2011), and Menezes-Filho and Muendler (2011). Of these studies, only the latter includes the increased imports resulting in changes in comparative advantage as described by the DFS model in the previous sections.

To derive estimation equations that represent changes in industry employment and annual wages, the works of Mann (1988), Freeman and Katz (1991), and Kletzer (2002) are followed. Labor demand in a representative industry is depicted by Equation (1), where L_{jt} is industry employment and η is the elasticity of labor demand with respect to the industry wage rate, W_{jt}. Z_{jt} is a vector comprised of several factors that may exogenously shift product demand and, thus, shift the labor demand curve. V_{jt} is a vector that contains several industry-specific variables that may influence employment. d is the difference operator, ln denotes the natural logarithm, and j and t are industry and time subscripts, respectively. Equation (2) is an analogous expression representing labor supply. λ is the elasticity of labor supply with respect to the wage rate, and R_{jt} is a vector of factors that underlie potential labor supply shifts.

$$dlnL_{jt} = -\eta dlnW_{jt} + dlnZ_{jt} + dlnV_{jt} \tag{1}$$

$$dlnL_{jt} = \lambda dlnW_{jt} + dlnR_{jt} \tag{2}$$

Factor markets are assumed to be competitive, and labor market clearing dictates that Equation (1) is equal to Equation (2) in equilibrium. Setting the two expressions equal and solving for the change in the industry wage rate, $dlnW_{jt}$, yields Equation (3).

Substituting Equation (3) into Equation (2) and rearranging produces Equation (4)—an expression representing the change in industry employment.

$$dlnW_{jt} = [1/(\lambda+\eta)][dlnZ_{jt} + dlnV_{jt} - dlnR_{jt}] \tag{3}$$

$$dlnL_{jt} = [1/(\lambda+\eta)][dlnZ_{jt} + dlnV_{jt}] - (\lambda/(\lambda+\eta)-1)dlnR_{jt} \tag{4}$$

While it may appear that estimation of Equations (3) and (4) would facilitate the examination of the effects that shifts in labor supply and product demand have on industry-level wages and employment, doing so would be a mistake as there is the potential for simultaneity to exist due to wage and employment pressures on product prices and, thus, on the levels of industry shipments. In an attempt to circumvent this possibility, the assumption that product prices depend solely on production costs is made. Thus, the relation between the industry wage rate and industry sales is represented as follows.

$$dlnQ_{jt} = -\psi dlnP_{jt} + dlnZ_{jt} \tag{5}$$

$$dlnP_{jt} = \phi dlnW_{jt} \tag{6}$$

Industry production is described by Equation (5), where Q_{jt} is output, P_{jt} is the price level, ψ is the price elasticity of product demand, and Z_{jt} is a vector of exogenous product demand shifters. Assuming this price level depends solely on production costs (Equation (6)) and that labor is the only factor input, the industry price level is determined solely by wages. Here, ϕ represents labor's share of total costs.

Returning to Equations (3) and (4), each element in the vector of industry-specific variables (R_{jt}) is set while those variables related to labor supply shifts (V_{jt}) equal to zero for the time being. Using θ to represent $1/(\lambda+\eta)$ and Φ in place of $\lambda/(\lambda+\eta)$, Equations (3) and (4) can be rewritten as Equations (7) and (8), respectively. This allows illustration of both the industry wage rate and the level of industry employment as functions of exogenous shifts in product demand, $dlnZ_{jt}$.

$$dlnW_{jt} = \theta dlnZ_{jt} \tag{7}$$

$$dlnL_{jt} = \Phi\, dlnZ_{jt} \tag{8}$$

Substituting Equation (6) into Equation (5) yields $d\ ln\ Q_{jt} = -\psi\phi dlnW_{jt} + dlnZ_{jt}$, which when substituted into the identity $dlnS_{jt} = dlnP_{jt} + dlnQ_{jt}$ (where S_{jt} is industry sales) produces Equation (9).

$$dlnS_{jt} = dlnP_{jt} - \psi\phi dlnW_{jt} + dlnZ_{jt} \tag{9}$$

Further substituting Equation (7) into Equation (9), $dlnS_{jt} = dlnZ_{jt} + (1-\psi)\ \phi dlnW_{jt}$, which when solved for $d\ ln\ Z_{jt}$, yields Equation (10).

$$dlnZ_{jt} = dlnS_{jt} - (1-\psi)\ \phi dlnW_{jt} \tag{10}$$

Substituting Equation (5) into Equation (10) results in $d\ ln\ Z_{jt} = [1/(1+(1-\psi)\ \phi\theta)]\ d\ lnS_{jt}$. Inserting this expression into Equation (8) and defining $\Lambda = \Phi/(1+(1-\psi)\ \phi\theta)$, the change in industry employment can be written as follows.

$$dlnL_{jt} = \Lambda\ dlnS_{jt} \tag{11}$$

Illustrating the relationship between the wages and sales, Equation (10) is substituted into Equation (7), $dlnW_{jt}$ is solved, and Γ is defined as $\theta/(1+(1-\psi)\phi\theta)$. The result is Equation (12).

$$dlnW_{jt} = \Gamma\ dlnS_{jt} \tag{12}$$

To facilitate a more thorough examination of the relationships between industry sales and both wages and employment, the sales identity is decomposed into its component parts: domestic sales (D_{jt}), exports (X_{jt}), and imports (M_{jt}). More specifically, the identity of *Sales = industry shipments + exports – imports* as $S_{jt} = D_{jt} + X_{jt} - M_{jt}$ is rewritten. Taking log-differences to approximate for % changes and momentarily dropping industry and time subscripts yields Equation (13).

$$\frac{dS}{S} = \left(\frac{D}{S}\right)\left(\frac{dD}{D}\right) + \left(\frac{X}{S}\right)\left(\frac{dX}{X}\right) - \left(\frac{M}{S}\right)\left(\frac{dM}{M}\right) \tag{13}$$

Setting $dS/S = \hat{S}$, $dD/D = \hat{D}$, $dX/X = \hat{X}$, $dM/M = \hat{M}$, Equation (13) can be written as:

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$$\hat{S}_{jt} = \left[\hat{D}_{jt} + \frac{\hat{\kappa}}{(1-\hat{\kappa}+\hat{\rho})} \right] \left(\frac{X}{S}\right)_{jt} - \left[\frac{(1-\hat{\kappa}+\hat{\rho})}{\hat{\rho}} \right] \left(\frac{M}{S}\right)_{jt} \tag{14}$$

Setting $\hat{\kappa} = X/S = \hat{X} - \hat{S}$ and $\hat{\rho} = M/S = \hat{M} - \hat{S}$ implies that $\hat{X} = \hat{\kappa} + \hat{S}$ and that $\hat{M} = \hat{\rho} + \hat{S}$. Substituting these identities into Equation (14), recognizing that $\hat{\kappa} = X/S$ and that $\hat{\rho} = M/S$, and reintroducing industry and time subscripts allow Equation (14) to be expressed as follows.

$$\hat{S}_{jt} = \hat{D}_{jt} + \left[\frac{\hat{\kappa}}{(1-\hat{\kappa}+\hat{\rho})} \right] \left(\frac{X}{S}\right)_{jt} - \left[\frac{\hat{\rho}}{(1-\hat{\kappa}+\hat{\rho})} \right] \left(\frac{M}{S}\right)_{jt} \tag{15}$$

Substituting Equation (15) into Equations (11) and (12), respectively, yields

$$dlnL_{jt} = \Lambda\pi_1 dlnD_{jt} + \Lambda\pi_2 dln\frac{X}{S}_{jt} - \Lambda\pi_3 dln\frac{M}{S}_{jt} \tag{16}$$

$$dlnW_{jt} = \Gamma\pi_1 dlnD_{jt} + \Gamma\pi_2 dln\left(\frac{X}{S}\right)_{jt} - \Gamma\pi_3 dln\left(\frac{M}{S}\right)_{jt} \tag{17}$$

where $\pi_1 = 1$, $\pi_2 = \left[\hat{\kappa}\big/(1-\hat{\kappa}+\hat{\rho})\right]$, and $\pi_3 = \left[\hat{\rho}\big/(1-\hat{\kappa}+\hat{\rho})\right]$.

Re-introducing the vectors $d\ ln\ R_{jt}$ and $d\ ln\ R_{jt}$ yields Equations (18) and (19), the general-form baseline estimation equations.

$$\begin{aligned} dlnL_{jt} = {} & \Lambda\pi_1 dlnD_{jt} + \Lambda\pi_2 dln\left(\frac{X}{S}\right)_{jt} \\ & - \Lambda\pi_3 dln\left(\frac{M}{S}\right)_{jt} + \beta_R dlnR_{jt} + \beta_V dlnV_{jt} \end{aligned} \tag{18}$$

$$\begin{aligned} dlnW_{jt} = {} & \Gamma\pi_1 dlnD_{jt} + \Gamma\pi_2 dln\left(\frac{X}{S}\right)_{jt} \\ & - \Gamma\pi_3 dln\left(\frac{M}{S}\right)_{jt} + \beta_R dlnR_{jt} + \beta_V dlnV_{jt} \end{aligned} \tag{19}$$

Equations (18) and (19) provide insight into the expected relationships between industry-level employment and wages and industry sales components. All else equal, employment (L) and wages (W) are expected to be positively related to increases in domestic demand (D) for domestic output. Similarly, positive relationships are expected between exports as a share of domestic shipments (X/S) and both employment and wages, but an increase in imports relative to domestic shipments (M/S) is expected to negatively affect wages and employment levels.

Equations (18) and (19) are modified to include a vector of time dummy variables, Ω_t, which control for unobservable variation in industry-level employment and/or wages due to policy changes. Also, a vector of dummy variables, ϑ_j, is included to control for time-invariant industry-specific characteristics. To finalize the regression models, i.i.d. error terms, ε^1_{jt} and ε^2_{jt}, and a common intercept term are added. To avoid possible multicollinearity problems, the change in total industry-level exports (X) is included as a measure of foreign demand for domestic output, while the change in the import penetration rate (M/D), that is, imports as a share of total domestic market sales is included in place of imports as a share of domestic shipments. Equations (20) and (21) represent our estimation equations.

$$dlnL_{jt} = \alpha_0 + \beta_1\, dlnD_{jt} + \beta_2 dlnX_{jt} - \beta_3 dln\left(\frac{M}{D}\right)_{jt} + \beta_R dlnR_{jt} + \beta_V dlnV_{jt} + \beta_\Omega \Omega_t + \beta_\vartheta \vartheta_j + \varepsilon^1_{jt} \tag{20}$$

$$dlnW_{jt} = \alpha_0 + \gamma_1\, dlnD_{jt} + \gamma_2 dlnX_{jt} - \gamma_3 d\,ln\left(\frac{M}{D}\right)_{jt} + \beta_R dlnR_{jt} + \beta_V dlnV_{jt} + \beta_\Omega \Omega_t + \beta_\vartheta \vartheta_j + \varepsilon^2_{jt} \tag{21}$$

where, in Equation (20), $\beta_1 \equiv \Lambda\pi_1$, $\beta_2 \equiv \Lambda\pi_2$ and $\beta_3 \equiv \Lambda\pi_3$. Correspondingly, in Equation (21), $\gamma_1 \equiv \Gamma\pi_1$, $\gamma_2 \equiv \Gamma\pi_2$ and $\gamma_3 \equiv \Gamma\pi_3$. Somewhat similarly, in both equations, β_R, β_V and β_Ω represent vectors of coefficients that correspond to the vectors of factors that underlie potential labor supply shifts (R), which identify industry-specific variables that may bear on employment levels (V) and that represent time-specific (that is, year) dummy variables (Ω), respectively.

To control for additional influences on employment, the vectors V_{jt} and R_{jt} are reintroduced, which include industry-level changes in technology and constructed as Solow (1957) residuals, and capital-labor ratios. Industry capital-labor ratios are given as the value of plant and equipment divided by production employment. To control for business cycle fluctuations, the annual change in the manufacturing sector capacity

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utilization rate is included.

$$dlnL_{jt} = \alpha_j + \beta_1 dlnDOM_{jt} + \beta_2 d\ln EXP_{jt} + \beta_3 dlnIMPPEN_{jt} + \beta_4 d\ln CAPUTIL_{jt} + \beta_5 dlnKL\ RATIO_{jt} + \beta_6 d\ln TECH_{jt} + \beta_\Omega \Omega_t + \beta_\vartheta \vartheta_j + \varepsilon_{jt} \tag{22}$$

In Equation (22), the vector L_{jt} includes production and non-production employment. Equation (23) is an analogous estimation equation where the vector W_{jt} includes average industry wages of production and non-production workers. In both equations, DOM_{jt} represents domestic demand and is equal to industry shipments less exports plus imports. Foreign demand is given by EXP_{jt}, while $IMPPEN_{jt}$ represents import competition.

$$dln W_{jt} = \alpha_j + \beta_1 dlnDOM_{jt} + \beta_2 dlnEXP_{jt} + \beta_3 dlnIMPPEN_{jt} + \beta_4 dlnCAPUTIL_{jt} + \beta_5 dlnKL\ RATIO_{jt} + \beta_6 dlnTECH_{jt} + \beta_\Omega \Omega_t + \beta_\vartheta \vartheta_j + \varepsilon_{jt} \tag{23}$$

The primary finding from the calibration exercise presented in Section III is that in recent decades the US has lost comparative advantage relative to lower income countries. This suggests that the effects of exports and imports on industry wages and employment may vary across trading partners grouped by average income levels. More specifically, distilling the effects of, say, import competition by income cohort, we anticipate a stronger proportional influence on domestic employment if the increased competition is from low wage countries and a weaker, but still potentially negative, effect related to high wage countries. Estimating variants of equations (22) and (23) allow us to examine such effects.

B. Empirical results

To examine the relationships among trade, employment, and average wages at the industry-level, trade data for the years 1972~2005 (Schott 2008) have been appended to data from the NBER-CES Manufacturing Industry database (Becker *et al*. 2013). The resulting dataset includes US manufacturing industries that are categorized at the 4-digit level according to the 1987 SIC classification system. An important note is that trade in services, along with its effects on wages and employment, is also of interest. The evolution of international trade for the US has been a trend towards increased exports of services and increased imports of manufactured goods. However, both industry-level data and trade data for services are not available for periods of time long enough to warrant direct consideration. This will remain an area for future research as data availability improves within the service sector.

In addition to examining general trade-related effects on labor in the US manufacturing sector, potential variation in the effects of import penetration across country cohorts defined by World Bank income classifications is examined. Finally, to further scrutinize trade-related industry characteristics, modified estimations of Equations (22) and (23) are performed using industry cohorts defined by trade orientation. Trade orientation is determined using a modified Grubel and Lloyd Index (1975).[2] Dropping the absolute value of net exports, a modified Grubel-Lloyd Index (mGLI) for industry j that ranges from zero to two is generated, where X_j is industry j exports and M_j is industry j imports in year t: $mGLI_j = 1 - \frac{(X_{jt} - M_{jt})}{(X_{jt} + M_{jt})}$. Industries are then classified into unbalanced exporters ($mGLI < 0.5$), balanced exporters ($0.5 < mGLI < 1.0$), balanced importers ($1.0 < mGLI < 1.5$), and unbalanced importers ($mGLI > 1.5$).

While the models to be estimated are dynamic, Table 3 includes descriptive statistics for the variables over the full reference period (Column A) and for the various cohorts determined by *mGLI* (Columns B to E).

[2] The Grubel-Lloyd index is $B_i = 1 - \frac{|X_i - M_i|}{(X_i + M_i)}$.

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Table 3. Descriptive statistics

	All	Unbalanced Importers	Balanced Importers	Balanced Exporters	Unbalanced Exporters
	(a)	(b)	(d)	(d)	(e)
	N = 13,876	N = 3,745	N = 3,915	N = 3,744	N = 2,472
Δ *ln*(*Production Worker Employment*$_{jt}$)	-0.0174	-0.0338***	-0.0177	-0.0112***	-0.0029***
	(0.1082)	(0.1185)	(0.0966)	(0.0946)	(0.1013)
Δ *ln*(*Non-Production Worker Employment*$_{jt}$)	-0.0080	-0.0208***	-0.0111	-0.0026**	0.0011***
	(0.1335)	(0.1686)	(0.1197)	(0.1085)	(0.1206)
Δ *ln*(*Average Production Worker Wages*$_{jt}$)	0.0002	0.0026**	0.0018*	-0.0001	-0.0010
	(0.0531)	(0.0633)	(0.0487)	(0.0459)	(0.0483)
Δ *ln*(*Average Non-Pro duction Worker Wages*$_{jt}$)	0.0006	0.0015	0.0033	0.0020	-0.0006
	(0.1547)	(0.2795)	(0.0824)	(0.0738)	(0.0834)
Δ *ln*(*Import Penetration Rate*$_{jt}$)	0.6367	0.0786***	0.0563***	0.0592***	1.0172***
	(3.3954)	(0.8613)	(0.1872)	(0.1670)	(4.2137)
Δ *ln*(*High Income Import Penetration Rate*$_{jt}$)	0.6125	0.0433***	0.0385***	0.0500***	1.0037***
	(3.3522)	(0.8644)	(0.2099)	(0.1842)	(4.1696)
Δ *ln*(*Upper Middle Income Import Penetration Rate*$_{jt}$)	0.5256	0.0699***	0.0913***	0.1053***	0.7515***
	(3.1011)	(1.4937)	(1.0153)	(1.3258)	(3.7766)
Δ *ln*(*Lower Middle Income Import Penetration Rate*$_{jt}$)	0.5608	0.0943***	0.1062***	0.1191***	0.8331***
	(3.0531)	(1.2850)	(0.6024)	(0.9383)	(3.7898)
Δ *ln* (*Low Income Import Penetration Rate*$_{jt}$)	0.5518	0.1953***	0.2265***	0.2673***	0.6049
	(3.1650)	(1.8940)	(1.6912)	(2.1738)	(3.8956)
Δ *ln*(*Exports*$_{jt}$)	0.0389	0.0126*	0.0372	0.0307	0.0694***
	(0.7015)	(0.8629)	(0.2132)	(0.1623)	(0.3226)
Δ *ln*(*Domestic Demand*$_{jt}$)	0.0089	0.0050	0.0067	0.0049*	0.0098
	(0.1388)	(0.1286)	(0.1107)	(0.1179)	(0.1675)
Δ *ln*(*Capital-Labor Ratio*$_{jt}$)	-0.0116	-0.0008***	-0.0054***	-0.0106	-0.0278***
	(0.1146)	(0.1349)	(0.1020)	(0.0999)	(0.1091)
Δ *ln*(*Technology*$_{jt}$)	0.0031	0.0029	0.0040	0.0020	0.0064**
	(0.0693)	(0.0755)	(0.0624)	(0.0622)	(0.0770)

(Notes) (i) Standard deviations in parentheses. All monetary values have been converted to year 2005 US dollars.
(ii) ***, **, and * denote statistical significance from the corresponding "All" (i.e. full sample) mean value at the 1%, 5%, and 10% levels, respectively."

From the values presented in Table 3, the following can be gleaned. In the typical manufacturing industry, negative growth in employment was greater in magnitude for production workers than non-production workers.[3] The typical manufacturing industry experienced an annual increase of about 0.64% in its import penetration rate. Dividing import sources based on income classifications shows that average growth in the import penetration rate was highest for high-income trading partners (0.6125), followed by lower middle income partners (0.5608), low income trading partners (0.5518), and upper middle income trading partners (0.5256).

Comparing the industry average values for the trade-related industry cohorts reveals significant deviation from overall averages. For example, the rate of change in production worker employment is significantly different than the overall average for unbalanced importers, balanced exporters, and unbalanced exporters. Similar differences exist for non-production workers. With respect to wages, only the change in average annual wages for production workers within the unbalanced importer and balanced importer cohorts are significantly higher than the overall average.

There is significant variation across cohorts in the average change in the log of the import penetration rate. Compared to the average for the entire sample, the average change for the same statistic is much lower for unbalanced importers, balanced importers, and balanced exporters. However, the average change for unbalanced exporters is significantly higher. The same relationship across cohorts exists when trading partners are split into income classifications.

Estimation of Equations (22) and (23) allows this paper to determine the respective effects of exports and import penetration on industry-level employment and average wages. Each regression model is first estimated for both production workers and non-production workers, without differentiating across the cohorts of trading partners or industry cohorts. Table 4 presents the results. To consider potential variation in the influences of import penetration across cohorts that, as described in Section III, have been determined based on per capita income, modified versions of Equations (22) and (23) are estimated. Results are presented in Table 5. Finally, the same equations are estimated for industry cohorts defined by trade orientation (i.e., based on *mGLI* values) with results presented in Table 6.[4]

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[3] Non-production workers includes supervisors above the line-supervisor level, clerical and office workers, individuals involved in sales, and those whose work is categorized as professional or technical in nature (Bartelsman and Gray 1996). All other employees are categorized as production workers.

[4] When examining variation based on industry trade-orientation, production workers are centered on since the trade-related effects for these workers are more pronounced (see Tables 4 and 5). Estimation results for non-production workers are available upon request

For all estimations, the two-step Generalized Method of Moments (GMM) estimation technique for Dynamic Panel Data (DPD) has been employed. The GMM DPD estimator, which addresses issues of serial correlation, heteroskedasticity, and endogeneity among explanatory variables through the use of instruments, follows the estimators developed by Arellano and Bond (1991), Arellano and Bover (1995), and Blundell and Bond (1998 and 2000). All standard errors presented in the tables are Windmeijer bias-corrected standard errors (Windmeijer 2005). In addition to the estimated coefficients, Tables 4 and 5 also include results from the Sargan test for overidentifying restrictions, with the results demonstrating no evidence of invalidity with the instruments used. The Arellano-Bond test is not rejected at the second order, suggesting no evidence of serial correlation between the instruments and residuals.

For production workers, annual increases in import penetration correspond, all else equal, with contemporaneous reductions in production worker employment (Column A of Table 4) and average industry wages of production workers (Column C). Given the functional forms of the estimation equations, it can be said that a 1% increase in the rate of import penetration for a typical industry results in 0.26% and 0.17% decreases in employment and the level of average wages, respectively, of production workers. The results in Table 4 show that a 1% increase in exports corresponds to a 0.10% increase in production worker employment. All other export effects on the other dependent variables do not significantly differ from zero.

from the authors.

Table 4. Trade-induced labor market dynamics, common exports and import penetration effects

Dependent Variable	Δ *ln*(Prod. Employment$_{jt}$)	Δ *ln*(Non-Prod. Employment$_{jt}$)	Δ *ln*(Avg. Prod. Wages$_{jt}$)	Δ *ln*(Avg. Non-Prod. Wages$_{jt}$)
	(a)	(b)	(c)	(d)
Δ *ln*(*Import Penetration Rate*$_{jt}$)	-0.0026*** (0.0002)	-0.0006 (0.0005)	-0.0017*** (0.0002)	-0.0005 (0.0013)
Δ *ln*(*Exports*$_{jt}$)	0.0010* (0.0006)	-0.0001 (0.0027)	0.0004 (0.0015)	0.0009 (0.0032)
Δ *ln*(*Domestic Demand*$_{jt}$)	0.0657*** (0.0122)	0.2008*** (0.0374)	0.0857*** (0.0127)	-0.0973** (0.0388)
Δ *ln*(*Capital-Labor Ratio*$_{jt}$)	-0.8738*** (0.0166)	-0.3663*** (0.0397)	0.1793*** (0.0247)	-0.1654* (0.0917)
Δ *ln*(*Technology*$_{jt}$)	-0.0655*** (0.0151)	-0.1031** (0.0463)	0.0891*** (0.0178)	0.3125*** (0.0776)
Lagged Δ *ln* (*Dependent Variable*$_{jt}$)	0.0299*** (0.0041)	-0.0550*** (0.0198)	-0.0537 (0.0848)	-0.0174 (0.2181)
Constant	-0.0147 (0.0103)	-0.0078 (0.1644)	0.0030 (0.0057)	-0.0137 (0.0785)
Wald Chi^2 *test statistic*	56,212***	1,004***	2,987***	1,619***
Arellano-Bond test statistic for AR(2)	-0.36	-0.13	-0.15	-0.91
Sargan test statistic	425.30	424.25	426.78	424.79

(Notes) (i) Number of observations in each estimation is 13,876, and the number of groups in each estimation is 448.
(ii) Year dummy variables are included in each estimation; however, due to space constraints, the coefficients are not reported here.
(iii) Robust standard errors in parentheses. ***, **, and * denote significance from zero at the 1%, 5%, and 10% levels, respectively.

Variation is observed when the effects of import penetration are examined across cohorts of trading partners. In Table 5, it can be seen that a 1% increase in import penetration rate for high income trading partners results in 0.21% and 0.18% decreases in employment and average wages of production workers, respectively. In addition, import penetration from goods imported from the low-middle income countries has a negative effect on production worker employment.

Table 5. Estimated trade-induced labor market dynamics, exports and cohort-specific import penetration effects

Dependent Variable	Δ *ln*(Prod. Employment$_{jt}$)	Δ *ln*(Non-Prod. Employment$_{jt}$)	Δ *ln*(Avg. Prod. Wages$_{jt}$)	Δ *ln*(Avg. Non-Prod. Wages$_{jt}$)
	(a)	(b)	(c)	(d)
Δ *ln*(*High Income Import Penetration Rate*$_{jt}$)	-0.0021*** (0.0004)	-0.0006 (0.0010)	-0.0018*** (0.0007)	-0.0007 (0.0018)
Δ *ln*(*Upper Middle Income Import Penetration Rate*$_{jt}$)	0.00003 (0.0003)	0.0006 (0.0008)	0.0003 (0.0005)	-0.0009 (0.0016)
Δ *ln*(*Lower Middle Income Import Penetration Rate*$_{jt}$)	-0.0007* (0.0004)	-0.0005 (0.0010)	0.0001 (0.0005)	0.0005 (0.0018)
Δ *ln*(*Low Income Import Penetration Rate*$_{jt}$)	0.00002 (0.0001)	-0.0003 (0.0006)	-0.0003 (0.0003)	0.0006 (0.0012)
Δ *ln*(*Exports*)	0.0010* (0.0005)	0.00004 (0.0027)	-0.0004 (0.0017)	0.0011 (0.0047)
Δ *ln*(*Domestic Demand*$_{jt}$)	0.0659*** (0.0125)	0.2001*** (0.0356)	0.0819*** (0.0126)	-0.0975** (0.0871)
Δ *ln*(*Capital-Labor Ratio*$_{jt}$)	-0.8731*** (0.0159)	-0.3644*** (0.0294)	0.1778*** (0.0242)	-0.1648 (0.1289)
Δ *ln*(*Technology*$_{jt}$)	-0.0657*** (0.0163)	-0.1020** (0.0425)	0.0901*** (0.0184)	0.3111*** (0.1480)
Lagged Δ *ln* (*Dependent Variable*$_{jt}$)	0.0301*** (0.0045)	-0.0568** (0.0230)	-0.0550 (0.0828)	-0.0176 (0.1672)
Constant	-0.0145 (0.0102)	-0.0065 (0.1517)	0.0032 (0.0183)	-0.0137 (0.0804)
Wald Chi^2 *test statistic*	53,404***	1,316***	2,779***	1,496***
Arellano-Bond test statistic for AR(2)	-0.38	-0.17	-0.17	-0.93
Sargan test statistic	431.68	420.49	422.13	415.53

(Notes) (i) Number of observations in each estimation is 13,876, and the number of groups in each estimation is 448.
(ii) Year dummy variables are included in each estimation; however, due to space constraints, the coefficients are not reported here.
(iii) Robust standard errors in parentheses. ***, **, and * denote statistical significance from zero at the 1%, 5%, and 10% levels, respectively.

Considering the remaining variables in Tables 4 and 5, it can be seen that increased domestic demand corresponds with higher employment and higher average wages for both production and non-production workers. Increases in industry-level capital-labor ratios correspond with lower employment of both production and non-production workers and higher average wages for production workers. Technological advances correspond with lower employment and higher average wages for both production and non-production workers.

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Table 6. Estimated trade-induced labor market dynamics by industry trade-orientation

	Δ *ln*(*Production Worker Employment*$_{jt}$)				Δ *ln*(*Average Production Worker Wages*$_{jt}$)			
Modified Grubel-Lloyd Index Group	Unbalanced Importers	Balanced Importers	Balanced Exporters	Unbalanced Exporters	Unbalanced Importers	Balanced Importers	Balanced Exporters	Unbalanced Exporters
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Δ *ln*(*High Income Import Penetration Rate*$_{jt}$)	-0.0127** (0.0065)	-0.0054$^{(p=0.125)}$ (0.0035)	-0.0050* (0.0026)	0.00003 (0.0008)	-0.0032*** (0.0012)	-0.0157** (0.0063)	-0.0009 (0.0069)	-0.0020*** (0.0006)
Δ *ln*(*Upper Middle Income Import Penetration Rate*$_{jt}$)	0.0006 (0.0005)	0.0004 (0.0005)	0.0001 (0.0002)	-0.0001 (0.0006)	0.0016 (0.0010)	-0.0011 (0.0010)	0.0002 (0.0010)	0.0005 (0.0005)
Δ *ln*(*Lower Middle Income Import Penetration Rate*$_{jt}$)	0.0005 (0.0008)	-0.0025* (0.0013)	0.0002 (0.0006)	-0.0006 (0.0006)	0.00003 (0.0011)	0.0006 (0.0020)	-0.0002 (0.0014)	-0.00003 (0.0007)
Δ *ln*(*Low Income Import Penetration Rate*$_{jt}$)	0.0005 (0.0004)	-0.0003 (0.0003)	0.0001 (0.0002)	-0.0002 (0.0002)	-0.0005 (0.0007)	0.0002 (0.0006)	0.0002 (0.0004)	-0.0005 (0.0004)
Δ *ln*(*Exports*$_{jt}$)	-0.0012 (0.0012)	0.0087** (0.0041)	0.0084** (0.0037)	0.0097** (0.0042)	-0.0007 (0.0016)	0.0107$^{(p=0.131)}$ (0.0071)	0.0179** (0.0077)	0.0068 (0.0052)
Δ *ln*(*Domestic Demand*$_{jt}$)	0.1183*** (0.0319)	0.0951*** (0.0185)	0.0530*** (0.0165)	0.0629*** (0.0170)	0.0946*** (0.0189)	0.1280*** (0.0227)	0.0924*** (0.0239)	0.0386** (0.0195)
Δ *ln*(*Capital-Labor Ratio*$_{jt}$)	-0.8361*** (0.0304)	-0.8822*** (0.0282)	-0.8951*** (0.0183)	-0.8105*** (0.0376)	0.1836*** (0.0239)	0.1601*** (0.0287)	0.1632*** (0.0209)	0.1187*** (0.0300)
Δ *ln*(*Technology*$_{jt}$)	-0.0756* (0.0426)	-0.1606*** (0.0536)	-0.1003*** (0.0240)	-0.0077 (0.0223)	0.1035*** (0.0308)	0.0548* (0.0281)	0.0423 (0.0273)	0.0639*** (0.0219)
Lagged Δ *in*(*Dependent Variable*$_{jt}$)	0.0168 (0.0104)	0.0030 (0.0093)	0.0204** (0.0095)	0.0186* (0.0108)	-0.1640*** (0.0336)	-0.0819*** (0.0310)	-0.1460*** (0.0392)	-0.1610*** (0.0388)
Constant	-0.0332 (0.1359)	-0.0802*** (0.0054)	-0.0322*** (0.0036)	-0.0094 (0.0059)	0.0342** (0.0160)	-0.0231** (0.0098)	-0.0149* (0.0085)	0.0050 (0.0039)
Number of Observations	3,745	3,915	3,744	2,472	3,745	3,915	3,744	2,472
Wald Chi^2 *test statistic*	24,017***	20,941***	21,373***	12,793***	637***	633***	969***	734***
Arellano-Bond test statistic for AR(2)	-0.13	-0.97	-1.29	1.29	-1.62	-1.24	-0.02	-1.43
Sargan test statistic	187.78	245.90	242.84	123.20	175.67	255.99	230.47	130.49

(Notes) (i) Number of observations in each estimation is 13,876, and the number of groups in each estimation is 448.
(ii) Year dummy variables are included in each estimation; however, due to space constraints, the coefficients are not reported here.
(iii) Robust standard errors in parentheses. ***, **, and * denote statistical significance from zero at the 1%, 5%, and 10% levels, respectively.

Examination of industries classified by their respective trade orientation shows some variation in the effects of the explanatory variables on production worker employment and wages. Similar to the results in Table 5, findings reported in Table 6 reveal that while imports from high-income trading partners account for the majority of the significant effects, the magnitudes of these effects vary across industry groups. A 1% increase in the change in import penetration rate for high income countries results in a 1.27% decrease in production worker employment for unbalanced importing industries. Though only marginally significant with a *p*-value of 0.125, a similar increase in import penetration rate results in a 0.54% decrease in employment for balanced importers. The same increase results in a 0.50% decrease in employment for balanced exporters, and an increase in import penetration rate for high income partners has similar negative effects on production worker average wages, though not in the same decreasing pattern across industry cohorts. The results also demonstrate the expected positive effects of exports on production worker employment. While there is no significant relationship between exports and employment for unbalanced importers, there is a significant positive relationship between industry exports and employment for the three other industry cohorts.

V. Conclusions

Using data from the Penn World Table, a stylized version of the Dornbusch-Fischer-Samuelson (DFS) model has been calibrated to motivate this study's analysis of the labor market influences of increased exports and import penetration. The US is evaluated relative to all other countries by aggregating these economies to form a cohort named the rest of the world or, more plainly stated, foreign. The US-foreign comparative advantage relationship is also explored in greater detail by disaggregating foreign into several cohorts based on average income levels: high income, upper middle income, lower middle income, and low income. The calibration exercise produces the prediction that there has been some labor market churning during the reference period that may be related to international trade.

Employing data for 4-digit SIC US manufacturing industries that span the years 1972~2005, regression analysis is employed to examine the influences of changes in the levels of industry-level exports and import penetration rates on average wages and on the employment of production and non-production workers. Results obtained from the estimation of a dynamic regression model indicate that, generally speaking, increased import competition is negatively related to both production worker employment and wages. Allowing for variation in the effects of import penetration across cohorts of trading partners, categorized based on average income levels, reveals some variation. In addition, estimating the effects of import penetration for industry groupings based on trade orientation reveal additional variation.

These results confirm the expectations gleaned from the calibration of the DFS model for US trade. The empirical model predicts that increased imports will result in lower employment and average wages at the industry level and that increased exports will correspond with higher levels of industry employment and average wages. Similarly, the DFS model predicts trade-induced labor market churning for the US. The results of the estimations presented in Table 4 provide evidence of these anticipated effects, with the variation across worker type. Industries that are more exposed to imports or exports (Table 6) also have trade-related effects consistent with the DFS model predictions for the US. While the lack of variation across trading partner cohorts (Table 5) somewhat deviates from the expected results, the overall results of the various estimations validate the empirical model's predictions and correspond to the predictions garnered from the calibration of the DFS model to US trade.

This paper's findings have important implications for future US international trade policy. First, trade-related effects on wages and employment need to be considered throughout the negotiations of two major trade agreements, the Transatlantic Trade and Investment Partnership (TTIP), and the Trans-Pacific Partnership (TPP). Both agreements are expected to increase overall trade, but as the results demonstrate, increases in imports and exports will affect employment and wages differently, both in direction and magnitude. In addition, the countries involved in the TTIP and TPP are considerably different based on income classifications, and this paper's results suggest that the effects of increased import penetration from high-income countries will have the most significant negative effects on production workers. These effects will also be higher for industries that are importing relatively more than they are exporting. Our results also show that the expected potential increases in exports as a result of these agreements will have very muted effects on the US labor market. Similarly, the recent export initiatives are likely to have very little success booting US manufacturing employment and average wages.

In addition to the effects of increased trade, the effects of import penetration play an important role in Trade Adjustment Assistance (TAA). policy, which seeks to offset the negative effects of job losses and wage reductions caused by international trade. This paper's results demonstrate that, for production workers, the effects on wages and employment are both significant. In addition, those effects are expected to be stronger for imports originating from high income countries compared to lower income countries and in industries that import relatively more than they export.

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Appendix

Country listing by Income Classification

High Income (24): Australia, Austria, Belgium, Canada, Cyprus, Denmark, Finland, France, Hong Kong, Iceland, Ireland, Israel, Italy, Japan, Netherlands, New Zealand, Norway, Singapore, Spain, Sweden, Switzerland, Taiwan, United Kingdom, United States.

Upper Middle Income (11): Barbados, Brazil, Gabon, Greece, Korea (Rep. of), Mexico, Portugal, South Africa, Trinidad & Tobago, Uruguay, Venezuela.

Lower Middle Income (29): Algeria, Argentina, Bolivia, Cameroon, Chile, Colombia, Costa Rica, Cote d`Ivoire, Dominican Republic, Ecuador, El Salvador, Fiji, Guatemala, Iran, Jamaica, Jordan, Malaysia, Morocco, Nicaragua, Panama, Paraguay, Peru, Philippines, Romania, Senegal, Syria, Thailand, Turkey, Zimbabwe.

Low Income (34): Bangladesh, Benin, Burkina Faso, Burundi, Central African Republic, Chad, China, Congo (Dem. Rep.), Egypt, Equatorial Guinea, Ethiopia, Gambia, Ghana, Guinea, Haiti, Honduras, India, Indonesia, Kenya, Madagascar, Malawi, Mali, Mauritania, Mozambique, Nepal, Niger, Nigeria, Pakistan, Rwanda, Sri Lanka, Tanzania, Togo, Uganda, Zambia.

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