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# Survival of the best fit: Exposure to low-wage countries and the (uneven) growth of U.S. manufacturing plants

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**Abstract**

This paper examines the role of international trade in the reallocation of U.S. manufacturing within and across industries from 1977 to 1997. Motivated by the factor proportions framework, we introduce a new measure of industry exposure to international trade that focuses on where imports originate rather than on their overall level. We find that plant survival and growth are negatively associated with industry exposure to low-wage country imports. Within industries, we show that manufacturing activity is disproportionately reallocated towards capital-intensive plants. Finally, we provide the first evidence that firms adjust their product mix in response to trade pressures. Plants are more likely to switch industries when exposure to low-wage countries is high.


*Keywords:* Low-wage country import competition; Manufacturing plant; Comparative advantage

*JEL classification:* F11; F14; L25; L60

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## 1. Introduction

The relative importance of U.S. manufacturing declined between 1960 and 2000. Employment fell from 26 percent to 14 percent of the U.S. workforce, while output as a share of GDP shrank from 27 percent to 16 percent. This overall decline, however, masks substantial reallocation of activity across industries within manufacturing, and across plants within industries. This paper finds that these reallocations follow the predictions of endowment-based trade theory. It also provides the first evidence that U.S. firms respond to the pressures of international trade by altering their product mix.

We focus on U.S. trade with low-wage countries. As U.S. trade barriers have fallen in recent years, low-wage countries like China and India have begun exporting to the United States many of the more labor-intensive products formerly produced domestically. This product cycling–where the United States moves out of labor-intensive products like t-shirts and sneakers as lower-cost developing countries move in–is a key feature of endowment-driven trade theory. Given their high relative wages, it is virtually impossible for U.S. firms to earn profits producing labor-intensive goods. As a result, industries like Apparel and Footwear are all but disappearing, while more skill- and capital-intensive sectors such as Instruments and Publishing thrive.

A primary contribution of this paper is the identification of multiple margins of adjustment to low-wage country imports. Our use of plant-level data allows examination of a richer set of U.S. responses to international trade, including exit and product upgrading, than is possible with industry-level data. It also permits analysis of whether reallocation *within* industries is consistent with U.S. comparative advantage. To the extent that plant input intensity indicates the (unobserved) type of products a plant produces within its industry, labor-intensive plants are relatively more susceptible to low-wage country imports than are capital- and skill-intensive plants in the same industry. As a result, within-industries, activity should shift towards relatively capital- and skill-intensive plants.

A second contribution of the paper is the introduction of a new method for identifying an industry's exposure to international trade. We concentrate on low-wage country import penetration, i.e., import penetration from countries with less than 5 percent of U.S. per capita GDP. This attention to where imports originate is motivated by the factor proportions framework and allows for a cleaner test of the influence of comparative advantage than aggregate import penetration, which treats imports from high- and low-wage countries symmetrically. We demonstrate throughout the analysis that our results are robust to the inclusion of import penetration from other countries.

We find evidence of reallocation in three dimensions. At the industry level, exposure to low-wage country imports is negatively associated with plant survival and employment growth. Within industries, the higher the industry's exposure to low-wage country imports, the bigger is the relative performance difference between capital- and labor-intensive plants. Finally, there is a positive association between exposure to low-wage country imports and industry switching. Plants that switch industries shift into industries with less exposure to low-wage country imports and greater capital- and skill-intensity than the industries left behind. Together, these results support the view that U.S. manufacturing is moving away from comparative-disadvantage activities and towards comparative-advantage industries via exit, growth and industry switching.

This paper builds upon previous industry-level studies of the effect of import competition on U.S. manufacturing employment. While the earliest of these efforts find little or no association between the level of imports and industry employment growth (e.g. Krueger, 1980; Grossman, 1987; Mann, 1988), more recent efforts based on larger sets of industries have established a negative correlation between employment growth and either imports (e.g. Freeman and Katz, 1991; Sachs and Shatz, 1994) or changes in import prices (e.g. Revenga, 1992). Our findings indicate that these negative relationships are driven to a large degree by a combination of plant closure, plant decline and plant product-mix changes in response to low-wage country imports.

The remainder of the paper is organized as follows. Section 2 summarizes the theoretical framework guiding the analysis and outlines testable hypotheses. Sections 3 and 4 describe the data and the construction of low-wage country import penetration. Sections 5 and 6 present the econometric results and robustness checks. Section 7 concludes.

## 2. The factor proportions framework

A key implication of the Heckscher–Ohlin trade model is that the set of industries produced by a country is a function of its relative endowments: in an open world trading system, relatively capital- and skill-abundant countries like the United States are expected to manufacture a more capital- and skill-intensive mix of industries than relatively labor-abundant countries like China.

The standard Lerner (1952) diagram for depicting this free-trade equilibrium is displayed in the left panel of Fig. 1. It illustrates the relative level of development of two countries–capital-abundant U.S. and labor-abundant China–in a world of two factors and four industries. Industries are represented by unit value isoquants, with the capital intensity of industries increasing from Apparel to Chemicals. Exogenous world prices identify

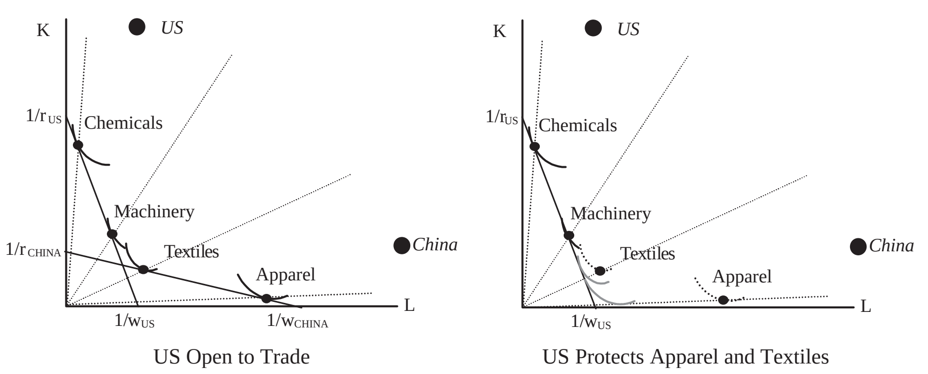


Fig. 1. Industry specialization in the factor proportions framework.

relative wages–which anchor isocost lines–for each cone of diversification.[3] The equilibrium depicted in Fig. 1 exhibits two isocost lines and three cones of diversification. The United States is in the capital-abundant cone, offers high wages ($w_{US}$) relative to the return to capital ($r_{US}$), and produces Machinery and Chemicals. China is in the labor-abundant cone, has a relatively low wage, and manufactures Apparel and Textiles. Relative wages render production of labor-intensive Apparel and Textiles in the United States, and capital-intensive Machinery and Chemicals in China, unprofitable.[4] Although Fig. 1 builds intuition for these relationships using just two factors and four goods, these results are easily generalized to a world of many factors and goods (Leamer, 1987).

The right panel of Fig. 1 illustrates an equilibrium where the United States imposes trade barriers on labor-intensive products. These trade barriers raise the U.S. price of labor-intensive industries (light grey isoquants) above the world price (dark isoquants).[5] Removal of trade barriers, i.e. moving from the right panel of Fig. 1 to the left panel, induces a reallocation of U.S. output and employment away from the labor-intensive imports formerly receiving protection and towards the capital-intensive industries in which the United States has comparative advantage. This reallocation causes the U.S. Apparel and Textile industries to decline as imports from labor-abundant low-wage countries increase.[6] It is precisely this link between changes in the low-wage country imports and plant performance that is the focus of our empirical work.

One difficulty in using the Heckscher–Ohlin model to motivate an inquiry into manufacturing plant behavior is that the model focuses on industries, not firms. An intuitive and reasonable solution to this problem is to assume that plants produce bundles of disaggregate products (Bernard et al., 2005). Under this interpretation, a plant's input intensity provides a signal about its mix of products and thus about its exposure to low-wage country imports. The most labor-intensive plants within an industry produce the most labor-intensive products, and are therefore more susceptible to competition from low-wage countries.

Viewing firms as bundles of products also provides an explanation for why trade liberalization does not result in the immediate death of all plants operating in labor-intensive industries. While protected by trade barriers, U.S. plants are indifferent to producing capital- and labor-intensive goods, with the result that some plants may produce both types while others produce only one type. As low-wage country exports enter the U.S. market, plants solely producing labor-intensive products disappear along with their product lines. However, plants that formerly produced both types of goods do not necessarily die. Instead, they may shrink or reallocate resources toward more viable products.

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[3] "Cone" refers to the set of endowment vectors that select each pair of industries.

[4] The negative profits that would be earned in those sectors can be seen by comparing the amount of capital and labor that can be bought for one dollar in each country to the amount of capital and labor needed to produce one dollar's worth of output. In this framework, factor price variation is driven by factor endowment differences across countries. Non-endowment sources of factor price variation would induce similar patterns of adjustment.

[5] Increasing an industry's price moves its isoquant toward the origin: less capital and labor are required to produce one dollar's worth of output.

[6] Once trade barriers are eliminated the U.S. will no longer have any products in common with low-wage countries. Here we analyze the reallocation that takes place during the important transition from protection to free trade.

We consider three testable hypotheses from the factor proportions framework:

**Hypothesis 1.** Plant employment growth and the probability of plant survival decrease with industry exposure to imports from low-wage countries.

Because we observe low-wage country import penetration by industry, this hypothesis is an industry-level prediction. It follows directly from Fig. 1, which implies a lower likelihood of survival and growth for plants in industries at odds with U.S. comparative advantage, i.e. industries where exposure to imports from low-wage countries is high or increasing.

**Hypothesis 2.** Plant capital and skill intensity increase employment growth and the probability of survival relatively more in industries with higher exposure to low-wage country imports.

The second hypothesis considers the interaction of industry exposure to low-wage country imports with plant characteristics. An underlying assumption is that plants with relatively capital- and skill-intensive production manufacture relatively capital- and skill-intensive goods within their industries. As a result, in industries facing high levels of low-wage country imports, capital- and skill-intensive plants are relatively less affected. In industries with low levels of low-wage competition, i.e. capital-intensive industries, the differences in outcomes across plants are muted.

**Hypothesis 3.** Exposure to low-wage country imports increases the probability that a plant switches to an industry with lower exposure.

Hypothesis three focuses on another potential margin of adjustment by the firm, i.e. a change in product mix. Exposure to low-wage country imports increases the likelihood that a plant changes industries. Such changes should move the plant into more capital- and skill-intensive industries as well as industries that are less exposed to low-wage country imports. We investigate whether these plant responses are systematically related to international trade from low-wage countries.

## 3. U.S. exposure to low-wage country imports

We introduce a new measure of import exposure to examine the link between U.S. manufacturing outcomes and international trade. It differs from traditional measures of import competition by focusing on *where* imports originate as well as their level. This focus is critical because the intra- and inter-industry reallocation implied by the factor proportions framework is a function of trade between countries with very different relative endowments. For the United States, imports from China are expected to have a different impact than imports from Germany. Our measure provides a strong signal about which U.S. industries are most exposed to trade with low-wage countries.[7]

[7] A number of factors, including tariff barriers, non-tariff barriers and transportation costs can induce heterogeneity of exposure, even across industries of similar labor intensity.

Table 1
Low-wage countries from 1972 to 1992

| | | | |
|---|---|---|---|
| Afghanistan | China | India | Pakistan |
| Albania | Comoros | Kenya | Rwanda |
| Angola | Congo | Lao PDR | Samoa |
| Armenia | Equatorial Guinea | Lesotho | Sao Tome |
| Azerbaijan | Eritrea | Madagascar | Sierra Leone |
| Bangladesh | Ethiopia | Malawi | Somalia |
| Benin | Gambia | Maldives | Sri Lanka |
| Bhutan | Georgia | Mali | St. Vincent |
| Burkina Faso | Ghana | Mauritania | Sudan |
| Burundi | Guinea | Moldova | Togo |
| Cambodia | Guinea-Bissau | Mozambique | Uganda |
| Central African Rep | Guyana | Nepal | Vietnam |
| Chad | Haiti | Niger | Yemen |

Let $\mathrm{LWPEN}_{it}$ denote the import penetration of low-wage countries in industry $i$ in year $t$,

$$\mathrm{LWPEN}_{it} = \left( \frac{M_{it}^{\mathrm{L}}}{M_{it} + Q_{it} - X_{it}} \right), \tag{1}$$

where $M_{it}^{\mathrm{L}}$ and $M$ it represent the value of imports from low-wage countries and all countries, respectively, $Q_{it}$ is domestic production, and $X_{it}$ represents U.S. exports. Low-wage country import penetration is the product of the share of imports from low-wage countries, $M_{it}^{\mathrm{L}}/M_{it}$ , and aggregate import penetration, $M_{it}/(M_{it}+Q_{it}-X_{it}$ ). Throughout the empirical analysis we also control for the import penetration of all other U.S. trading partners, which we refer to as OTHPEN it (for 'other penetration'):

$$\mathrm{OTHPEN}_{it} = \left( \frac{M_{it} - M_{it}^{\mathrm{L}}}{M_{it} + Q_{it} - X_{it}} \right). \tag{2}$$

We classify a country as low-wage in year $t$ if its per capita GDP is less than 5 percent of U.S. per capita GDP.[8] Our cutoff captures an average of 50 countries per year. Table 1 provides a list of the countries which are classified low wage in all years of the sample. It includes China and India as well as relatively small exporters such as Haiti. Using data and concordances compiled by Feenstra (1996) and Feenstra et al. (2002), we are able to compute LWPEN for 385 of 459 four-digit 1987 Standard Industrial Classification (SIC) manufacturing industries between 1972 and 1992. These 385 industries encompass 88 percent of manufacturing employment and 91 percent of manufacturing value.

We choose a 5 percent cutoff to classify countries as low wage for several reasons. Most important, it represents the world's most labor-abundant cohort of countries and therefore the set of countries most likely to have an effect on U.S. manufacturing plants

[8] We compare countries to the U.S. in terms of dollar-denominated, non-PPP adjusted per capita GDP. For countries with such low levels of income, the use PPP-adjusted per capita GDP sharply limits the number of available countries and years due to a lack of data. Similarly, manufacturing wages are available for few countries and years.

Table 2
The components of low-wage import penetration

| Industry | Share of imports from low-wage countries (%) | | | | Overall import penetration (%) | | | | Employment change (%) |
|---|---|---|---|---|---|---|---|---|---|
| | 1977 | 1982 | 1987 | 1992 | 1977 | 1982 | 1987 | 1992 | 1972–1997 |
| 20 Food | 9 | 4 | 6 | 9 | 12 | 12 | 12 | 13 | −3 |
| 21 Tobacco | 6 | 1 | 15 | 15 | 6 | 9 | 11 | 3 | −45 |
| 22 Textile | 11 | 13 | 18 | 19 | 7 | 7 | 9 | 11 | −38 |
| 23 Apparel | 8 | 11 | 20 | 32 | 13 | 16 | 23 | 32 | −40 |
| 24 Lumber | 4 | 3 | 8 | 9 | 18 | 17 | 17 | 15 | 8 |
| 25 Furniture | 1 | 2 | 3 | 5 | 3 | 4 | 8 | 11 | 6 |
| 26 Paper | 0 | 0 | 0 | 0 | 29 | 25 | 20 | 24 | 1 |
| 27 Printing | 0 | 0 | 1 | 3 | 3 | 3 | 3 | 4 | 42 |
| 28 Chemicals | 1 | 2 | 2 | 2 | 17 | 16 | 20 | 17 | 3 |
| 29 Petroleum | 1 | 4 | 5 | 7 | 10 | 8 | 10 | 9 | −28 |
| 30 Rubber and Plastic | 0 | 1 | 1 | 13 | 10 | 16 | 14 | 33 | 49 |
| 31 Leather | 4 | 4 | 6 | 20 | 21 | 28 | 42 | 54 | −69 |
| 32 Stone and Ceramic | 1 | 1 | 2 | 4 | 12 | 14 | 17 | 20 | −14 |
| 33 Primary Metal | 1 | 2 | 3 | 4 | 11 | 14 | 18 | 18 | −39 |
| 34 Fabricated Metal | 1 | 1 | 1 | 4 | 8 | 9 | 11 | 13 | −4 |
| 35 Industrial Machinery | 0 | 0 | 0 | 1 | 11 | 13 | 18 | 31 | 14 |
| 36 Electronic | 1 | 2 | 3 | 5 | 22 | 26 | 31 | 38 | 10 |
| 37 Transportation | 0 | 0 | 0 | 0 | 17 | 20 | 25 | 27 | 4 |
| 38 Instruments | 0 | 0 | 1 | 3 | 12 | 15 | 18 | 22 | 10 |
| 39 Miscellaneous | 6 | 6 | 9 | 19 | 23 | 32 | 45 | 58 | −9 |
| Average | 2 | 2 | 3 | 6 | 15 | 17 | 22 | 28 | −2 |
| Standard deviation | 5 | 4 | 6 | 10 | 11 | 12 | 14 | 18 | – |

Notes: Columns two through five report the share of imports originating in countries with less than 5% of U.S. per capita GDP by two-digit SIC industry. Columns six through nine report import penetration. Figures for each year are averages across the preceding five years (e.g. the 1977 values are the average over 1972 to 1976). Column ten reports the change in employment over the entire sample using Bureau of Labor Statistics data (www.bls.gov). The final two rows of the table report the share of imports from low-wage countries and import penetration for manufacturing as a whole. Standard deviations are across four digit industries.

according to the factor proportions framework. Second, although this cohort of countries is responsible for a relatively small level of exports, it accounts for a relatively significant share of U.S. import growth over time.[9] Among countries with less than 30 percent of U.S. GDP per capita, the cohort of countries below the 5 percent cutoff experienced the largest increase in import share, by far, between 1972 and 1992. Finally, the set of countries defined by this cutoff is relatively stable, few countries enter or leave the set over the sample period we consider.[10]

Table 2 summarizes the two components of LWPEN–the share of imports from low-wage countries and aggregate import penetration–by two-digit SIC manufacturing industry

[9] Even a low level of imports from low-wage countries can play a significant role in U.S. manufacturing outcomes. The key consideration is whether or not imports from low-wage countries overlap with goods produced in the U.S. (Leamer, 1999). The impact of such overlap is the focus of this paper.

[10] In sensitivity analyses not reported here, we obtain similar results when using cutoffs of 10 and 15 percent of U.S. per capita GDP.

and year. Data are reported at 5-year intervals, and the final row of the table summarizes trends for aggregate manufacturing.[11] Both components of LWPEN rise over the sample period. For manufacturing as a whole, the share of imports from low-wage countries increases from 2 percent to 6 percent, while aggregate import penetration rises from 15 percent to 28 percent. For both measures, increases are greater in the second half of the sample period.

The rows of Table 2 reveal that low-wage country import shares and overall penetration vary substantially across both industries and time. Both components tend to be higher and to increase more rapidly among labor-intensive industries such as Apparel and Leather. Other industries such as Textiles see only modest rises in both series. Finally, more capital- and skill-intensive sectors such as Transportation and Industrial Machinery experience rapid growth of import penetration but little or no increase in the share of imports from low-wage countries.

Increases in low-wage country import shares and overall penetration are negatively correlated with employment growth. The last column of Table 2 reports the change in employment between 1972 and 1997 by industry. Overall, U.S. manufacturing employment declined 4 percent over this period. This aggregate loss, however, obscures the fact that some industries (e.g. Industrial Machinery, Instruments) have grown substantially even as others (e.g. Apparel, Textiles) have declined. Examining the forces behind this reallocation is the focus of the remainder of this paper.

## 4. U.S. manufacturing plant activity

Manufacturing plant data are from the Longitudinal Research Database (LRD), developed from the U.S. Census Bureau's Census of Manufactures starting in 1977 and conducted every fifth year through 1997. The sampling unit for the Census is a manufacturing establishment, or plant, and the sampling frame in each Census year includes detailed information on inputs, output, and products on all establishments. Regression analysis covers plant outcomes for four panels: 1977 to 1982, 1982 to 1987, 1987 to 1992 and 1992 to 1997.[12]

### *4.1. Plant characteristics*

In each Census year we observe plant characteristics that include the total value of shipments, total employment, total capital stock ($K$, the book value of machinery, equipment, and buildings) and the quantity of and the wages paid to non-production ($N$) and production ($P$) workers. Plant output is recorded at the four-digit SIC level of aggregation. Plant death (alternately plant exit or plant shutdown) is defined as the

[11] The years for which data are reported conform to the years for which we can observe plant activity in the U.S. Census of Manufactures. Figures for each year are averages of the preceding 5 years ($t-5$ to $t-1$) to smooth out annual fluctuations.

[12] We do not consider plant outcomes from earlier Censuses of Manufactures because we do not observe LWPEN prior to 1972.

cessation of operations of the plant and represents a 'true' death; plants that merely change owners between Census years remain in the sample.

In constructing the sample, we make several modifications to the basic data. First, while the LRD does contain limited information on very small plants (so-called Administrative records), we do not include these records in this study due to the lack of information on inputs other than total employment. Second, we drop any industry whose products are categorized as 'not elsewhere classified' because these 'industries' are typically catch-all categories for relatively heterogeneous products. In practice, this corresponds to any industry whose four-digit code ends in '9'. This reduces the number of industries in the sample to 337. Finally, we drop any manufacturing establishment that does not report one of the required input or output measures. We are left with roughly 448,000 observations encompassing roughly 245,000 unique plants in the four panels.

We construct two measures of plant input intensity. The first, capital intensity, is measured as the ratio of a plant's capital stock to its production workers. The second, skill intensity, is harder to measure as there is no information in the LRD on the skill attainment of workers. As a result, we measure a plant's skill intensity as the ratio of total payments made to non-production workers to total payments made to production workers. We use the wagebill ratio rather than the raw input ratio ($N/P$) to account for unobserved skill variation across plants and regions (Bernard et al., 2004b).[13]

Our empirical analysis also controls for plant efficiency via an estimate of total factor productivity (TFP). As is well known, estimating an accurate measure of TFP is quite difficult, and we are constrained here in the choice of productivity measures because we have only single observations for many of the establishments in the sample. We measure TFP as the residual of a five-input Cobb–Douglas production function for each industry and year, where the inputs are two types of capital, two types of labor and purchased inputs. By construction, this estimate is mean zero for each industry in each period.[14]

### *4.2. Industry affiliation*

The LRD reports all of a plant's output in one four-digit SIC industry. Plants whose production spans four-digit industries are assigned the industry where they produce the most output.[15] A large fraction of product mix changes by a plant occur within four-digit industries, and therefore will not affect the assigned industry code (see Bernard et al., 2005). On the other hand, some changes occur across four-digit industries and may be

[13] In the two-factor version of the factor proportions framework developed in Fig. 1, industries were identified by their capital intensity. Our empirical work controls for both the capital and skill intensity of an industry to fix its location in a three-dimensional factor space.

[14] We recognize this procedure's inability to control for the co-movements of variable inputs and productivity. We note that our reported results are robust to using plant TFP estimates generated from Bartelsman et al. (2000) industry cost shares. We also note that the relationship we find between plant outcomes and exposure to low-wage countries is robust to omitting TFP from all specifications.

[15] For a multi-product plant that produces in more than one four-digit SIC industry, its primary four-digit industry is given by the industry that represents the greatest share of plant output. Some plants may have less than 50 percent of total output in their primary industry category.

large enough to cause the plant's industry to switch. We analyze these observable switches in product mix to determine if they are related to industry exposure to imports from low-wage countries.[16] Although plants producing roughly equal amounts of two industries may "switch industries" spuriously, this random variation should bias us against finding any systematic changes in the capital- and skill-intensity of a plant's old and new industries.

## 5. Empirical results: plant survival and growth

In this section we examine the effects of low-wage country imports on plant survival and employment growth. These outcomes between Census years $t$ and $t+5$ are related to a set of year $t$ plant characteristics ($\mathbf{V}_{\mathrm{pt}}$), the average import penetration by low-wage countries across years $t-5$ to $t-1$ ($\mathrm{LWPEN}_{i,t-1}$), and interactions of plant input intensities and productivity with $\mathrm{LWPEN}_{i,t-1}$ ($\mathbf{X}_{ipt}$),

$$\mathrm{Outcome}_p^{t:t+5} = f\left(\mathbf{V}_{pt}, \mathrm{LWPEN}_{i,t-1}, \mathbf{X}_{ipt}\right). \tag{3}$$

Recognizing the potential endogeneity of industry-level low-wage country import penetration, we also report specifications that instrument low-wage country import penetration with industry-year ad valorem tariff and freight rates.

We consider two plant outcomes. The first is plant death, which we estimate via a logistic regression,

$$Pr\left(\mathrm{Death}_p^{t:t+t_5}\right) = \Phi\left(\mathbf{V}_{pt}'\alpha + \mathrm{LWPEN}_{i,t-1}'\beta + \mathbf{X}_{ipt}'\gamma + \delta_t + \delta_i\right). \tag{4}$$

Our set of plant characteristics encompasses log total employment ($N+P$), age, log TFP, log capital intensity ($K/P$) and skill intensity, i.e. the $N/P$ wagebill ratio.[17] Our inclusion of controls for total employment and plant age is motivated by the empirical work of Dunne et al. (1988, 1989) and subsequent theoretical models by Hopenhayn (1992), Olley and Pakes (1996) and others.[18] Eq. (4) also includes time fixed effects, $\delta_t$,for each panel. In every case, we include industry fixed effects to control for unobserved factors affecting plant survival.

The factor proportions framework provides predictions on the sign of the coefficients on $\mathrm{LWPEN}_{i,t-1}$ and $\mathbf{X}_{ipt}$. $\beta>0$ indicates that plant failure is positively associated with industry exposure to low-wage country imports (Hypothesis 1), while $\gamma<0$ indicates the probability of plant death is relatively lower for more capital- and skill-intensive plants the higher the level of low-wage country import penetration (Hypothesis 2).

[16] Bernard and Jensen (2004) find that plants that switch industries have a higher probability of becoming exporters. This movement into more viable products is consistent with the view that plants escape low wage country competition by upgrading their product mix.

[17] The LRD does not record the precise start year for any plant. Our measure of plant age is the difference between the current year and the first recorded Census year. Plants that are in their first Census are given an age of zero.

[18] The model of Olley and Pakes (1996) predicts faster growth for more capital-intensive and productive plants. See Bartelsman and Doms (2000) for a survey on the predicted relationship between productivity and plant survival and growth.

Our second set of results examines the influence of low-wage country imports on employment growth at surviving plants,

$$\Delta\ln\ \text{Employment}_p^{t:t+5} = c + \mathbf{V}'_{pt}\alpha + \text{LWPEN}_{i,t-1}\beta + \mathbf{X}'_{ipt}\gamma + \delta_t + \delta_p + \varepsilon_{pt}. \quad (5)$$

This regression employs the same plant characteristics as the death specification.[19] It also includes plant fixed effects. $\beta<0$ indicates reallocation of workers away from industries where the United States is at a comparative disadvantage (Hypothesis 1), while $\gamma>0$ indicates faster reallocation towards more capital- and skill-intensive plants in industries with greater low-wage country import penetration (Hypothesis 2).

### 5.1. Death

Table 3 reports the relationship between the probability of plant death and the average industry exposure to imports from low-wage countries. The first column of Table 3 reports coefficients from a logistic regression of plant death on levels of LWPEN and plant characteristics. We include year and industry fixed effects to control for aggregate variation in plant death rates and unobservable industry characteristics that shift the probability of death, e.g. variation in industry sunk costs of entry.

Consistent with the factor proportions framework, the positive and statistically significant coefficient on LWPEN in column one indicates that the probability of plant death increases with an industry's exposure to imports from low-wage countries. As in Dunne et al. (1988, 1989), the results also confirm that plant death is more likely for smaller, younger and less productive plants. We also find plant death to be inversely related to capital intensity.

In the second column, we add the measure of import penetration from other countries to control for the possibility that we are picking up overall import penetration rather than the desired effects of imports from low-wage countries. Comparison of the first and second columns indicates that low-wage country penetration continues to be positively and significantly related to the probability of plant death.[20] Import penetration from other countries is also significantly positively related to plant death although the magnitude of the effect is smaller. The results in column 2 indicate that a 4.7 percentage point increase in LWPEN (equal to one standard deviation) for the mean plant is associated with a 2.2 percentage point increase in the probability of death. For the average plant, this represents an 8.3 percent increase in the probability of death.

The third column of Table 3 includes interactions of LWPEN with plant capital intensity, skill intensity and productivity. LWPEN by itself remains positive and significant as predicted by theory. The interactions of LWPEN with capital and skill intensity are

[19] Numerous studies on mean reversion in plant employment growth have documented the relationship between initial size and age and subsequent changes in employment (e.g. Hall, 1987 and Blonigen and Tomlin, 2001). See Sutton (1997) for a survey. While we are not interested in testing Gibrat's law per se, we include the log of initial employment as well as plant age in all our specifications.

[20] Breaking the other country import penetration measure into subgroups does not affect the coefficient on LWPEN.

Table 3
Plant death and low-wage country import penetration

| | Logistic | | | IV | | |
|---|---|---|---|---|---|---|
| | $Death_{pt:t+5}$ | $Death_{pt:t+5}$ | $Death_{pt:t+5}$ | $Death_{pt:t+5}$ | $Death_{pt:t+5}$ | $Death_{pt:t+5}$ |
| log($employment_{pt}$) | −0.266*** (0.003) | 0.268*** (0.003) | −0.269*** (0.003) | −0.249*** (0.004) | −0.238*** (0.005) | −0.236*** (0.005) |
| $Age_{pt}$ | −0.027*** (0.0004) | −0.027*** (0.0004) | −0.027*** (0.0004) | −0.026*** (0.0005) | −0.026*** (0.0005) | −0.026*** (0.0005) |
| log($TFP_{pt}$) | −0.393*** (0.012) | −0.392*** (0.012) | −0.399*** (0.013) | −0.394*** (0.014) | −0.395*** (0.014) | −0.380*** (0.018) |
| log($K/P_{pt}$) | −0.076*** (0.004) | −0.077*** (0.004) | −0.065*** (0.004) | −0.065*** (0.005) | −0.062*** (0.006) | 0.016** (0.008) |
| $N/P$ wagebill $ratio_{pt}$ | 0.002* (0.001) | 0.002* (0.001) | 0.003*** (0.001) | 0.001 (0.004) | 0.001 (0.004) | 0.002 (0.002) |
| Other penetration ($OTHPEN_{it}$) | | 0.559*** (0.048) | 0.619*** (0.048) | | −2.521*** (0.803) | −3.163*** (0.783) |
| Low-wage penetration ($LWPEN_{it}$) | 3.493*** (0.234) | 2.394*** (0.252) | 6.638*** (0.462) | 27.137*** (4.450) | 27.729*** (4.636) | 42.217*** (4.941) |
| × log($TFP_{pt}$) | | | 0.664 (0.544) | | | −1.868 (1.269) |
| × log($K/P_{pt}$) | | | −2.007*** (0.184) | | | −12.557*** (0.813) |
| × $N/P$ wagebill $ratio_{pt}$ | | | −0.040* (0.022) | | | −0.188* (0.110) |
| Industry fixed effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Year fixed effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 448,484 | 448,485 | 448,486 | 349,119 | 349,119 | 349,119 |
| Log likelihood/deviance | −245,186 | −245,119 | −245,052 | 389,667 | 389,655 | 389,244 |

Notes: Plant-level logistic and IV regression results. Regressions cover four panels: 1977–82, 1982–87, 1987–92 and 1992–97. Dependent variable is an indicator for plant death between years $t$ and $t+5$. $N/P$ wagebill ratio is total plant wages paid to non-production workers ($N$) divided by total plant wages paid to production workers ($P$). LWPEN and OTHPEN are low-wage country import penetration and the import penetration of other countries, respectively. Final three right-hand side variables are interactions with LWPEN. IV regressions instrument LWPEN and OPEN with ad valorem tariff and freight rates as well as lagged LWPEN. Robust standard errors are in parentheses below coefficient estimates. IV estimation employs an error correction algorithm developed by Hardin et al. (2004). Fit refers to the log likelihood ratio for the first three columns and deviance for the second three columns. ***Significant at the 1% level; **Significant at the 5% level; *Significant at the 10% level. Coefficients for the regression constant and fixed effects are suppressed.

negative and significant, in line with the predictions of Hypothesis 2, while the LWPEN-productivity interaction is positive but statistically insignificant.[21] The results on the capital and skill interactions with LWPEN emphasize the importance of production technique in influencing plant survival. Capital-intensive plants face a lower probability of death than labor-intensive plants in general, but the difference is magnified in industries that face substantial low-wage country import penetration.

Using the point estimates in column three, we find that a high capital-intensity plant (one standard deviation above the mean) has a probability of death that is 1.3 percentage points (4.7 percent) below that of the average plant for an industry with mean LWPEN. If the low-wage country import penetration in the industry rises by one standard deviation, the gap between the high capital-intensity plant and the average plant increases to 2.8 percentage points (9.3 percent). In this case, the higher plant capital intensity offsets two thirds of the direct negative effects of the low-wage country import penetration.

The final three columns of Table 3 report instrumental variable versions of the base specifications. These estimations instrument the penetration variables with ad valorem tariff rates and transport costs.[22] IV results offer the same message: low-wage country penetration is positively and significantly associated with plant death and, within industries, relative survival probabilities are higher for capital- and skill-intensive plants in the face of substantial low-wage country imports. The magnitudes of the LWPEN coefficients are higher in the IV specifications, increasing the estimated impact on plant death by an order of magnitude.[23]

### 5.2. Employment growth

Table 4 summarizes the relationship for surviving plants between plant employment growth and the average industry exposure to imports from low-wage countries. The first three columns report OLS coefficients while the final three columns report IV estimates which again use tariff and freight rates to instrument for the import penetration variables. Both sets of regressions include year and plant fixed effects to control for aggregate variation in manufacturing employment growth and unobservable industry and plant characteristics.

The findings again support the factor proportions framework. OLS results reveal that low-wage country import penetration is negatively and significantly correlated with

[21] In results not reported here, we also find support for the importance of skill in plant outcomes using wages as an alternative measure of skill.

[22] We use ad valorem tariff and freight rates from Bernard et al. (2004a) that are tabulated from product-level U.S. import data compiled by Feenstra (1996) and Feenstra et al. (2002). Results from the first-stage regressions indicate no problems with weak instruments (available on request). Our IV results are estimated via a generalized linear model estimation that employs an error correction algorithm developed by Hardin et al. (2004). See http://www.stata.com/merror/.

[23] The large increases in the IV coefficients may result from non-classical measurement error in LWPEN. See Kane et al. (1999) for an explanation. To assess the economic impact of low-wage country imports, we use the more conservative estimates throughout the paper.

Table 4
Employment growth and low-wage country import penetration

| | OLS | | | IV | | |
|---|---|---|---|---|---|---|
| | Employment change$_{pt:t+5}$ | Employment change$_{pt:t+5}$ | Employment change$_{pt:t+5}$ | Employment change$_{pt:t+5}$ | Employment change$_{pt:t+5}$ | Employment change$_{pt:t+5}$ |
| log(employment$_{pt}$) | −0.158*** (0.001) | −0.158*** (0.001) | −0.158*** (0.001) | −0.179*** (0.001) | −0.179*** (0.001) | −0.179*** (0.001) |
| Age$_{pt}$ | −0.001*** (0.000) | −0.001*** (0.000) | −0.001*** (0.000) | −0.001*** (0.000) | −0.001*** (0.000) | −0.001*** (0.000) |
| log(TFP$_{pt}$) | 0.024*** (0.002) | 0.024*** (0.002) | 0.023*** (0.002) | 0.024*** (0.001) | 0.024*** (0.001) | 0.026*** (0.001) |
| log($K/P_{pt}$) | 0.008*** (0.001) | 0.008*** (0.001) | 0.008*** (0.001) | 0.007*** (0.000) | 0.007*** (0.000) | 0.007*** (0.001) |
| $N/P$ wagebill ratio$_{pt}$ | −0.00001 (0.00002) | −0.00001 (0.00002) | −0.00001 (0.00002) | 0.00000 (0.00002) | 0.00000 (0.00002) | 0.00001 (0.00002) |
| Other penetration (OTHPEN$_{it}$) | | −0.034*** (0.011) | −0.037*** (0.011) | | −0.068 (0.095) | −0.037 (0.101) |
| Low-wage penetration (LWPEN$_{it}$) | −0.452*** (0.045) | −0.423*** (0.045) | −0.840*** (0.103) | −0.551*** (0.034) | −0.500*** (0.079) | −0.515*** (0.197) |
| × log(TFP$_{pt}$) | | | 0.104 (0.090) | | | −0.289* (0.150) |
| × log($K/P_{pt}$) | | | 0.181*** (0.035) | | | 0.034 (0.101) |
| × $N/P$ wagebill ratio$_{pt}$ | | | −0.023 (0.026) | | | −0.150 (0.059) |
| Plant fixed effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Year fixed effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 323,569 | 323,569 | 323,569 | 246,855 | 246,855 | 246,855 |
| $R^2$ | 0.76 | 0.76 | 0.76 | 0.43 | 0.43 | 0.43 |

Notes: Plant-level OLS and IV regression results. Regressions cover four panels: 1977–82, 1982–87, 1987–92 and 1992–97. Dependent variable is log difference in plant employment between years $t$ and $t+5$. $N/P$ wagebill ratio is total plant wages paid to non-production workers ($N$) divided by total plant wages paid to production workers ($P$). LWPEN and OTHPEN are low-wage country import penetration and the import penetration of other countries, respectively. Final three right-hand side variables are interactions with LWPEN. IV regressions instrument LWPEN and OPEN with ad valorem tariff and freight rates as well as lagged LWPEN. Robust standard errors adjusted for clustering at the plant level are in parentheses below coefficient estimates. ***Significant at the 1% level; **Significant at the 5% level; *Significant at the 10% level. Coefficients for the regression constant and fixed effects are suppressed.

employment growth. Controlling for penetration from other countries changes neither the sign, magnitude nor significance of the coefficient on LWPEN. [24] Coefficient estimates in column 2 indicate that a one standard deviation increase in LWPEN is associated with a decrease in annual plant employment growth of 2 percentage points.

The interaction of LWPEN with plant capital intensity is positive and significant. While increases in low-wage country imports reduce employment growth, the effect is smaller for the most capital-intensive plants in the industry and is largest for the most labor-intensive plants. The interactions of plant skill intensity and productivity with LWPEN are positive and negative, respectively, but neither is statistically significant.

The instrumental variable estimates reported in the final three columns of Table 4 confirm that plant employment growth remains negatively and significantly related to low-wage country penetration; again the magnitude of the IV estimates is larger. With respect to the interactions of LWPEN with plant characteristics, the capital intensity interaction remains positive but is no longer significant.

In the sample, manufacturing employment fell by 674,689 between 1977 and 1997. We estimate the fraction of this job loss attributable to rising low-wage country import penetration by applying the LWPEN coefficient reported in column three of Table 4. Using this estimate, we find that 14 percent of aggregate job losses in manufacturing were due to rising low-wage country import penetration. We caution that this estimate does not account completely for plant shutdown nor does it incorporate the possibility that import penetration in one industry facilitates efficiency increases in other industries, allowing them to expand.

## 6. Industry switching

In this section, we provide the first evidence that firms systematically adjust their product mix in response to pressure from international trade. Roughly 25,000 U.S. manufacturing plants switch industries in the four panels, an average of 7.8 percent of surviving plants in each 5-year period. Table 5 compares the industry capital intensity, skill intensity and LWPEN across the old and new industries of switching plants. For each switch occurring between years $t$ and $t+5$, we compare the year $t$ characteristics of the plants' old and new industries. Results indicate that destination industries are 2.0 percent more capital-intensive and 6.7 percent more skill-intensive. They also reveal that switchers move into industries with less import penetration from low-wage countries (5.6 percentage points lower) but greater import penetration from other countries (3.2 percentage points higher). All differences are statistically significant at the 1 percent level.

Table 6 explores whether low-wage country imports are related to the probability of switching industries and to the direction of changes in industry capital and skill intensity. The first two columns report results for industry switching using plant controls and

[24] In an early version of this paper, we demonstrate that the relationship between trade with low-wage countries and output growth is similar to its relationship with employment growth. This similarity indicates that plants facing high exposure to low-wage country imports are truly shrinking and not merely substituting away from relatively expensive U.S. labor. These results are omitted here to save space.

Table 5
Characteristics of old and new industries for plants that switch industries

| Characteristic | Mean difference across plants between new and old industries (%) | $T$ statistic (mean=0) | $P$ value |
|---|---|---|---|
| Plant capital intensity ($K/P$) | 2.0 | 5.6 | 0.00 |
| Plant $N/P$ wagebill ratio | 6.7 | 8.8 | 0.00 |
| Low-wage penetration (LWPEN) | −5.6 | 2.8 | 0.00 |
| Other penetration (OTHPEN) | 3.2 | 4.0 | 0.00 |

Notes: Calculations based upon a sample of 26,796 plants that switched their four-digit SIC industry over four 5-year panels: 1977–82, 1982–87, 1987–92 and 1992–97.

LWPEN .The first column reports logistic coefficients, while the second column reports an IV specification using the trade cost instruments noted above. Both columns indicate that the probability of switching industries is positively associated with exposure to low-wage country imports. The IV specification exhibits a higher magnitude for this relationship, but it is not statistically significant.

The third and fourth columns of Table 6 regress via OLS the log difference in industry factor intensity for switching plants on plant characteristics and LWPEN . Results in column two indicate that plants leaving industries with high LWPEN move to industries with higher capital intensity than the average switching plant. The fourth column indicates

Table 6
Industry switching and exposure to imports from low-wage countries

| Independent variables | Logistic | IV | OLS | |
|---|---|---|---|---|
| | Industry $\text{switch}_{t:t+5}$ | Industry $\text{switch}_{t:t+5}$ | Change in $K/P_{t:t+5}$ | Change in wagebill $\text{ratio}_{t:t+5}$ |
| log($\text{employment}_{pt}$) | 0.076*** (0.005) | −0.048*** (0.007) | 0.000 (0.003) | −0.021*** (0.006) |
| $\text{Age}_{pt}$ | −0.021*** (0.001) | −0.016*** (0.001) | 0.001* (0.000) | −0.003*** (0.001) |
| log($\text{TFP}_{pt}$) | −0.042* (0.025) | −0.054* (0.028) | 0.052*** (0.012) | 0.249*** (0.029) |
| log($K/P_{pt}$) | −0.052*** (0.006) | 0.074*** (0.009) | −0.050*** (0.004) | 0.008 (0.010) |
| $N/P$ wagebill $\text{ratio}_{pt}$ | 0.001 (0.001) | 0.000 (0.000) | 0.002 (0.002) | −0.001 (0.005) |
| Other penetration ($\text{OTHPEN}_{it}$) | 1.221*** (0.073) | 12.957*** (0.557) | −0.651*** (0.047) | −0.508*** (0.090) |
| Low-wage penetration ($\text{LWPEN}_{it}$) | 0.764* (0.466) | 1.069 (1.771) | 1.932*** (0.231) | 0.428 (0.405) |
| Observations | 330,233 | 26,734 | 26,734 | 253,546 |
| $R^2$ | – | – | 0.02 | 0.01 |
| Log likelihood/deviance | −93,165 | 134,954 | – | – |

Notes: Plant-level regression results covering four panels: 1977–82, 1982–87, 1987–92 and 1992–97. Dependent variable in first two columns is an indicator that the plant switches industries between years $t$ and $t+5$. First column reports logistic coefficients. IV coefficients for second column regression use ad valorem tariff and freight rates as well as lagged values of LWPEN as instruments for LWPEN and OTHPEN. IV estimation employs an error correction algorithm developed by Hardin et al. (2004). Second and third columns report OLS regression results. Robust standard errors adjusted for clustering at the plant level are in parentheses. Dependent variables in second and third columns are log difference of plant capital ($K/P$) and skill ($N/P$ wagebill ratio) intensity, respectively, between years $t$ and $t+5$. $N/P$ wagebill ratio is total plant wages paid to non-production workers ($N$) divided by total plant wages paid to production workers ( $P$).***Significant at the 1% level; **Significant at the 5% level; *Significant at the 10% level.

no statistically significant relationship between changes in industry skill intensity and LWPEN.

The results presented in this section provide the first evidence of a new margin of adjustment to competition from low-wage countries. U.S. plants systematically alter the mix of goods they produce when they face exposure to low-wage country imports.

## 7. Conclusions

Imports from low-income countries were the fastest growing component of U.S. trade from 1972 to 1997, increasing more rapidly than aggregate imports. This paper considers the role of imports from low-wage countries in U.S. manufacturing plant outcomes over time.

Across industries, we find that plant survival and growth are disproportionately lower in industries with higher exposure to imports from low-wage countries. Within industries, the higher the exposure to low-wage countries, the bigger is the relative performance difference between capital-intensive plants and labor-intensive plants in terms of survival and growth. Finally, we show that some U.S. manufacturing plants adjust their product mix in response to competition from low-wage countries. Plants facing higher shares of imports from low-wage countries are more likely to switch industries. When plants do switch, they jump towards industries that are on average less exposed to low-wage countries and are more capital- and skill-intensive.

These results support the view that the U.S. manufacturing is shifting resources towards activities consistent with U.S. comparative advantage. They also suggest that trade with low-wage countries has accelerated U.S. capital deepening across and within manufacturing industries over time.

Our results raise a number of interesting questions worthy of further inquiry. High productivity, like high capital intensity, improves plant performance and survival. Unlike capital intensity, however, high productivity does not disproportionately benefit plants facing high exposure to low-wage country imports. We also find that skill intensity does little to mitigate the effects of low-wage country imports, also a puzzling result. Finally, it would be useful to examine the relationship between low-wage country imports and intermediate inputs to determine whether the trends documented here are also associated with greater flexibility in downstream industries.

This paper only begins to examine the role of increased trade with low-income countries on firms and industries in the United States. To the extent that manufacturing output is not uniform across regions within the United States, the results also suggest significant variation in the regional responses to low-wage country competition. Additional theoretical and empirical progress is needed on the menu of responses available to firms, including investment, workforce upgrading, and product switching and innovation.

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