NBER WORKING PAPER SERIES

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Working Paper No. 5121

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
May 1995

Forthcoming in "Political Economy of Trade Policy: Essays in Honor of Jagdish Bhagwati," Cambridge: MIT Press. The authors thank Peter Lindert, David Richardson, Alwyn Young, Adrian Wood and seminar participants for helpful comments. This paper is part of NBER's research program in International Trade and Investment. Any opinions expressed are those of the authors and not those of the National Bureau of Economic Research.

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ABSTRACT

In this paper we examine the reduction in the relative employment and wages of unskilled workers in the U.S. during the 1980's. We argue that a contributing factor to this decline was rising imports reflecting the outsourcing of production activities. In a theoretical model, we show that any increase in the Southern capital stock relative to that of the North, or neutral technological progress in the South, will increase the relative wage of skilled workers in *both* countries due to a shift in production activities to the South. Corresponding to this change in the relative wage is an increase in the price index of Northern activities within each industry, relative to that of the South. We confirm that this change in relative prices occurred for the U.S. and other industrialized countries relative to their trading partners. We also estimate that 15-33% of the increase in the relative wage of nonproduction (or skilled) workers in the U.S. during the 1980's is explained by rising imports.

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1. Introduction

One of the most controversial issues in the U.S. presidential campaign of 1992 was the impact of the proposed North American Free Trade Agreement (NAFTA) on employment and wages in the United States. Many observers feared that this legislation would lead to an exodus of U.S. companies across the border to take advantage of the lower wages in Mexico: the "giant sucking sound," to use the oft-cited phrase of Ross Perot. With the passage of this legislation in November 1993, the possible impact on unskilled workers in the U.S. remains an important issue. Initial studies for the 1980s have argued that trade competition, among other factors, will contribute to a fall in the relative employment and wages of unskilled workers (Revenga, 1990; Murphy and Welch, 1991; Borjas, Freeman and Katz, 1992).

Surprisingly, this conclusion is not obtained by the most recent studies, which focus on the accelerating decline in the employment and wages of production workers relative to nonproduction workers in the U.S. Instead, the proximate cause of this decline is thought to be biased technological change, due to the introduction of computers and other research and development activities. This view is expressed most strongly by Bound and Johnson (1992) and Berman, Bound and Griliches (1994), who identify the decreasing ratio of production to nonproduction workers *within* industries as the crucial determinant of the wage and employment pattern. Lawrence and Slaughter (1993) argue that this decreasing ratio cannot be due to import competition: from the Stolper-Samuelson theorem, if import competition reduces the relative wages of production workers, then all industries should substitute *towards* this factor, whereas the data show substitution away from it. Thus, both the shift away from production workers and their reduced relative wages must be due to another cause, of which biased technological change seems most likely.[1]

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[1] This conclusion is reiterated by Krugman and Lawrence (1994), but has been challenged by Borjas and Ramey (1993), Leamer (1994), Sachs and Shatz (1994) and Wood (1994), among others. Davis (1992) compares wage trends in the U.S. with various trading partners, and Berman, Machin and Bound (1994) compare the employment shifts across countries. See also the discussion in the "The Global Economy," *The Economist*, October 1, 1994, 14-24.

The average annual wages of nonproduction relative to production workers for the U.S., which is used as a proxy for the skilled/unskilled wage ratio, are plotted in Figure 1.[2] These data show the increase in the relative wages of nonproduction workers in the U.S. during the 1980's. For comparison, Figure 1 also plots the ratio of nonproduction/production wages for Mexico, computed from the Industrial Census for the period 1965 to 1988. This relative wage shows a sharp increase after 1985, following a steady decline over the previous decades. While the magnitude of these changes are very different (as reflected in the differing scales), the timing of the increase in relative wages in the two countries is surprisingly similar. Given the proximity and integration of these economies, a model that explains the movement in the relative wage for the U.S. should also account for the movement in Mexico.

The similarity of these wage movements on both sides of the border suggests that they are *not* due to trade liberalization directly, since in that case we generally expect factor prices to move in opposite directions across countries (as goods prices fall in the country formerly protected, and rise in the other). However, with the liberalization of foreign ownership in Mexico, there has been a substantial movement of capital across the border, which has its own impact on factor prices. We shall argue that capital mobility from the North to the South, or more generally, any increase in the relative capital stock of the South, will lower the relative wage of unskilled workers in *both* countries. This result holds also for neutral technological progress in the South, which is complementary with the earnings of skilled labor worldwide. These findings support the suggestion of Bhagwati and Dehejia (1994, p. 55) that the increased globalization of firms "could well be a contributing factor of some, perhaps growing, importance" in explaining the increasing wage gap, though our model is quite different from the process they have in mind.

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2 These data are taken from Lawrence and Slaughter (1993) and Sachs and Shatz (1994). While there are problems with the production/non-production classification (Leamer, 1994), there is evidence suggesting that in practice the classification is successful in tracking employment by skill category (Berman, Bound, and Griliches, 1994; Sachs and Shatz, 1994).

The model we shall use is described in sections 2 and 3, and has a single manufactured good produced from a continuum of intermediate inputs, that are in turn produced using skilled workers, unskilled workers, and capital. Capital has the same degree of substitution with either type of labor in the production of intermediate inputs. The structure of this model is very similar to the Hecksher-Ohlin model with a continuum of goods, as in Dornbusch, Fischer and Samuelson (1980), except that we can interpret all the activities as occurring within a *single* industry. Assuming that trade does not lead to factor-price equalization, the equilibrium is described by the South producing and exporting a range of inputs up to some critical ratio of skilled to unskilled labor, with the North producing the remainder of the inputs. The Northern inputs will include such activities as R&D and marketing, for example, which use little or no unskilled labor, while those activities that are more intensive in unskilled labor are "outsourced" to the South.

Growth of the relative capital stock in the South, or neutral technological progress relative to the North, will raise the critical ratio dividing the Northern and Southern activities. The activities transferred from the North to the South will be more skilled-labor intensive than those formerly produced in the South, but less skilled-labor intensive than those now produced in the North. It follows that the relative demand for skilled labor in *both* countries increases, which results in a higher relative wage for skilled workers. It is not the case, however, that unskilled workers in the North (or South) need be worse off in real terms, because the increase in Southern supply lowers the prices of goods available through trade, which may be enough to offset the wage reduction. Corresponding to the change in factor prices is an increase in the price index of Northern inputs relative to that of the South, so that a modified Stolper-Samuelson result applies by comparing the country price indexes *within* each industry.

In section 4, we use the results of our model to reinterpret the evidence for the United States. Berman, Bound and Griliches (1994) have argued that the magnitude of outsourcing - defined as the import of materials by U.S. firms - is too small to account for the observed wage and employment changes. Similarly, Lawrence (1994) and Krugman (1994) argue that outsourcing and foreign direct investment through multinational firms is also too small to account for the changes. In contrast, we adopt a more general definition of outsourcing, which in addition to imports by U.S. multinationals, includes all imported intermediate or final goods that are used in the production of, or sold under the brandname of, an American firm. This definition of outsourcing corresponds to common usage, and would include a very wide range of textiles and apparel, footwear, consumer electronics, and many other imports.

In our model, outsourcing increases the relative demand for skilled labor in both countries, and therefore acts as a type of "endogenous technical change" biased in favor of the skilled factor. Using the same data source as Berman, Bound and Griliches (1994), we show that the increasing share of nonproduction workers in the U.S. is *positively and significantly* correlated with increasing imports: the rising import share over 1979-87 explains 15-33% of the shift towards nonproduction labor in U.S. manufacturing. Furthermore, using data from Lawrence and Slaughter (1993) and Lawrence (1994), we show that the modified Stolper-Samuelson result holds for the U.S. and other countries, so that the commodity price movements are consistent with the factor price changes. This reinforces our view that trade and investment are an important part of the explanation for the pattern of wage and employment changes.

In section 5 we describe in more detail the movements in relative wages and employment in Mexico during the 1980's. A change in regulations during this period led to a very substantial inflow of foreign direct investment, particularly to the U.S.-Mexico border region. This is also the region where the greatest increase in the relative wages of nonproduction workers occurred. These observations support our theoretical model, under which the activities transferred to the border region would have a higher ratio of nonproduction/production workers than those previously in place. In section 6 we compare our results to other studies, and provide conclusions.

2. The Model

Our goal in this section is to construct a simple model that is consistent with the observations for the U.S. and Mexico, of rising relative wages for skilled workers. We will suppose that there is a single manufactured good, which is assembled from a continuum of intermediate inputs, indexed by $z \varepsilon [0,1]$. Each unit of the input z uses $a_L(z)$ of unskilled labor and $a_H(z)$ of skilled labor, with the total usage of these factors in input z denoted by L(z) and H(z). We shall arrange goods such that the ratio $a_H(z)/a_L(z)$ is *increasing* in z. In addition, the production of each input requires capital K(z), which substitutes for labor in a Cobb-Douglas production function:

$$x(z) = A_i\left[\min\left\{\frac{L(z)}{a_L(z)}, \frac{H(z)}{a_H(z)}\right\}\right]^{\theta} \left[K(z)\right]^{1-\theta}, \tag{1}$$

where A_i is a constant that can differ between the North and South, i=N,S. Given these inputs, the final good Y is then costlessly assembled (in either country) according to the Cobb-Douglas function:

$$\ln Y = \int_0^1 \alpha(z) \ln x(z)\, dz \ , \quad \text{with} \ \int_0^1 \alpha(z) dz = 1. \tag{2}$$

In addition to the "neutral" technological difference A_i, the North and the South differ in their supplies of the three factors. We will denote their endowments of unskilled labor, skilled labor and capital by L_i, H_i and K_i, respectively, with the factor prices denoted by w_i, q_i, and r_i, for i=N,S. We will suppose that the technologies and factor endowments are sufficiently different so that factor prices are not equalized, with Northern capital earning a lower rate of return ($r_N<r_S$), and the ratio of skilled/unskilled wages being lower in the North ($q_N/w_N < q_S/w_S$). We will also let the supply of skilled and unskilled labor respond to the relative wages, with $L_i'(q_i/w_i) \leq 0$ and $H_i'(q_i/w_i) \geq 0$. These supply responses may be due to more unskilled workers becoming skilled as the relative wage rises, or may reflect excess supply from the rest of the economy, which we leave unspecified. Capital will flow between countries in response to the difference in the rates of return, though initially, restrictions on foreign investment prevent this flow from occurring.

The minimum costs of producing one unit of x(z) in country i takes the form,

$$c(w_i, q_i, r_i; z) = B_i[w_i a_L(z) + q_i a_H(z)]^{\theta} r_i^{1-\theta}, \tag{3}$$

where $B_i \equiv \theta^{-\theta}(1-\theta)^{-(1-\theta)}A_i^{-1}$. For fixed wages, we will suppose that $c(w_i, q_i, r_i; z)$ is a continuous function of z. The locus of minimum costs for intermediate inputs produced in the North and South are graphed in Figure 2 as C_NC_N and C_SC_S, respectively. While the absolute slopes of these minimum cost lines are not determined, if inputs are produced in both countries (as we assume) then the relative slopes are determined: C_SC_S must lie *above* C_NC_N at high ratios of skilled to unskilled labor, indicating that the North has a cost advantage in that range (reflecting a lower relative wage of skilled workers), while the reverse holds at the low ratios. It can be verified that since capital enters with the same cost share (1-θ) for all goods z in (2), costs are equalized at most at a single point, shown by z^* in Figure 2 and satisfying:

$$c_S(w_S, q_S, r_S; z^*) = c_N(w_N, q_N, r_N; z^*). \tag{4}$$

It follows that the activities $z > z^*$ will take place in the North, while the activities $z < z^*$ will take place in the South.

To determine the dividing point z^*, we utilize the full employment conditions. The total demand for each factor is obtained by differentiating (3) with respect to its factor price, and integrating over all industries producing in each country. For the South, the full employment conditions for the two types of labor are given by:

$$L_S(q_S/w_S) = \int_0^{z^*} B_S\theta\left[\frac{r_S}{w_S a_L(z) + q_S a_H(z)}\right]^{1-\theta} a_L(z)x_S(z)\,dz\,, \tag{5}$$

and,

$$H_S(q_S/w_S) = \int_0^{z^*} B_S\theta\left[\frac{r_S}{w_S a_L(z) + q_S a_H(z)}\right]^{1-\theta} a_H(z)x_S(z)\,dz\,. \tag{6}$$

An analogous expression can be written for capital, but instead, we will utilize the Cobb-Douglas production function in (1) to divide Southern national income $(w_S L_S + q_S H_S + r_S K_S)$ into the labor share of θ, and the capital share of $(1-\theta)$. It follows that,

$$r_S K_S = [w_S L_S + q_S H_S](1-\theta)/\theta. \tag{7}$$

With demand for the intermediate inputs obtained from the Cobb-Douglas production function in (2), each input z receives the share of expenditure $\alpha(z)$. The price of each input equals the minimum of the unit-costs across the two countries. Letting E denote world expenditure on the final good Y, the demand for an input from the South is given by:

$$x_S(z) = \alpha(z)E/c_S(z), \quad z \varepsilon [0,z^*) . \tag{8}$$

Then making use of the unit-costs in (3) along with (8), the factor demands on the right-side of (5) and (6) are simplified to obtain:

$$L_S(q_S/w_S) = \int_0^{z^*} \theta \left[\frac{a_L(z)\alpha(z)E}{w_S a_L(z) + q_S a_H(z)}\right] dz , \tag{5'}$$

and,

$$H_S(q_S/w_S) = \int_0^{z^*} \theta \left[\frac{a_H(z)\alpha(z)E}{w_S a_L(z) + q_S a_H(z)}\right] dz . \tag{6'}$$

Notice that the return to capital r_S no longer appears in these expressions.

The equilibrium of the model is described by equations (4), (5'), (6'), (7), the analogous three full-employment conditions for the North, and the definition of world expenditure E as the sum of factor payments in both countries. This will give 8 equations in 8 unknowns - the three factor prices in each country, z^*, and world expenditure E. One equation can be dropped from Walras' Law, and one variable can be chosen as numeraire. We will choose to normalize world expenditure at unity, $E\equiv 1$, so that all factor prices are being measured as shares of world factor income (equal to expenditure) in this industry. Then wages of each type of labor are simply determined as functions of z^* from (5') and (6'), with the return to capital determined by (7), and z^* determined by (4).[3]

3. Effects of Southern Capital Growth

Relative Wages

We have assumed that the return to capital in the South exceeds that in the North, reflecting the scarcity of capital in the South. Suppose now that an amount of capital dK flows from the North to the South, earning the additional return $(r_S - r_N)dK > 0$. What will be the effect on relative wages?

Notice that for fixed z^*, the wages of both types of labor are constant in (5') and (6'), so that initial impact of the capital flow is to lower the return to capital in the South from (7), and raise it in the North from the analogous condition there. This will lower the Southern cost locus C_SC_S in Figure 2, and raise the Northern locus C_NC_N. Because the Southern locus cuts the Northern locus from below, this must *increase* the critical value of z^* to z' (at fixed wages), so that activities in the range $[z^*, z')$ now take place in the South rather than the North.

The activities in the range $[z^*, z')$ are more skilled-labor intensive than any that formerly occurred in the South, but less skilled-labor intensive than any that now occur in the North. Thus, at unchanged wages, this will increase the relative demand for skilled labor in *both* countries. This can be verified by defining relative demand for skilled labor in the South as the ratio of (6') and (5'):

$$D_S(q_S/w_S, z^*) \equiv \frac{\int_0^{z^*}\left[\dfrac{a_H(z)\alpha(z)E}{w_S a_L(z) + q_S a_H(z)}\right]dz}{\int_0^{z^*}\left[\dfrac{a_L(z)\alpha(z)E}{w_S a_L(z) + q_S a_H(z)}\right]dz}. \tag{9}$$

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[3] We do not impose trade balance in this industry across countries, since the allocation of expenditure across the countries will have no impact on factor prices or the critical value z^*.

The relative demand for skilled labor in the North, $D_N(q_N/w_N,z^*)$, is defined by evaluating the integrals in (9) over $[z^*,1]$, and using the Northern factor prices. Letting $L_i(z^*)=\theta a_L(z^*)\alpha(z^*)E/[w_i a_L(z^*)+q_i a_H(z^*)]$ denote the unskilled labor used in z^* if it is produced only in country i, several properties of the relative demands are:

<u>Lemma 1</u>

(a) $$\frac{\partial \ln D_S}{\partial z^*} = \frac{L_S(z^*)}{H_S}\left[\frac{a_H(z^*)}{a_L(z^*)} - \frac{H_S}{L_S}\right] > 0; \quad \frac{\partial \ln D_N}{\partial z^*} = \frac{L_N(z^*)}{H_N}\left[\frac{H_N}{L_N} - \frac{a_H(z^*)}{a_L(z^*)}\right] > 0;$$

(b) $$\frac{\partial \ln D_i}{\partial \ln(q_i/w_i)} < 0, \ i=N,S.$$

Condition (a) follows directly from differentiation of (9) and the analogous relative demand for the North. These expressions are positive because the skilled/unskilled labor ratio at the critical value z^* exceeds the average for the South, and is less than the average for the North. Condition (b) states that the relative demand curves are a downward sloping function of the relative wage. While we provide a proof in the Appendix, this condition actually follows directly from the well-behaved optimization problems solved by competitive markets in both countries. Letting $p_i(z)\equiv\min\{c_S(w_S,q_S,r_S;z),c_N(w_N,q_N,r_N;z)\}$ denote the prices of the intermediate inputs, competitive markets will maximize the value of industry production in each country, given the endowments (L_i,H_i,K_i):

$$E_i(L_i,H_i,K_i) \equiv \max_{x_i(z)} \int_0^1 p_i(z)\, x_i(z)\, dz, \tag{10}$$

subject to the production functions (1) and the full-employment conditions in each country. Note that at the prices $p_i(z)$, the production of Southern inputs $x_S(z)$ is chosen optimally as zero in (10) for $z\varepsilon(z^*,1]$, and the production of Northern inputs $x_N(z)$ is zero for $z\varepsilon[0,z^*)$. Since the production functions (1) are concave, as is the objective function in (10), the resulting industry-value functions $E_i(L_i,H_i,K_i)$ are a concave function of the factor endowments. The derivatives of the industry-value functions equal the factor prices, and then the downward sloping relative demand for skilled labor follows from the well-behaved isoquants of $E_i(L_i, H_i, K_i)$.

Summing up, the capital flow will lead to an increase in z^*, which results in an increase in relative demand for skilled labor from A to B in Figure 3. The situation in the North is analogous: the increase in z^* at fixed factor prices leads to a concentration of production in more skilled-labor intensive activities, which raises the relative demand for skilled labor. The result is that the relative wage (q_i/w_i) in *both* countries increases. Of course, these factor price changes feed back into Figure 2, shifting both the cost loci. Under a stability condition that is verified below, we find that z^* will still increase after these factor prices changes are taken into account. We then obtain:

<u>Proposition 1</u>

With a capital flow from the North to the South:

(a) the relative wage of skilled labor in *both* countries increases;

(b) the ratio of skilled/unskilled labor used in total production in each country is unchanged or increases.

Both these results follow from Figure 3, where the equilibrium moves from A to C. The ratio of skilled/unskilled labor used in production in each country equals the relative supply $H_i(q_i/w_i)/L_i(q_i/w_i)$, which will increase if either of these factor supplies respond to the relative wage.

A further implication of the capital flow is that *variance* of the ratio of nonproduction/production workers across activities within the South increases, if the factor supplies are fixed. This is seen from Figure 2, where the South moves into the range of activities $[z^*, z')$ that are more skilled-labor intensive than any inputs formerly produced. If the supplies of skilled and unskilled labor are fixed, then full-employment of these factors can occur only if employment at the lowest-skilled activities also increases, with less employment in the middle of the range $[0,z')$. Thus, there is an expansion of the production of activities using both the highest and lowest ratios of skilled/unskilled labor, which corresponds to an increase in the variance of this ratio within the industry. We will confirm this prediction using data for Mexico in section 5.

While the gap between the wages of skilled and unskilled labor increases in both countries, it is not necessarily the case that any of these factors are worse off in real terms. To determine the pattern of factor price changes more fully, we can add w_S times (5') plus q_S times (6'), and the analogous conditions for the North, to obtain:

$$w_S L_S + q_S H_S = \theta \int_0^{z^*} \alpha(z) dz \ , \qquad (11a)$$

and

$$w_N L_N + q_N H_N = \theta \int_{z^*}^{1} \alpha(z) dz \ . \qquad (11b)$$

From these conditions, we see that the increase in z^* implies that payments to labor (expressed as a fraction of total factor payments) will increase in the South, but decline in the North. In this sense, Southern labor gains relative to Northern labor. These results can also be expressed by letting $\lambda_{Li} = w_i L_i/(w_i L_i + q_i H_i)$ denote the share of unskilled labor in total wage payments in country i, with $\lambda_{Hi} = 1 - \lambda_{Li}$ denoting the share of skilled labor. Letting $\hat{z}=dz/z$ denote a logarithmic change, the implications of increasing z^* in (11) are summarized by:

<u>Proposition 2</u>

With a capital flow from the North to the South:

(a) $\lambda_{LS}\hat{w}_S + \lambda_{HS}\hat{q}_S > 0 > \lambda_{LN}\hat{w}_N + \lambda_{HN}\hat{q}_N$;

(b) $\hat{q}_S > \max\{0,\hat{w}_S\}$; $\hat{w}_N < \min\{0,\hat{q}_N\}$;

(c) If the change in z^* is sufficiently small, then all workers in both countries gain.

Result (a) follows directly from differentiating (11). Note that the first inequality can be stated as $\hat{q}_S > \lambda_{LS}(\hat{q}_S - \hat{w}_S)$, which is positive because the relative wage of skilled workers rises. This implies that skilled workers in the South will obtain a greater share of total factor payments, and establishes the first result in (b). The second result in (b) is obtained by working with the inequalities in (a) for the North, and implies that unskilled workers in the North must obtain a smaller share of total factor payments. Despite this, we will argue that all workers can gain from the capital flow.

To obtain the *real return* to any factor, we need to determine the change in the price index for the final good Y, denoted by π. Multiplying this price index by aggregate output we should obtain total expenditure, so $E=\pi Y$. With the normalization $E\equiv 1$, it can be confirmed that the increase in total output Y due to the capital flow is precisely $\hat{Y} = (r_S - r_N)dK > 0$,[4] so the price index π will fall by an equivalent amount: $\hat{\pi} = -\hat{Y} = -(r_S - r_N)dK < 0$. Notice that this fall in the price index is related to the initial differences in the return to capital, but *not* to the extent of change in the critical value z^*.

However, the change in the factor prices reported in Proposition 2 are all related to the extent of change in z^*. To consider an extreme case, suppose that z^* does not change due to a discontinuity in the cost loci, as illustrated in Figure 4. The point of discontinuity z^* satisfies the condition that Southern costs are below Northern for $z < z^*$, and above Northern for $z > z^*$. A small capital flow from the North to the South will shift down the minimum-cost loci in Figure 4 to the left of z^*, as illustrated by $C_S'C_S'$, and shift it up to the right of z^*, as illustrated by $C_N'C_N'$, but would not affect the critical value z^*. It follows that the labor demand equations in (5') and (6') are *unchanged*, and so are wages in both countries as a share of total factor payments. However, the new minimum-cost profile must correspond to a

[4] This is obtained by differentiating (2) with respect to the capital flow K, holding fixed z^* and the quantities of labor in the various activities z (from the envelope theorem), and simplifying the resulting expression using (8).

reduced price index π, so that the real returns w_i/π and q_i/π are *increased*, i=N,S. Thus, all workers gain in real terms.

The result that all workers can gain is surprising, and contradicts our intuition from a one-good model that in the country where capital is leaving, the marginal product of labor - and their real wage - must fall. However, the intuition that some workers must lose does not extend to a two-good, two-factor model, for example, where each country is fully specialized in its export good. In that case a capital flow from the North to the South will lower the Northern wage in terms of its own good, but also lower the relative price of the Southern good. It is straightforward to show that if the elasticity of substitution in consumption is less that or equal to that in production, then the wage of Northern labor in terms of the Southern good will *rise*. Under this same condition, if the share of the two goods in consumption for all workers equal their world production shares (i.e. tastes are the same across countries), then both Northern and Southern workers necessarily gain in terms of their cost of living index. Thus, we see that even in a conventional two-good trade model, capital mobility can improve the conditions of all workers. The same result is obtained in our model if the change in z^* is sufficiently small.

Stability Condition

We still need to confirm the stability condition used in our results above, that the capital flow will lead to an increase in z^* even with factor prices changing endogenously. It turns out that a careful examination of this stability condition will allow us to generalize the above results to apply to *any* increase in the Southern capital stock relative to the Northern (not necessarily due to capital mobility), and also to technological progress in the South relative to the North.

Let us consider changes in the capital endowments $\hat{K}_i$ and in the technological parameters $\hat{A}_i$, i=N,S. Then in the Appendix we show that:

Lemma 2

The change in z^* is due to a change in capital endowments and technology is:

$$dz^* = \Delta\left[(1-\theta)(\hat{K}_S - \hat{K}_N) + (\hat{A}_S - \hat{A}_N)\right], \text{ where } 0 < \Delta < \left[\frac{\alpha(z^*)}{E_N} + \frac{\alpha(z^*)}{E_S}\right]^{-1} . \qquad (12)$$

Thus, growth in the relative Southern capital stock ($\hat{K}_S > \hat{K}_N$) or in its technology ($\hat{A}_S > \hat{A}_N$) will ensure that the critical value z^* increases, leading to the changes in factor prices discussed in Propositions 1 and 2. Formally, we state this as:

Corollary

The pattern of relative wage and employment changes in Propositions 1(a,b) and 2(a,b) hold for any increase in the Southern capital stock relative to that in the North, or any increase in the technology parameter A_S relative to A_N.

Thus, the changes in wage and employment patterns that we have identified are not dependent on capital mobility across countries, but apply more generally to any neutral increase in relative supply from the South. This generalization is important because, as noted by Bhagwati (1995, p. 46), more foreign direct investment entered the U.S. during the 1980's than exited, which would cast doubt on the applicability of our results if they relied solely on capital mobility. It is quite possible than the inbound foreign investment employed a higher ratio of skilled/unskilled labor than the outbound, as with foreign companies acquiring firms in Silicon Valley for their R&D expertise, for example. It follows that the *net flow* of capital is not sufficient to determine the impact on relative employment and wages. But regardless of the net flow of capital, the rapid growth of economies outside the U.S. - such as in the border region of Mexico, and the newly-industrialized countries more generally - is enough to cause the "outsourcing" of intermediate inputs and the corresponding increase in the relative wage of skilled workers.

Terms of Trade

The bounds on the magnitude of dz^* in (12) can be used to establish a modified version of the Stolper-Samuelson Theorem in this model. With the South exporting inputs in the range $z\varepsilon[0,z^*)$, and the North exporting those in the range $z\varepsilon(z^*,1]$, the *terms of trade* is the ratio of the price index for inputs from each country. We will define the input price index implicitly, by taking the ratio of the nominal and real values of production. The nominal value of production $E_i(L_i,H_i,K_i)$ was given by (10). Let us define the $F_i[L_i,H_i,K_i;\overline{p}(z)]$ as the "real" value of production, evaluated at some fixed prices $\overline{p}(z)$:

$$F_i[L_i,H_i,K_i;\overline{p}(z)] \equiv \max_{x_i(z)} \int_0^1 \overline{p}(z)\, x_i(z)\, dz \ . \tag{13}$$

Then we will define the price index for country i=N,S as:

$$\pi_i[L_i,H_i,K_i;\overline{p}(z)] \equiv E_i(L_i,H_i,K_i)/F_i[L_i,H_i,K_i;\overline{p}(z)] \ , \tag{14}$$

and the terms of trade are $\pi_N/\pi_S = (E_N/F_N)/(E_S/F_S)$.

Obviously, when evaluating "real" production at the equilibrium prices, then $\pi_i[L_i,H_i,K_i;p(z)]\equiv 1$. Keeping $\overline{p}(z)$ fixed at the initial equilibrium prices p(z), we can consider a small change in the price schedule p(z), and in the endowments (L_i,H_i,K_i) and technology parameters A_i, to obtain the following change in the price index π_i:

$$\begin{aligned}\hat{\pi}_i &= \frac{1}{E_i}\left[\int_0^1 p(z)\,dx_i(z)\,dz + \int_0^1 dp(z)\,x_i(z)\,dz\right] - \frac{1}{F_i}\left[\int_0^1 \overline{p}(z)\,dx_i(z)\,dz\right] \\ &= \frac{1}{E_i}\left[\int_0^1 dp(z)\,x_i(z)\,dz\right] \qquad (15)\\ &= \int_0^1 \hat{p}(z)\,\gamma_i(z)\,dz, \quad \text{where } \gamma_i(z)\equiv p(z)x_i(z)/E_i.\end{aligned}$$

The first line in (15) follows by definition of the price index in (13); the second line follows because we are evaluating $F_i[L_i,H_i,K_i;\overline{p}(z)]$ at $\overline{p}(z)=p(z)$; and the third line follows by definition of γ_i as the shares of production for each intermediate input z. From the last line, we can interpret $\hat{\pi}_i$ as a weighted average of the (percentage) change in inputs prices, where the weights $\gamma_i(z)$ equal zero for $z\varepsilon[0,z^*)$ and i=N, or for $z\varepsilon(z^*,1]$ and i=S. Thus, the change in the terms of trade π_N/π_S is:

$$\hat{\pi}_N - \hat{\pi}_S = \int_{z^*}^{1} \hat{p}(z)\gamma_N(z)dz - \int_{0}^{z^*} \hat{p}(z)\gamma_S(z)dz .$$

This is simply the difference in a weighted-average of the change in input prices for each country. The question we wish to address is whether this change in this terms of trade can be related to change in relative wages.

With the normalization $E\equiv1$, the values of industry production E_i in (10) can be written alternatively as shares of world production, $E_N=\int_{z^*}^{1}\alpha(z)dz$ and $E_S=\int_{0}^{z^*}\alpha(z)dz$. Then $\hat{E}_N-\hat{E}_S=-\{[\alpha(z^*)/E_N]+[\alpha(z^*)/E_S]\}dz^*$. Furthermore, the change in the "real" outputs due to changes in capital and technology are simply $\hat{F}_i=\hat{A}_i+(1-\theta)\hat{K}_i$, i=N,S. Then by definition of the terms of trade $\pi_N/\pi_S=(E_N/F_N)/(E_S/F_S)$, it follows that:

$$\hat{\pi}_N - \hat{\pi}_S = [(1-\theta)(\hat{K}_S-\hat{K}_N)+(\hat{A}_S-\hat{A}_N)] - \left[\frac{\alpha(z^*)}{E_N}+\frac{\alpha(z^*)}{E_S}\right]dz^*,$$

which is *positive* whenever $[(1-\theta)(\hat{K}_S-\hat{K}_N)+(\hat{A}_S-\hat{A}_N)]>0$, from (12). Thus, we have established:

Proposition 3

Corresponding to the increase in the relative wage of skilled labor in both countries, there is an increase in the price index of the Northern inputs relative to that of the South.

Given that all the inputs produced in the North are more skilled-labor intensive than those in the South, this result is in the same spirit as the Stolper-Samuelson Theorem. In contrast to that theorem, however, the Northern and Southern price indexes refer to the intermediate inputs used in the production of a given final output. In practice, we could measure these indexes as the price deflators for domestic value-added as compared to imports, either within a given industry, or aggregated across the entire economy. Note that in our model, the assembly of the aggregate output Y requires no additional factors beyond the intermediate inputs, so that value-added in this activity is zero; thus, it can be done in either country, and will not affect the price deflators for value-added. A comparison of domestic and import prices for the U.S. and other industrialized countries will be made in the next section.

4. Reinterpretation of U.S. Evidence

Domestic and Import Prices

The results we have obtained above offer some guidance on how to interpret the existing evidence on U.S. wages and employment. We begin by re-examining the price evidence of Lawrence and Slaughter (1993). They have found that the prices of U.S. imports that are intensive in production workers *did not fall* relative to imports that are intensive in nonproduction workers, and for this reason argue that the rising relative wages of nonproduction workers could not be attributed to the price movements. Lawrence (1994) finds similar evidence for Japan and Germany. Their results for these countries are reproduced in Table 1.

The first rows of Table 1 report the percentage change in U.S. domestic and import prices, where the aggregate price change is obtained as a weighted sum of the 3-digit SIC price changes, using the employment of either nonproduction or production workers as weights. For domestic prices these alternate weighting schemes make little difference, but for import prices the average price change using nonproduction workers as weights is *lower* than the change using production workers as weights. This indicates that the prices of imports intensive in production labor *rose* slightly relative to the prices of imports intensive in nonproduction labor: just the opposite of the expected Stolper-Samuelson pattern. Exactly the same result is obtained by comparing the domestic or import prices with the differing weighting schemes for Japan and Germany, even after office machines and also petroleum products are excluded from the aggregate indexes.

However, the difference between the price indexes obtained with production and nonproduction weights - which is of principal interest to Lawrence and Slaughter - seems to be of second-order compared to the direct comparison of the domestic and import prices in Table 1: for all countries and indexes, the domestic prices rose by more than the import prices. This is precisely the pattern of price changes reported in Proposition 3, and is fully consistent with an increase in the relative wages of nonproduction workers. This modified Stolper-Samuelson result recognizes that the factor-intensities of Northern production and imports from the South within the same industry are likely to differ, with the domestic industry employing a higher ratio of nonproduction workers. Thus, the increase in the price of domestic production relative to imports is fully consistent with the increase in the relative wage of these workers.

Outsourcing

We have seen in Figure 3 that the transfer of activities from the North to the South - or the increase in z^* - increases the relative demand for skilled labor in both countries. In this sense, the transfer of activities acts as a form of "endogenous technical change." Our model thus provides a simple formalization of the idea that trade will induce a shift in the factor-intensities in production, as discussed by Wood (1994, 1995). While Berman, Bound and Griliches find very substantial evidence of a change in the skilled/unskilled ratio across many U.S. industries, they reject outsourcing as a possible explanation. In their working paper (1993, pp. 19-20), they note that the 1987 *Census of Manufactures* reports that foreign materials constitute only 8% of all materials purchased in manufacturing. Based on this figure, they calculate that replacing all outsourcing with domestic activity would raise manufacturing employment of production workers by only 2.8%.

There are several reasons, however, why this calculation may underestimate the extent of outsourcing. First, an imported intermediate input could be processed and resold several times between firms, but would only be counted as an "import" when it first enters the U.S. This means that there could be double-counting in the "domestic materials" as compared to imports, so the 8% figure may be biased downwards. Second, the value of "imported materials" in the 1987 *Census of Manufactures* includes only the "cost of materials, parts, components, containers, etc.", but *explicitly excludes* the "cost of products bought and sold as such" and "contract work done for you by others."[5] This means that the measure of outsourcing obtained from the Census excludes all offshore assembly and goods purchased on an OEM (original equipment manufacturer) basis. For example, Nike currently employs 2,500 person in the U.S. for marketing and other headquarters services, while about 75,000 persons are employed in Asia producing shoes that are sold to Nike.[6] Since these shoes are finished products when they enter the United States, they would not be counted as "materials" nor included in the Census measure of outsourcing. The same is true for General Electric, which currently imports all of the microwaves marketed under its brandname from Samsung in Korea (Magaziner and Patinkin, 1989), but these imports occur as finished products rather than as materials. Activity of this sort is certainly typical of footwear (Yoffie and Gomes-Casseres, 1994, case 7), textiles (Waldinger, 1986;

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5 Specifically, the question asked to the sample of firms in the 1987 *Census of Manufacturers* (U.S. Bureau of the Census, 1991, Appendix D, pp. D-25,26) was "What percentage (approximate) of the total materials used as reported in item (a) [i.e. cost of materials, parts, components, containers, etc.] is accounted for by foreign sources? Materials used should not include items partially fabricated abroad which reenter the country usually under Items 806 and 807, of Schedule 8 of TSUSA". Also excluded are materials in the categories: "(b) cost of products bought and sold as such; (c) cost of fuels consumed for heat or power; (d) cost of purchased electricity; and (e) cost of contract work done for you by others."

6 "Shoe and Tell," *The New Republic*, September 12, 1994.

Gereffi, 1993), electronics (Alic and Harris, 1986), and many other industries in the United States, and must be included in any valid measure of outsourcing.

A related question about what constitutes outsourcing arises in Lawrence (1994), who focuses on the imports of U.S. multinational firms as one measure of outsourcing. Similarly, Krugman (1994) argues that flows of foreign direct investment through multinational firms is also too small to account for the observed wage or employment changes. In contrast, we adopt a more general definition of outsourcing, which in addition to imports by U.S. multinationals, includes all imported intermediate or final goods that are used in the production of, or sold under the brandname of, an American firm. The reason the brandname is important is that some of these U.S. firms will also be engaged in manufacturing activities, and therefore included in the *Census of Manufactures*. As these firms choose to import rather than produce domestically, the composition of their workforce between production and nonproduction workers will certainly be affected. In our model, such outsourcing occurs due to growth in the relative Southern capital stock, or neutral technological progress in that country relative to the North.

If our more general definition of outsourcing is accepted, the question is whether this can account for a significant part of the shift towards nonproduction workers in the U.S. To determine this, we extend the regressions presented by Berman, Bound and Griliches (1994), in which changes in the share of nonproduction labor in the total wage bill is explained on the basis of various industry variables. They did not include imports as an explanatory variable, whereas we shall include the change in the import share.[7] The data are a panel of 450 four-digit SIC industries in the U.S., which is an revised version of that used by Berman, Bound and Griliches.[8]

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7 Borjas, Freeman and Katz (1992, p. 223) also included the change in the import share in regressions explaining the relative employment share of production workers in the U.S. We shall follow Berman, Bound and Griliches (1994) in using the share of nonproduction workers in the total wage bill as the dependent variable.

8 The domestic data is taken from the NBER productivity database (Bartelsman and Gray, 1994), while the import data is taken from the trade database (Abowd, 1991).

The mean values for the variables over several time periods are presented in Table 2.[9] We see that the annual increase in the share of nonproduction labor in the wage bill doubled from 0.21% to 0.43% between the 1973-79 period and 1979-87. Capital is measured both as an aggregate, and separately as plant and equipment. Production became more capital-intensive over all the periods shown, but this is explained by the growth of equipment/output rather than plant/output, while the growth of output slowed continuously over the time periods. It is notable that the annual increase in the import share also doubled from 0.29% to 0.66% between 1973-79 and 1979-87 (the aggregate value of the import share was 8.3% in 1979 and 13.1% in 1987).

In Table 3 we report the results from regressing the annual change in the share of nonproduction workers on a constant, dummy variables for the 1973-79 and 1979-87 periods, other variables used by Berman, Bound and Griliches, and the change in the import share. The first equation in Table 3 shows the result of just including the import share and time dummies. The coefficient of 0.17 on the import share is highly significant, and is also economically important: multiplying this by the annual growth rate of 0.656% for the import share we obtain an impact of 0.11% on the share of nonproduction labor, or about *one-quarter* of the annual change in this variable over 1979-87. The same estimate is obtained when the change in the capital/output ratio is included. However, when plant and equipment are included separately in regression (3), the coefficient on the change in the import share drops to 0.098. Again multiplying this by the annual growth rate of 0.656% we obtain an impact of 0.064% annually on the share of nonproduction labor, or 15% of the annual change over 1979-87. When the growth in output is included along with the capital/output labor in regression (4), the import coefficient drops further; but when output growth is included along with plant and equipment in regression (5), we again find that rising imports explains about 15% of the increase in the share of nonproduction labor.

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[9] We follow Berman, Bound and Griliches in weighting the data by the share of the industry wage bill in manufacturing averaged over the years 1959 and 1973 for the 1959-73 change, 1973 and 1979 for the 1973-79 change, and 1979 and 1987 for the 1979-87 change.

In Table 4 we repeat the same regressions, but using only the 1979-87 period. When the change in the import share is included alone, or with the capital/output ratio, then its coefficient of 0.225 explains fully *one-third* (0.225 x 0.656/0.431) of the increase in the share of nonproduction labor. The import coefficient is entirely insignificant when plant and equipment are entered seperately (regression 3), but becomes significant again when the output variable is included. If we are willing to ignore the highly imprecise estimate in regression (3), then the range of coefficients obtained indicate that the growth of imports over 1979-87 explains 15-33% of the increase in the share of nonproduction labor, which is slightly wider than the range we obtain over the entire 1959-87 period.

It would be of interest to extend this estimation to later years, especially since the wages of nonproduction workers rose so much at the end of the 1980's. While the nonproduction share and other domestic variables are available for later years, this is not the case for the import data, which are available only on an SIC basis until 1985. For the data used in Tables 2-4, we have followed Berman, Bound and Griliches (1994, note 7) in extrapolating the import data forward to 1987, treating the annual growth of import shares over 1979-85 and 1979-87 as identical. Obviously, there is little point in estimating these regressions over later time periods until the import data are concorded to the domestic SIC data, as described for the years before 1985 in Abowd (1991).

Extending the data forward would also allow the estimation to be performed separately within individual industries (or narrow groups), since there is no reason for the coefficients of the import shares and other variables to be identical across industries, as we have presumed. This point can be emphasized by plotting the values for the change in the nonproduction share of the wage bill (ΔS_N) against the change in the import share (ΔS_M), over 1979-87, as in Figure 5; both variables are weighted by the share of the industry wage bill in total manufacturing, averaged over the two years 1979 and 1987, and then multiplied by 100. This is the same weighting scheme that was used in the regressions in Table 4, and means that only those SIC industries that have a large change in the shares, and are also reasonably large within total manufacturing, will be important. The regression line shown in Figure 5 has the slope 0.225, as in the first regression of Table 4.

It is evident from the Figure 5 that there is an enormous variation across industries in the relation between the change in the import shares, and the change in the nonproduction share of the wage bill. Moving in a clockwise direction, the SIC industries labeled in Figure 5 are as follows:

1972 SIC Number	Description
3662	Radio and TV communications equipment
3661	Telephone and telegraph apparatus
2711	Newspapers
3721	Aircraft
3674	Semiconductors and related devices
3573	Electronic computing equipment
3679	Electronic components, not elsewhere classified
3312	Blast furnaces and steel mills
3714	Motor vehicle parts and accessories
2033	Canned fruits and vegetables
2037	Frozen fruits and vegetables
3711	Motor vehicles and passenger car bodies

Except for the first and last industries listed, the others all show a positive relation between the increase in the nonproduction share of the wage bill and rising imports, though the magnitude of this relation varies considerably. The first industry above (radio and TV communications equipment) has a very large increase in the nonproduction wage-bill share, but a fall in imports, and conversely for the last industry (motor vehicles and car bodies).[10] Prominent in the list above are various industrial machinery, electronic and transportation industries (SIC 35, 36 and 37).

10 If we exclude SIC 3711 (motor vehicles and car bodies) from the regressions in Tables 3 and 4, then our results are strengthened, and we find that 20-40% of the increase in the share of nonproduction labor in the wage bill is explained by rising imports.

Also present are canned and frozen fruits and vegetables (SIC 203), which has experienced a significant outflow of foreign investment to Mexico as processing of these products occurs closer to the growing sites (Feenstra and Rose, 1993). Curiously absent from the list, however, are textile, apparel and footwear industries (SIC 22, 23, and 31). These observations underscore the importance of investigating the link between imports and wages using an industry-by-industry approach.

5. Evidence from Mexico

Foreign Investment

During the 1980's, Mexico experienced a dramatic increase in foreign capital inflows. Figure 6 shows foreign direct investment (FDI) in Mexico, and FDI as a share of total fixed capital investment. The measure of FDI we use is that calculated by the Mexican National Commission on Foreign Investment, which collects data directly from foreign firms on new investments and reinvestments from retained earnings (Nacional Financiera, 1990). Between 1983 and 1989, the level of FDI in Mexico increased from $478 million to $3,635 million; the share of FDI in total investment increased from 1.4 percent to 9.7 percent.

The boom in FDI is attributable, at least in part, to reforms by the Mexican government during the 1980's which eased restrictions on foreign ownership. Mexico has a long history of regulating the activities of multinational enterprises. Restrictions on foreign investment reached their height in the 1970's, when the government began to strictly enforce a 49-percent foreign ownership cap on equity holdings in a given firm. Following the onset of the Mexican debt crisis in 1982, the government reversed its policy and began to eliminate impediments to foreign capital. In particular, the government waved the 49-percent foreign ownership cap for many new investors. A new foreign investment law passed in 1989 formally lifted the 49-percent cap, and opened most sectors of the economy to FDI (Whiting, 1992).

A large share of the FDI in Mexico has gone into in-bond assembly operations, known as *maquiladoras*, which are an example of foreign outsourcing by multinationals.

Not all maquiladoras are foreign-owned, but the majority appear to be; of the 100 largest maquiladoras in 1990, 88 were majority-owned by foreign entities.[11] While we do not have data on the portion of FDI which has gone into maquiladoras, we do have data which show that the FDI boom coincided with a large expansion in assembly operations. Figure 7 shows total maquiladora employment from 1978 to 1990, both in the number of workers and as a share of manufacturing employment. During the period 1978 to 1983, assembly employment grew at an average annual rate of 10.2 percent; during the period 1983 to 1990, it grew at an average annual rate of 15.9 percent.[12] The share of maquiladora workers in total manufacturing employment increased dramatically from 4.9 percent in 1980 to 19.0 percent in 1990. Maquiladora activities are concentrated in states along the Mexico-U.S. border: in 1990, the border region accounted for 90.3 percent of total assembly employment.

Relative Wages and Employment

Mexico's FDI boom represents a natural experiment of sorts, since it was large in relation to total capital investment and in the employment generated. The model we developed in the previous sections predicts that such capital inflows will increase the demand for skilled workers relative to that of unskilled workers, and cause the relative wages of skilled workers to increase. This prediction was confirmed for Mexico as a whole from the Industrial Census data in Figure 1. Since much of the foreign investment has been concentrated in the Mexico-U.S. border region, the relative-demand effects should be strongest for border states. Hence, it is the border where we expect to observe the largest changes in relative wages.

We report data on the wages and employment of skilled and unskilled workers in Mexico from a panel of 2,354 manufacturing plants for the period 1984-1990 surveyed

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11 "Las maquiladoras mas importantes de Mexico," *Expansion*, October 24, 1990, pp. 35-52.

12 While the majority of production workers in maquiladoras are female, this share has been declining over time, from 77.3% in 1980 to 63.1% in 1988. Despite this declining share, we will see that the relative wage of production workers has been falling in assembly plants.

by the Mexican Ministry of Trade (SECOFI).[13] This sample classifies employees either as production workers or as nonproduction workers. Table 5 shows that there has been a dramatic increase in the wage of nonproduction relative to production workers in the SECOFI sample of plants. Between 1984 and 1990, the ratio of average hourly nonproduction and production wages increased from 1.93 to 2.55; the ratio of average annual earnings showed a similar change.[14] These data reinforce the conclusion from Figure 1 of rising relative wages in the latter-half of the 1980's, that reverses a prolonged period of falling relative wages.

Despite the magnitude of the relative-wage changes, there were only small changes in the relative employment of nonproduction and production workers in Mexico during the 1980's. Table 6 shows the ratio of nonproduction and production employment for the SECOFI panel of plants. Between 1984 and 1990, the ratio of aggregate employment in the SECOFI sample of plants increased from 0.431 to 0.433; the ratio of aggregate total hours declined from 0.427 to 0.421. While average relative employment did not change, the variance in relative employment within industries changed considerably. The fifth and final columns of Table 6 report the weighted-average standard deviation in relative employment for four-digit industries, where weights are industry shares of total employment. The standard deviation of relative employment increased by approximately 25 percent between 1984 and 1990. This is consistent with the pattern of production and employment changes that occur in our model. As noted in section 2, when the South moves into new activities that are more skilled-labor intensive than those previously performed, an increase in the variance of skilled/unskilled labor in activities within the industry is expected. This prediction is confirmed by the standard deviations in Table 6.

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13 The sample contains medium and large plants that account for approximately 30 percent of Mexican manufacturing employment in any given year.

14 The data we report are averages over manufacturing plants, and do not control for changes in the composition of the labor force, but similar results have been found in studies that use microlevel data (Feliciano, 1993 and Bell, 1994). The drop in annual earnings for 1988 in Table 5 is due to the very high rate of inflation from June 1987-June 1988, which are the dates for the consumer prices indexes used to deflate earnings.

One striking feature of Mexico's wage structure is that relative wages and changes in relative wages vary considerably across regions within the country. Table 7 shows relative average hourly wages and relative average annual earnings for the SECOFI sample by region.[15] Not only does the Border have the highest relative wages in any given year, but that region also experienced the largest increased in relative wages over the period 1984-1990. The region with the next highest relative wages and the next highest increase in the relative wage is the North.

One explanation for the regional variation in relative wages may be that the border, for whatever reason, contains a relatively high concentration of industries that are relatively intensive in the use of skilled labor. To control for the effects of industry composition on regional relative wages, we calculate the regional average wage differential, which is defined as the weighted sum of the log difference between the plant's relative wage and the industry average relative wage, where weights are the plant share of the regional wage bill. Table 8 reports the results. Controlling for industry, we still find that the border has the highest relative wages and the largest increase in the relative wage. This confirms our expectations about the regional effects of FDI on Mexico's wage structure.

The boom in FDI was certainly not the only shock to the Mexican economy in the 1980's. Two events of particular importance for the labor market were the liberalization of trade, which was initiated in 1985, and the relaxation of minimum wages, which began in 1983. We regard the trade liberalization as an additional cause of the foreign investment boom, since firms entering Mexico would be able to import inputs at lower tariffs, and could also be anticipating the future reduction of U.S. and Canadian trade barriers under the NAFTA. Thus, the liberalization of trade and foreign investment are highly complementary, and we shall not attempt to disentangle these effects.

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15 The Border contains states that border the United States; the North contains the next tier of northern states; the Center contains states surrounding Mexico City; Mexico City contains the two states the capital occupies; and the South contains all states south of the capital.

The relaxation of minimum wages, by contrast, does not appear to have been an important factor in the relative wage movement. During the 1980's, the Mexican government chose not to increase minimum wages in line with inflation. The result was a decrease in the real product minimum wage by 30.8 percent between 1984 and 1990. Bell (1994) studies minimum wages and labor demand in Mexico over the period 1984 to 1990 using the SECOFI sample data. She finds that in 1984, the year minimum wages were most binding, only 1.9 percent of manufacturing plants had an average production worker wage at or below the minimum. She also finds no evidence of a negative correlation between minimum wages and employment. These results suggest that the decline in minimum wages do not account for the fall in the relative wage of production workers.

6. Conclusions

For the United States, the regression results reported in section 4 indicate that 15-33% of the shift towards nonproduction labor within U.S. manufacturing industries over 1979-85 is explained by the rising import share. This figure can be compared to the estimated impact of computers from Berman, Bound and Griliches (1994), who find that 40% of the increase in the share of nonproduction labor can be attributed to the rapid introduction of computers during the 1980's. (These authors find also find that just under 40% of the shift towards non-production labor can be explained by R&D expenditures). While the impact of trade in these estimates is less than the impact of computers, we have not considered several other ways that trade competition can affect wages and employment.

First, trade has an impact on wages and employment through the amounts of skilled versus unskilled labor embodied in exports and imports, which can be modeled as (hypothetical) changes in the endowments these factors. Borjas, Freeman and Katz (1992) find that trade flows between 1980 and 1980 can explain up to 15% of the increase in the earnings differential between college-educated workers and those with only high-school education's in the U.S. Leamer (1993) obtains a somewhat higher estimate of 20% as the amount of income transferred away from low-skilled workers in the U.S. in 1985, that can be attributed to trade. On the employment side, Wood (1994) suggests that no less than 20% of the decline in the demand for unskilled relative to skilled workers in developed countries over 1960-1990 is due to trade, with three-quarters of this decline taking place during the 1980's. Most recently, Sachs and Shatz (1994) estimate that as much as 40% of the difference between the employment growth during 1950-1978 and employment decline during 1978-1990 in U.S. manufacturing can be attributed to the impact of trade. The employment decline during the latter period has been disproportionately on production workers.

Second, it is quite possible that a cross-sectional analysis of industry changes misses some of the impact of trade. We have already seen this in our data for Mexico, where there was little change in the ratio of production to nonproduction workers within individual industries or manufacturing overall (Table 6), but substantial changes in employment and wages across regions of the country (Table 7), especially the border with the U.S. This suggests that *regional variation* may be able to pick up effects of trade that cross-industry data does not. This is confirmed for Mexico in Feenstra and Hanson (1995), who find that over 50% of the increase in the share of skilled labor in total wages is explained by growth in FDI in the border region. Borjas and Ramey (1993) have used data on wages across metropolitan areas in the U.S. to study the impact of trade in durable goods, and obtain a lower-bound of 10% as the impact of trade on wages. Furthermore, *time-series variation* within each industry can be expected to give a more accurate description of the impact of imports, since there is no reason for the amount of outsourcing to be similar across industries.

Finally, variation in plants within each industry can also show greater changes than the industry data itself. We found this was true for the Mexican plant-level data, which showed increases in the variance of nonproduction/production employment across plants within each industry (Table 6), consistent with our theoretical model. For the U.S., Bernard and Jensen (1993) have used plant-level data to decompose the increase in relative nonproduction employment into "within" versus "between" plant effects. They obtain much higher estimates of the "between" effect than found by Berman, Bound and Griliches (1994) using industry-level data, and furthermore, these effects are dominated by the changes in employment at *exporting plants.* Their results reinforce our conclusion that, in addition to technological change, trade and investment are important contributing factors to the decline in the relative wages and employment of unskilled workers in the United States.

Appendix

Proof of Lemma 1:

Part (a) follows from differentiation of (9) and the analogous relative demand for the North. To establish part (b) for the South, we can differentiate (9) and rewrite terms to obtain:

$$\frac{\partial \ln D_S}{\partial \ln(q_S/w_S)} = \int_0^{z^*} [g_L(z) - g_H(z)]\, f_H(z)\, dz \ ,$$

where, $f_j(z) \equiv a_j(z)/[a_L(z)+(q_S/w_S)a_H(z)]$, and

$$g_j(z) \equiv \alpha(z)f_j(z)/\int_0^{z^*}\alpha(z)f_j(z)dz, \text{ for } j=H,L.$$

From our assumption that $a_H(z)/a_L(z)$ is increasing in z, it follows that: (a) $f_H(z)$ is increasing in z; (b) $g_L(z)/g_H(z)$ is decreasing in z. In addition, $\int_0^{z^*} g_j(z)dz = 1$ so that there exists at least one point $z^0 \varepsilon (0,z^*)$ at which $g_L(z^0)=g_H(z^0)$. From (b), it follows that $g_L(z)>g_H(z)$ for $z<z^0$, and $g_L(z)<g_H(z)$ for $z>z^0$, and that:

$$\int_0^{z^0} [g_L(z)-g_H(z)]dz = - \int_{z^0}^{z^*} [g_L(z)-g_H(z)]dz > 0.$$

In addition, from (a) we have that $f_H(z)<f_H(z^0)$ for $z<z^0$, and $f_H(z)>f_H(z^0)$ for $z>z^0$. Combining these various results, we obtain:

$$\int_0^{z^*} [g_L(z) - g_H(z)]\, f_H(z)\, dz < \int_0^{z^0} [g_L(z) - g_H(z)]\, f_H(z^0)\, dz + \int_{z^0}^{z^*} [g_L(z) - g_H(z)]\, f_H(z^0)\, dz = 0,$$

which establishes that $\partial \ln D_S/\partial \ln(q_S/w_S) < 0$. The proof for the Northern relative demand curve is similar. QED

Proof of Lemma 2:

The stability condition can be obtained by totally differentiating condition (4), allowing for changes in the capital stocks K_i and the technology parameters A_i, i=N,S. We let $\theta^*_{Li} \equiv w_i a_L(z^*)/[w_i a_L(z^*)+q_i a_H(z^*)]$ denote the share of unskilled labor in the total wage bill of the critical input z^*, i=N,S, with $\theta^*_{Hi}=1-\theta^*_{Li}$ denoting the share of skilled labor. The share of the wage bill in total costs of production for each input is θ. Then differentiating (4) we obtain:

$$\left(\frac{\partial \ln C_S}{\partial z^*} - \frac{\partial \ln C_N}{\partial z^*}\right)dz^* = \theta[(\theta^*_{LN}\hat{w}_N+\theta^*_{HN}\hat{q}_N)-(\theta^*_{LS}\hat{w}_S+\theta^*_{HS}\hat{q}_S)]+(1-\theta)(\hat{r}_N-\hat{r}_S)+(\hat{A}_S-\hat{A}_N), \quad \text{(A1)}$$

using $\hat{A}_i=-\hat{B}_i$. The term in brackets on the left is the difference between the slopes of the C_SC_S locus and the C_NC_N locus at the point z^*, which is positive. Other terms in this expression can be simplified as follows:

(i) With the normalization $E\equiv1$, the values of industry production E_i in (10) can be written alternatively as shares of world production, $E_N=\int_{z^*}^{1}\alpha(z)dz$ and $E_S=\int_{0}^{z^*}\alpha(z)dz$. Then the changes in the returns to capital are computed from (7) and (11) as $\hat{r}_N=-\hat{K}_N-[\alpha(z^*)/E_N]dz^*$ and $\hat{r}_S=-\hat{K}_S+[\alpha(z^*)/E_S]dz^*$.

(ii) The change in the labor costs of producing the critical input z^* in the North, $(\theta^*_{LN}\hat{w}_N+\theta^*_{HN}\hat{q}_N)$, can be rewritten as:

$$(\theta^*_{LN}\hat{w}_N+\theta^*_{HN}\hat{q}_N) = (\lambda_{LN}\hat{w}_N+\lambda_{HN}\hat{q}_N) + (\theta^*_{HN}-\lambda_{HN})\frac{\partial \ln(q_N/w_N)}{\partial z^*}dz^*$$

$$= \left\{-\left[\frac{\alpha(z^*)}{E_N}\right]+(\theta^*_{HN}-\lambda_{HN})\frac{\partial \ln(q_N/w_N)}{\partial z^*}\right\}dz^*,$$

where the first line follows because the cost-shares and factor-shares each sum to unity, and the second line follows from (11b). The cost share of skilled-labor used in z^* in the North is less than the average for the economy, $\theta^*_{HN}<\lambda_{HN}$, and also

$\partial \ln(q_N/w_N)/\partial z^* > 0$ as illustrated in Figure 3, so that the final term in the brackets above is negative.

(iii) Similarly, for the South we have:

$$(\theta^*_{LS}\hat{w}_S + \theta^*_{HS}\hat{q}_S) = \left\{\left[\frac{\alpha(z^*)}{E_S}\right] + (\theta^*_{HS} - \lambda_{HS})\frac{\partial \ln(q_S/w_S)}{\partial z^*}\right\} dz^*.$$

The cost share of skilled-labor used in z^* in the South exceeds the average for the economy, $\theta^*_{HS} > \lambda_{HS}$, and also $\partial \ln(q_S/w_S)/\partial z^* > 0$, so that the final term in the brackets above is positive.

Substituting these various results in (A1), (12) is established with:

$$\Delta^{-1} = \left[\left(\frac{\partial \ln C_S}{\partial z^*} - \frac{\partial \ln C_N}{\partial z^*}\right) + \left(\frac{\alpha(z^*)}{E_N} + \frac{\alpha(z^*)}{E_S}\right) + \theta\left((\theta^*_{HS} - \lambda_{HS})\frac{\partial \ln(q_S/w_S)}{\partial z^*} - (\theta^*_{HN} - \lambda_{HN})\frac{\partial \ln(q_N/w_N)}{\partial z^*}\right)\right]$$

$$> \left(\frac{\alpha(z^*)}{E_N} + \frac{\alpha(z^*)}{E_S}\right).$$

where the final inequality follows from the signs established above. QED

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Table 1: Employment-Weighted Percentage Changes in Wholesale and Import Prices

United States (1980-89)	Domestic Prices	Import Prices
All manufacturing industries		
Nonproduction weights	33.1	26.0
Production weights	32.3	28.1
Japan (1980-90)		
All manufacturing industries		
Nonproduction weights	-5.60	-18.23
Production weights	-3.90	-17.29
• without Office Machines		
Nonproduction weights	-7.09	-18.69
Production weights	-4.72	-17.50
• also without Petroleum Products		
Nonproduction weights	-6.98	-18.45
Production weights	-4.66	-17.39
Germany (1980-1990)		
All manufacturing industries		
Non-manual weights	23.98	15.24
Manual weights	26.03	17.07
• without Office Machines		
Non-manual weights	24.79	15.38
Manual weights	26.21	17.11
• also without Petroleum Products		
Non-manual weights	24.97	15.70
Manual weight	26.28	17.24

Notes
Nonproduction and non-manual weights weigh each industry's price change by that industry's share of total manufacturing employment of nonproduction and non-manual workers; and similarly for production and manual worker weights. Industries are defined at the 3-digit SIC level for the U.S., and generally correspond to the 2-digit SITC level for Japan and Germany.

Sources: Lawrence and Slaughter (1993, Table 3 and 4); Lawrence (1994, Table 4).

Table 2: Annual Rates of Change in U.S. Variables, Selected Periods

Variable	1953-1973	1973-1979	1979-1987
ΔS_N	0.070	0.208	0.431
$\Delta \ln(K/Y)$	0.241	1.159	0.813
$\Delta \ln(P/Y)$	-0.445	-0.463	-0.557
$\Delta \ln(E/Y)$	1.281	2.589	1.858
$\Delta \ln Y$	4.095	2.221	1.800
ΔS_M	0.249	0.290	0.656

Notes:
Data are weighted by the average share of the industry wage bill in manufacturing.

The sample consists of 450 4-digit SIC manufacturing industries for all variables except ΔS_M, in which case data is available for 436 manufacturing industries (435 in 1979-87).

Variables are defined as:

ΔS_N = 100 x annual change in nonproduction workers' share of wage bill;
$\Delta \ln Y$ = 100 x annual change in natural log of real output
$\Delta \ln(K/Y)$ = 100 x annual change in ln(capital stock/real output)
$\Delta \ln(P/Y)$ = 100 x annual change in ln(plant/real output)
$\Delta \ln(E/Y)$ = 100 x annual change in ln(equipment/real output)
ΔS_M = 100 x annual change in imports/(shipments+imports)

Source:
NBER productivity (Bartelsman and Gray, 1994) and trade database (Abowd, 1991).

Table 3: Regression Results with Import Share

Dependent Variable: Annual Change in Nonproduction Workers' Share in Wage Bill (ΔS_N), 1959-73, 1973-79, 1979-87 Combined

Regression	(1)	(2)	(3)	(4)	(5)
$\Delta\ln(K/Y)$		0.012		0.066	
		(0.004)		(0.007)	
$\Delta\ln(P/Y)$			-0.018		0.057
			(0.005)		(0.010)
$\Delta\ln(E/Y)$			0.027		0.020
			(0.005)		(0.006)
$\Delta\ln Y$				0.051	0.060
				(0.005)	(0.006)
ΔS_M	0.170	0.173	0.098	0.056	0.095
	(0.029)	(0.029)	(0.034)	(0.036)	(0.038)
1973-79	0.138	0.126	0.105	0.180	0.231
	(0.081)	(0.083)	(0.084)	(0.096)	(0.097)
1979-87	0.299	0.291	0.311	0.425	0.463
	(0.083)	(0.083)	(0.085)	(0.096)	(0.098)
Constant	0.024	0.020	-0.002	-0.172	-0.205
	(0.058)	(0.059)	(0.060)	(0.071)	(0.071)
R^2	0.058	0.073	0.107	0.311	0.309

Notes:

Equations are weighted by the average share of industry wage bill in manufacturing.

Sample consists of the 436 industries (435 in 1979-87) 4-digit SIC industries for which import data is available.

Table 4: Regression Results with Import Share

Dependent Variable: Annual Change in Nonproduction Workers' Share in Wage Bill (ΔS_N), 1979-87 Only

Regression	(1)	(2)	(3)	(4)	(5)
$\Delta\ln(K/Y)$		0.013		0.096	
		(0.005)		(0.006)	
$\Delta\ln(P/Y)$			-0.083		0.062
			(0.006)		(0.015)
$\Delta\ln(E/Y)$			0.104		0.047
			(0.007)		(0.008)
$\Delta\ln Y$				0.066	0.074
				(0.003)	(0.007)
ΔS_M	0.225	0.225	0.019	0.119	0.136
	(0.030)	(0.030)	(0.027)	(0.023)	(0.028)
Constant	0.287	0.277	0.178	0.156	0.158
	(0.054)	(0.053)	(0.043)	(0.040)	(0.039)
R^2	0.115	0.126	0.429	0.527	0.538

Notes:

Equations are weighted by the average share of industry wage bill in manufacturing.

Sample consists of the 435 4-digit SIC industries in 1979-87 for which import data is available.

Table 5: Average Annual Real Wages in Manufacturing, 1984-1990
(values are in 1980 pesos)

	Nonproduction Workers		Production Workers		Nonproduction/ Production	
Year	Annual Earnings	Hourly Wages	Annual Earnings	Hourly Wages	Annual Earnings	Hourly Wages
1984	138,793	62.127	72,528	32.191	1.914	1.930
1985	143,692	63.856	74,952	32.783	1.917	1.948
1986	137,444	60.641	68,525	29.929	2.006	2.027
1987	134,474	59.014	67,559	29.243	1.991	2.018
1988	122,241	53.557	57,781	24.729	2.116	2.166
1989	145,487	64.278	62,755	26.809	2.318	2.398
1990	160,502	70.460	64,935	27.691	2.472	2.545

Notes:

Real wages are nominal annual remuneration per worker and per hour worked, deflated by the June consumer price index. All figures are weighted averages, where weights are the plant share of national employment or hours.

Source: Authors' calculations based on SECOFI sample data.

Table 6: Relative Employment in Manufacturing, 1984-1990

	Number of Production and Nonproduction Workers				Thousands of Hours Worked			
	Prod'n Workers	Non-Prod'n	Mean Ratio	S.D. of Ratio*	Prod'n Workers	Non-Prod'n	Mean Ratio	S.D. of Ratio*
1984	234,851	545,477	.431	.398	524,666	1,229,016	.427	.395
1985	239,847	560,738	.428	.374	539,713	1,282,056	.421	.392
1986	242,189	550,963	.440	.401	548,925	1,261,465	.435	.414
1987	241,528	545,937	.442	.446	550,368	1,261,272	.436	.438
1988	243,741	549,839	.443	.468	556,327	1,284,741	.433	.458
1989	248,840	566,737	.439	.474	563,229	1,326,644	.425	.456
1990	250,066	577,405	.433	.492	569,629	1,353,991	.421	.492

Notes:

* This figure is computed by first calculating the standard deviation of the ratio of production/nonproduction workers or hours across plants within each four-digit industry. A weighted sum of these standard deviations is then taken, where the weights are the 4-digit industry share of total employment or total hours.

Source: Authors' calculations based on SECOFI sample data.

Table 7: Nonproduction/Production Wages by Region

Region	Year	Hourly Wage	Log Change 1984-90	Annual Wage	Log Change 1984-90
Border	1984	2.007		1.970	
	1985	2.121		2.103	
	1986	2.192		2.123	
	1987	2.271		2.220	
	1988	2.409		2.442	
	1989	2.579		2.611	
	1990	3.019	0.408	3.020	0.427
North	1984	2.002		2.061	
	1985	2.020		2.052	
	1986	2.012		2.015	
	1987	1.778		1.787	
	1988	1.697		1.868	
	1989	2.408		2.482	
	1990	2.620	0.269	2.632	0.245
Center	1984	1.798		1.695	
	1985	1.740		1.731	
	1986	1.825		1.849	
	1987	1.799		1.770	
	1988	1.860		1.849	
	1989	2.041		2.045	
	1990	1.980	0.096	2.036	0.183
Mexico City	1984	1.931		2.023	
	1985	1.908		1.986	
	1986	2.005		2.036	
	1987	1.934		2.007	
	1988	2.086		2.134	
	1989	2.279		2.402	
	1990	2.523	0.267	2.605	0.253
South	1984	1.889		1.943	
	1985	1.892		1.928	
	1986	1.989		2.042	
	1987	1.994		2.060	
	1988	2.147		2.224	
	1989	2.357		2.465	
	1990	2.473	0.269	2.573	0.281

Source: Authors' calculations based on SECOFI sample data.

Table 8: Relative Wages by Region, Controlling for Industry

Region	Mean for 1984-1990* RLWGE1	Mean for 1984-1990* RLWGE2	Change for 1984-1990 RLWGE1	Change for 1984-1990 RLWGE2
Border	0.0539 (0.0281)	0.0575 (0.0288)	0.0561	0.0506
North	0.0356 (0.0762)	0.0552 (0.0727)	-0.0484	-0.0801
Center	-0.0263 (0.0159)	-0.0340 (0.0154)	-0.0484	0.0130
Mexico City	-0.0134 (0.0127)	-0.0161 (0.0089)	0.0345	0.0163
South	-0.0169 (0.0193)	-0.0129 (0.0190)	0.0111	-0.0024

Notes:

Figures are the regional weighted sums of variables defined below, where the weights are plant share of the regional wage bill, and relative wage is the nonproduction/production wage. Industries are defined at the four-digit level.

RLWGE1 = log plant relative annual wage - log industry relative annual wage
RLWGE2 = log plant relative hourly wage - log industry relative hourly wage

* Means and standard deviations (in parentheses) are taken over the seven years for which the weighted sums are calculated.

Source: Authors' calculations based on SECOFI sample data.

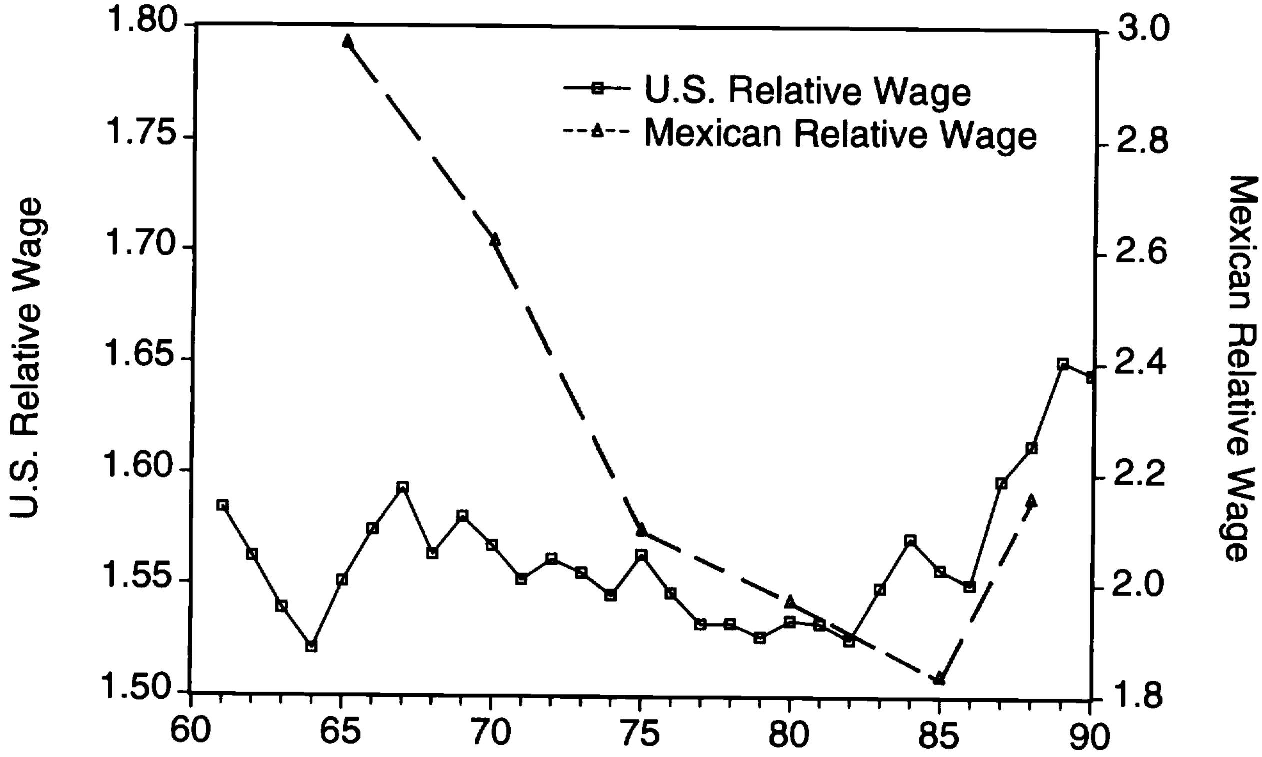


Figure 1: Relative Wages of Nonproduction/Production Workers

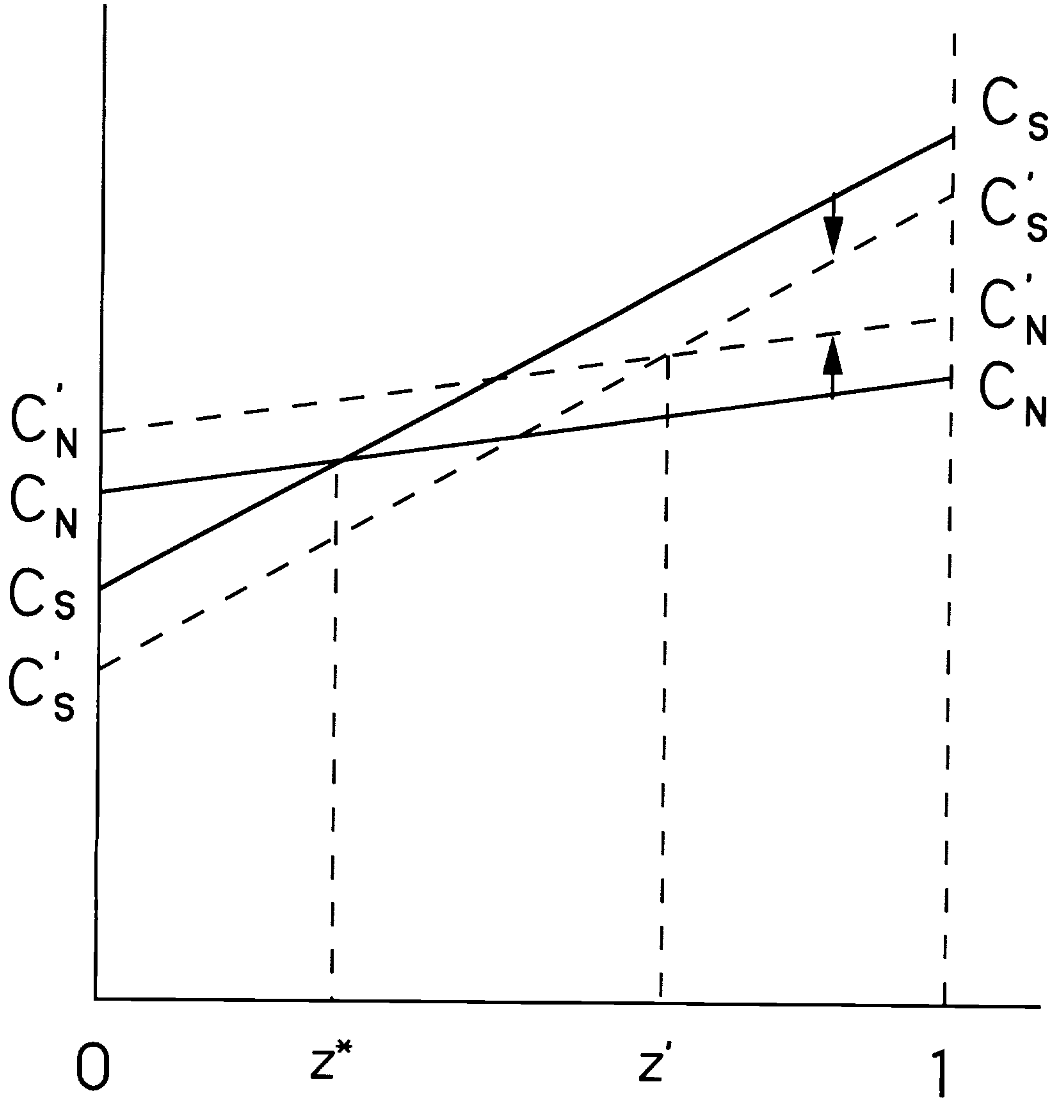


Figure 2

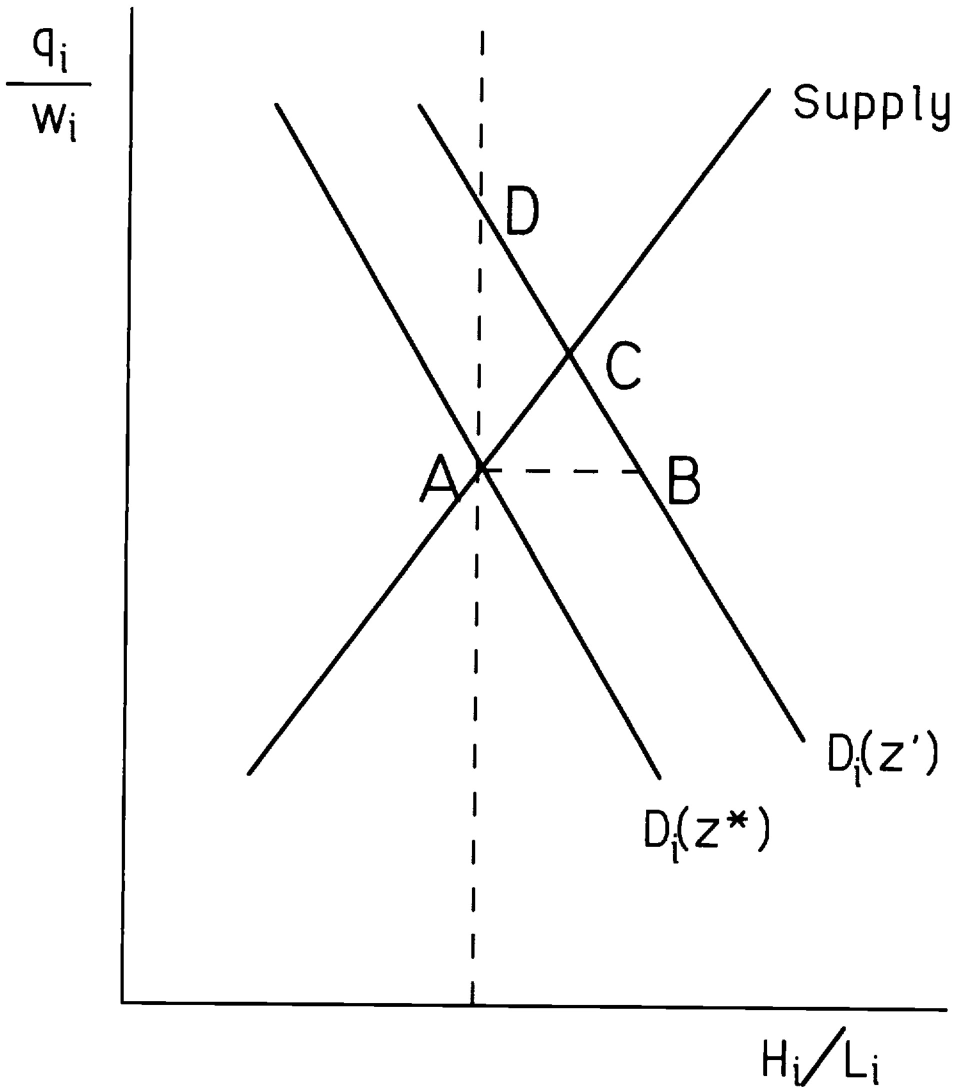


Figure 3

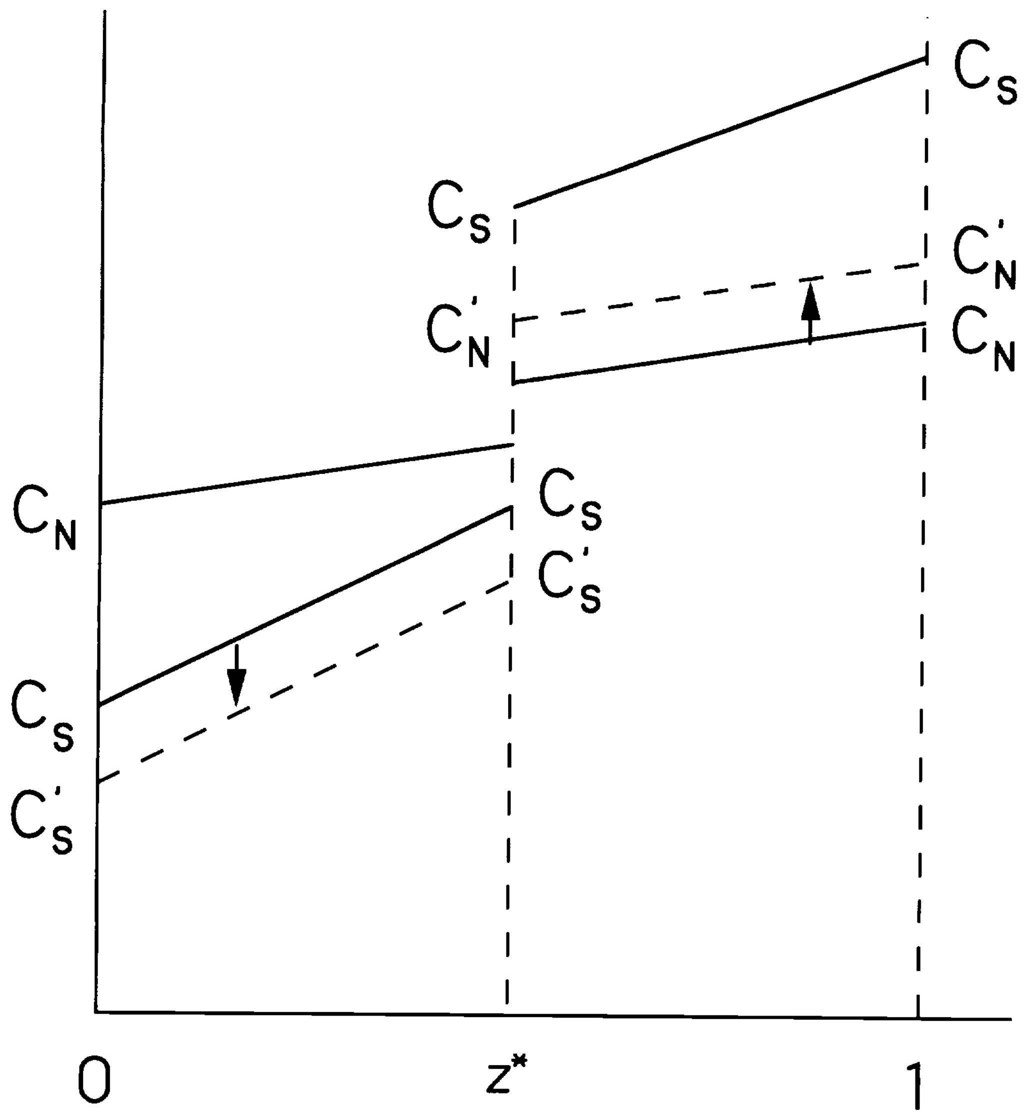
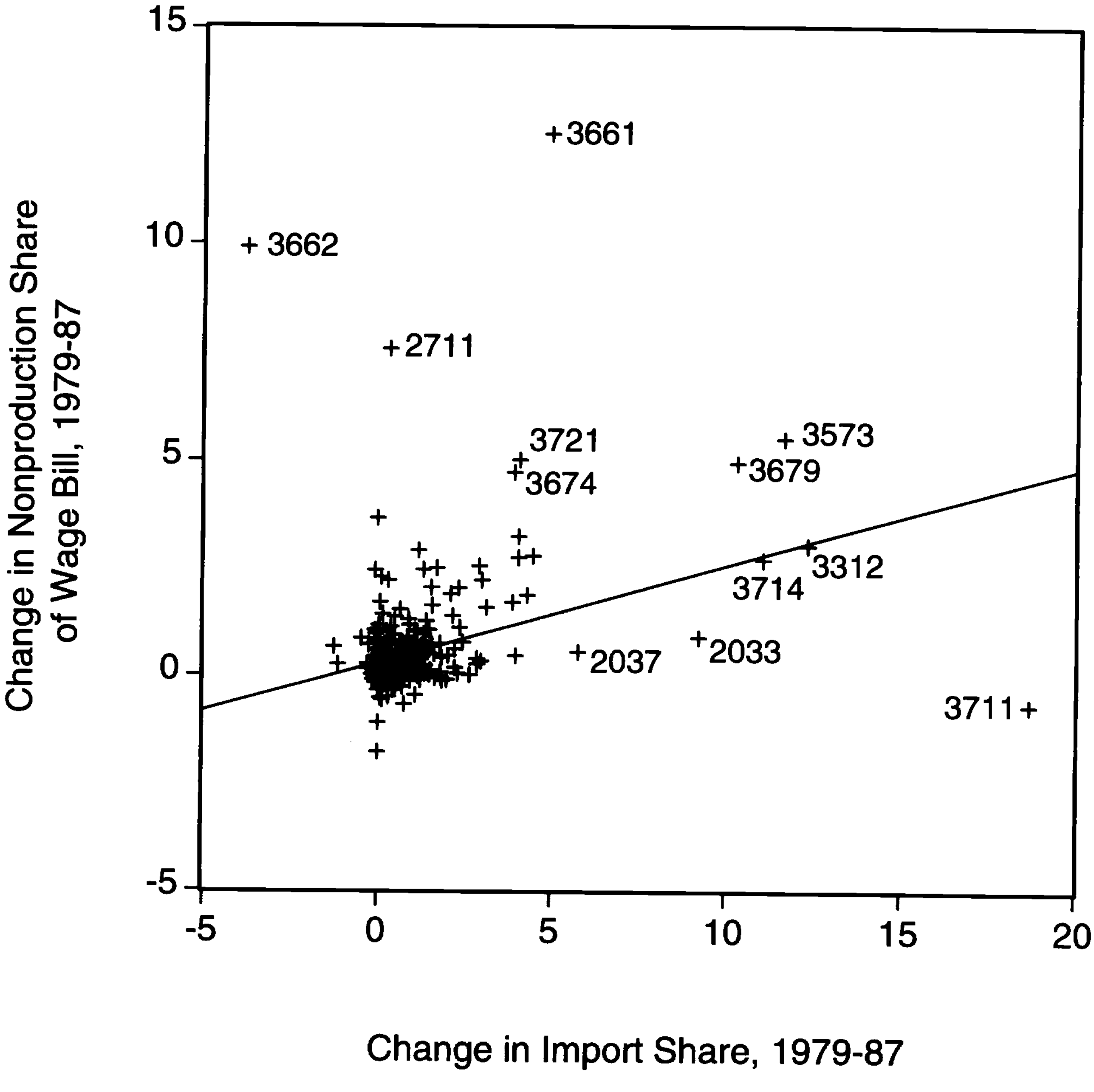


Figure 4



Change in Nonproduction Share of Wage Bill, 1979-87
Change in Import Share, 1979-87
15
10
5
0
-5
-5
0
5
10
15
20
3661
3662
2711
3721
3674
3573
3679
3714
3312
2037
2033
3711

Figure 5

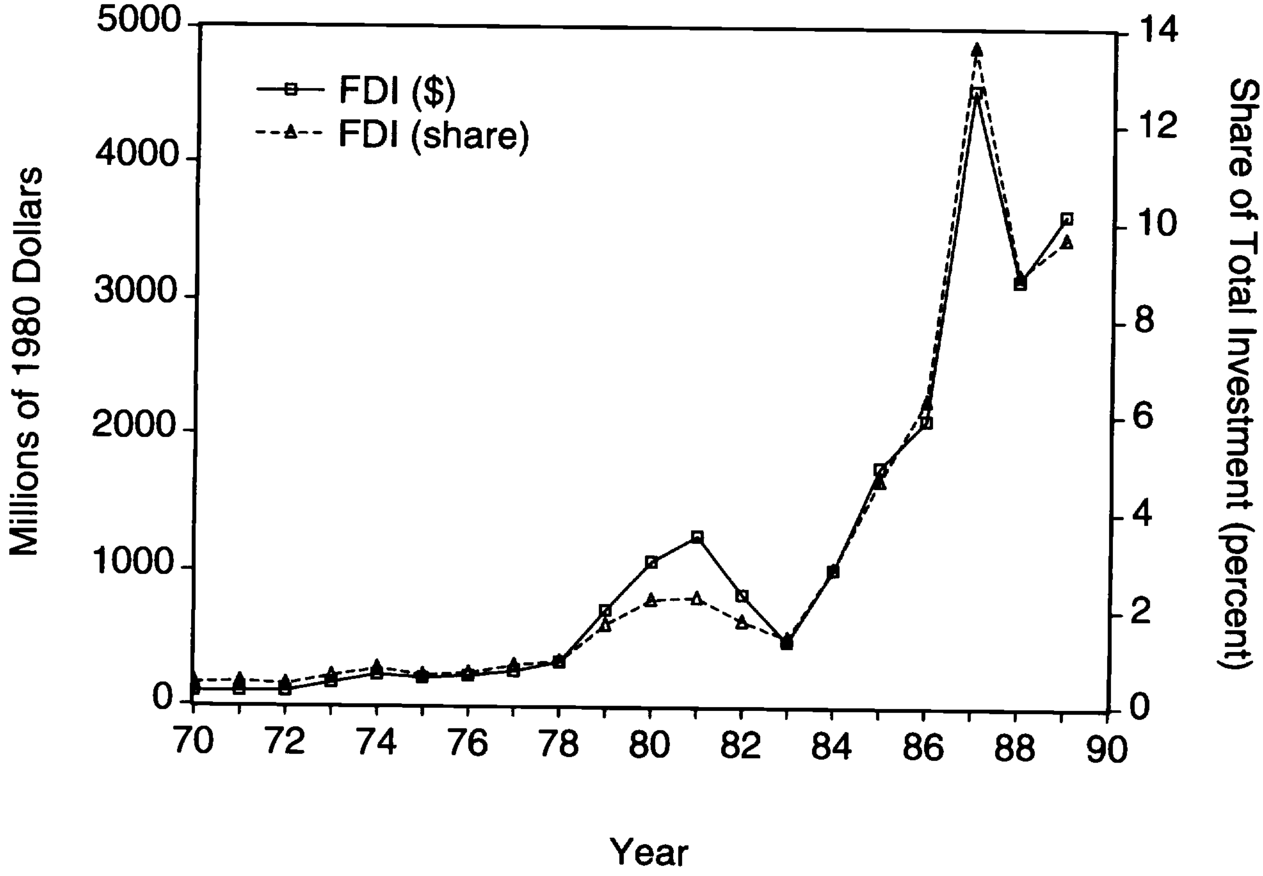


Figure 6: Foreign Direct Investment into Mexico

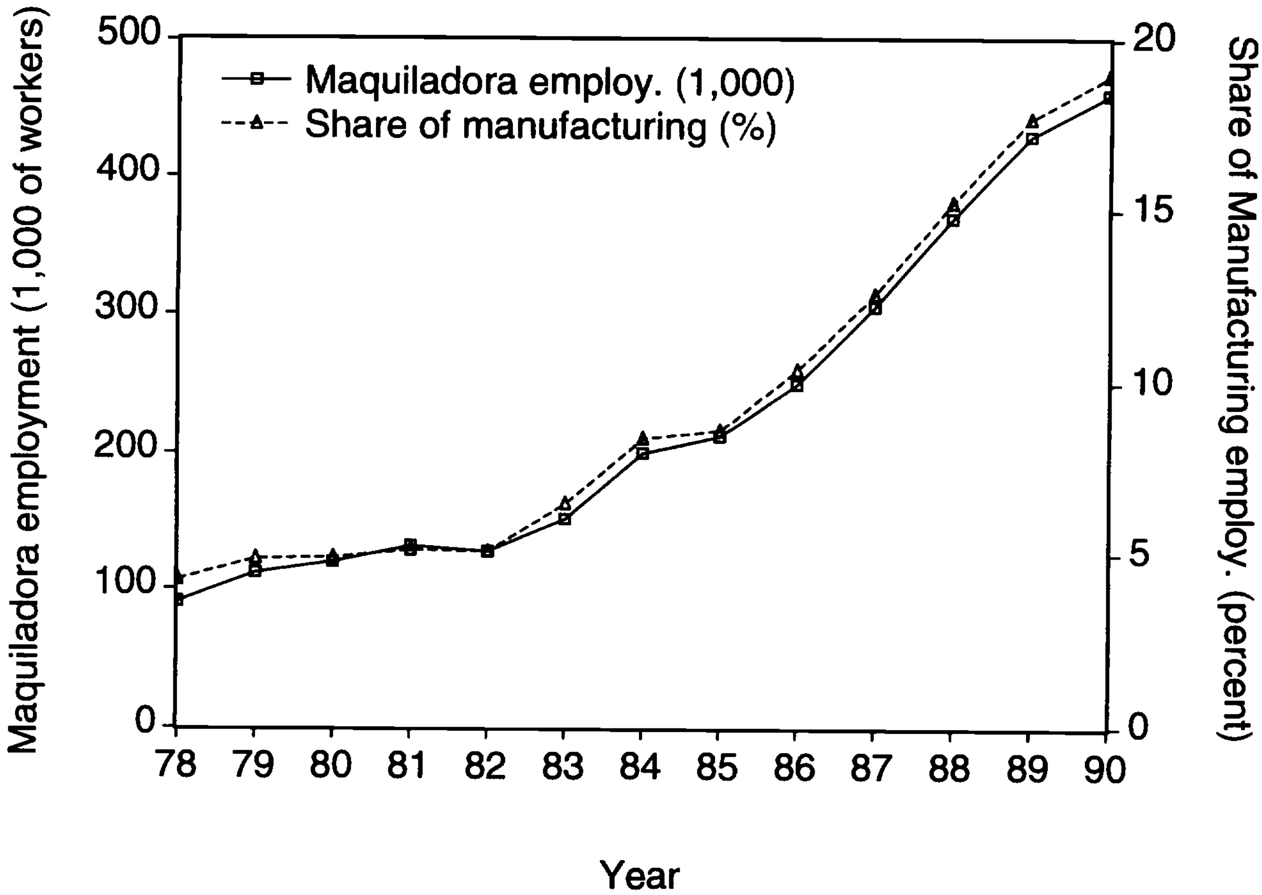


Figure 7: Maquiladora Employment