Trade and Variety-Skill Complementarity:

A Simple Theoretical Resolution of Trade-Wage Inequality Anomaly

(Job Market Paper)

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The Stolper-Samuelson theorem predicts that the relative wage of high-skilled labor will increase in the high-skill abundant U.S. but decrease in low-skill abundant Mexico after trade liberalization, while data shows that the skill premium began to rise in both countries in the late 1980s. This paper presents a simple theoretical resolution of this "trade-wage inequality anomaly." The resolution is a straightforward application of well-known variety trade models. Intra-industry trade increases the variety of intermediate goods used by the final good. If the varieties and high skill are complements, the skill premium rises in both countries. This linking of intra-industry trade to wage inequality is consistent with evidence. Our numerical experiments show that increased intra-industry trade can account for much of the increase in U.S. and Mexican skill premium for a reasonable parameterization of the model. (*JEL* F12, F16)

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One of the most well documented empirical facts in recent U.S. economic history is that, as Figure 1 shows, the relative wage of high-skilled to low-skilled labor began to rise in the late 1980s, and this fact was observed in Mexico as well.[1] As can be seen, these two countries showed a surprising similar timing of the rise in relative wage.

One traditional explanation for this rising wage inequality is based on technological change. A sharp decline in equipment prices in the 1980s led to an increase in the demand for high-skilled workers, who were complements for this equipment, and a decline in the demand for low-skilled workers, who were substitutes (Per Krusell et al., 2000).[2] This technology-based explanation is consistent with the decline in the price of high-tech goods and the increase in the wage inequality both in the U.S. and in Mexico.

A second explanation for the rising wage inequality is based on trade. The U.S. import of low-skill intensive goods from Mexico causes the relative demand for U.S. low-skilled workers to decline, and, therefore, the relative wage of low-skilled to high-skilled workers declines.[3] This trade-based explanation has often been criticized due to the small volume of trade. Paul R. Krugman (1995, 2000) provides a theoretical argument to explain why the small volume of trade in the U.S. makes it unlikely that trade can account for the change in wages.

However, as Figure 2 shows, U.S.-Mexican trade (as a percent of U.S. GDP) has been dramatically increasing along with the rise in relative wage since the late 1980s. Hence, we can no longer ignore the effect of trade on the recent increase in skill premium in wages. However, this poses a serious theoretical challenge. This is because the previous trade-based explanations, the standard H-O (Heckscher-Ohlin) model and its applications (Robert C. Feenstra and Gordon H. Hanson, 2003), demonstrate a

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1 We calculate the U.S. relative wage during the period 1980-1994 on the basis of the U.S. Annual Survey of Manufactures (ASM). On the other hand, we calculate the Mexican relative wage on the basis of the Mexican Monthly Industrial Survey (EIM) by means of the following method. We first calculate the average monthly wage of non-production relative to production labor. The annual average is then produced by averaging this monthly relative wage. We note that we have used non-production and production workers as an index for high-skilled and low-skilled workers in the U.S. and Mexican manufacturing industries. We follow Eli Berman et al. (1994) who show that the non-production and production classification (as well as the white- and blue-collar classification) works well as a division of the labor force by skill.

2 Lawrence F. Katz and David H. Autor (1999) and Eli Berman et al (1998) also relate technological change to wage inequality.

3 Many papers relate trade to wage inequality in the U.S. George J. Borjas and Valerie A. Ramey (1994), for example, show how trade volumes can be linked to wage inequality in the U.S. There are also many papers focusing on Mexico. Gordon H. Hanson and Ann Harrison (1999) and Ana Revenga (1997) link changes in Mexican wage inequality to changes in trade policy.

discrepancy between the model and data.[4]

The Stolper-Samuelson theorem of the H-O model predicts that the relative wage of high-skilled to low-skilled labor will increase in the high-skill abundant U.S. but decrease in low-skill abundant Mexico after trade liberalization. These models thus generate a positive relationship between the trade and wage inequality in the U.S. but generate a negative relationship in Mexico. On the other hand, as we have seen, the data shows that the trade and skill premium began to rise in both countries in the late 1980s, and thus generated a positive relationship between the trade and wage inequality in both countries. This is a “trade-wage inequality anomaly.”[5]

This paper presents a simple theoretical resolution of this trade-wage inequality anomaly on the basis of a trade model consistent with data. Our resolution is based on a straightforward application of well-known variety trade models. The standard variety trade models with monopolistic competition (Krugman, 1979; Avinash Dixit and Victor Norman, 1980; Wilfred J. Ethier, 1982) say that the variety of goods, which consumers can consume or producers can use, increases in both countries after trade, and, therefore, their utility or production increases. Let us emphasize again that they say something increases in both countries after trade.

Upon application of their logic, we show that the intra-industry trade in differentiated intermediate goods increases the variety of intermediate goods used by the final good in both countries. The increased variety of inputs then can mean the increased variety of tasks to be handled and thus corresponds to higher demand for high-skilled labor. Through this variety-skill complementarity, the relative wage of high skill—the skill premium—rises in both countries. Thus the trade-wage inequality anomaly is eliminated in our model.[6]

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4 Feenstra and Hanson (2003) interpret the standard H-O model as the model of trade in two intermediate goods which are high-skill and low-skill intensive. It is shown that the decline in low-skill intensive imported input causes the fall in the relative wage of low skill. They define the import of low-skill intensive input as the “outsourcing.” Their model displays that the price of domestic final good relative to the price of imported input rises, which is consistent with U.S. data during the 1980s.

5 The focus of this paper is on the discrepancy between the standard H-O model and the data since the late 1980s until 1994, when the North America Free Trade Agreement (NAFTA) was enacted. We should also consider whether this discrepancy remained or not after the NAFTA. Unfortunately, the movements of the Mexican skill premium after the NAFTA are unclear as will be discussed in Section IV. This problem is outside of the scope of this paper; however, further investigation is needed.

6 Elias Dinopoulos et al. (2002) also link intra-industry trade to wage inequality. Their model, however, modifies the standard one-sector variety trade model by introducing quasi-homothetic preferences for varieties and non-homothetic technology in the

This linking of the intra-industry trade to the wage inequality is consistent with available empirical evidence. The intra-industry trade between the U.S. and Mexico was extensive, and the correlation between the U.S.-Mexican intra-industry trade and the relative wage of high-skilled labor was high, over 0.98, in both U.S. and Mexican manufacturing industries during the period 1980-1994. The variety-skill complementarity is an innocuous assumption as shown by the facts about U.S. production organization, and the movements of the relative price of high-skill intensive good and the relative wage of high skill are also consistent with the observations in the U.S.

Thus the evidence presented above supports our hypothesis that trade—in particular, intra-industry trade—is one of possible causes for the rising wage inequality across countries along with technological change.

We then quantitatively test our hypothesis. For a reasonable parameterization of the model, our numerical experiments show that increased intra-industry trade is capable of explaining much of the increase in skill premium in both U.S. and Mexican manufacturing industries from 1987 to 1994.

Of course, some economists have also been successful in eliminating the anomaly on the basis of trade models. One major explanation is based on foreign direct investment. Robert C. Feenstra and Gordon H. Hanson (1996) show that foreign direct investment shifts production activities from the North to the South—an endogenous transfer of technology—and thus increases the North's outsourcing the low-skill intensive goods to the South, and these goods are high-skill intensive goods by the South standards.[7]

A second major explanation is based on the Schumpeterian mechanism. Elias Dinopoulos and Paul Segerstrom (1999) show that trade increases the relative price of innovation (the reward for innovation relative to the current level of R&D difficulty), thus encouraging high-skill intensive R&D investment in each country.[8] Daron

production of each variety, thus relating an increase in the output of each variety—not an increase in the number of variety—to an increase in the relative demand for high-skilled labor by each variety.

7 Susan C. Zhu and Daniel Trefler (2005) also show a mechanism closely related to this mechanism by Feenstra and Hanson (1996).

8 Dinopoulos and Segerstrom (1999) show that a contemporaneous correlation between an index of the relative price of innovation and an index of the U.S. skill premium was 0.80 during the period 1963-1989.

Acemoglu (2003) shows that trade "induces" skill-biased technological change in the U.S., and this improved technology can be transferred to other countries by spillover effects. Thus these explanations also demonstrate the rise in the relative wage of high-skilled labor across the countries.[9]

Compared to these past studies, this paper is successful in formulating a simpler trade model without introducing any foreign direct investment or dynamic Schumpeterian mechanism. Thus we can now show in a simpler way that increased trade is a possible explanation of increased wage inequality across countries.

The rest of this paper is organized as follows. In Section I, we formulate a very simple model of trade in differentiated intermediate goods, and we show that our model can eliminate the trade-wage inequality anomaly. In Section III, we present our numerical experiments. Finally, we summarize main results and mention future research in Section IV.

I. Model

In this section, we first formulate our model. Second, we explicitly solve the model and show that trade can increase the skill premium in both countries, thus eliminating the trade-wage inequality anomaly. Finally, we mention some economic reasons for the derived results.

A. *Ingredients of the Model*

Consider an economy with a final good sector and an intermediate goods sector. There are two types of skills: high-skilled and low-skilled labor. Their endowments are given by $\overline{H}$ and $\overline{L}$, respectively. These skills differ in that the high-skilled labor can do both high-skill and low-skill tasks while the low-skilled labor can do only a low-skill task. As will be shown later, this excludes the possibility that the relative wage of high-skilled to low-skilled labor is less than one in equilibrium.

The production side is as follows. The final good sector is perfectly competitive and non-traded. It uses a continuum of differentiated intermediate goods and the high skill.

9 Acemoglu (2003) might not be successful in explaining the fact that the U.S. and Mexico showed the surprisingly similar timing of the rise in skill premium. This is because the rise in skill premium in Mexico should be driven by the spillover effects in his model but this spillover process usually takes many years.

The technology is then given by the following constant returns to scale production function:

$$y = \left[\left(\int_0^n x(j)^{\rho} dj \right)^{\varepsilon/\rho} + H^{\varepsilon} \right]^{1/\varepsilon},$$

where y is the output of final good, $x(j)$ and H are the demand for differentiated intermediate good j and high skill, the total number of variety is n, and $0 < \rho < 1$. In our model, handling a variety of inputs is represented as handling a variety of tasks and thus corresponds to a high-skill task. We thus assume that $\varepsilon < 0$, that is, the elasticity of substitution between the varieties and high skill is given by $\sigma = 1/(1-\varepsilon) < 1$. We define this case $\varepsilon < 0$ ($\sigma < 1$) as the case where the varieties and the high skill are complements.[10]

On the other hand, the differentiated intermediate goods sector is monopolistically competitive. Firms are symmetric and follow Cournot pricing rules. There is also free entry and exit. The intermediate goods can be traded.[11] Each variety does not require handling a variety of inputs and thus can use the low-skill. The technology of each variety is then given by the following increasing returns to scale production function:

$$x(j) = \left(\frac{1}{b} \right) \max[l(j) - f, 0], \quad \forall j,$$

where $l(j)$ is the demand for low skill to produce each variety j, f is the fixed cost in terms of low skill, and b is the unit low-skill requirement. We note that the high skill can also do this low-skill task.

The demand side is as follows. For simplicity, we focus on a representative consumer who has the endowments of high skill and low skill: $\overline{H}$ and $\overline{L}$. He or she consumes the final good. His or her utility function is given by:

$$u(c) = c,$$

where c is the quantity of the final good he or she consumes. His or her budget constraint is given by:

10 In some papers, the number of inputs plays a role in a related way. Olivier Blanchard and Michael Kremer (1997) define the index of complexity which relates the increased number of inputs to more complexity in production processes. Kremer (1993) shows that higher skill workers will use more complex technologies that incorporate more tasks.

11 Trade in these differentiated goods is interpreted as intra-industry trade (Dixit and Norman, 1980; Ethier, 1982). Thus in the following discussion, the word “trade” refers to intra-industry trade.

$$p_y c = w^H H^S + w^L L^S ,$$

where p_y is the price of the final good, w^H is the wage for the high skill, and w^L is the wage for the low skill. H^S is the supply of high skill for the final sector, and L^S is the supply of low skill for the intermediate sector, which can include the high skill. We assume $0 \le H^S \le \overline{H}$, $\overline{L} \le L^S \le \overline{L} + \overline{H}$, and $H^S + L^S = \overline{H} + \overline{L}$.

The feasibility conditions for high-skilled labor and low-skilled labor are:

$$H = H^S \quad \text{and} \quad \int_0^n l(j)dj = L^S .$$

B. *Explicit Solutions and the Autarky Equilibrium*

We explicitly solve our model. First, we derive the solutions in the intermediate goods sector.[12]

Given an arbitrary n, each producer of a variety facing the indirect demand by the final good sector maximizes the profit $p(j)x(j) - w^L bx(j) - w^L f$ where $p(j)$ is the price of intermediate good j. By using the symmetry $x(j) = \overline{x}$, each variety's output $\overline{x}$ and price $\overline{p}$ corresponding to this n can be given by:

$$\overline{x} = \left[\left(\frac{w^L b}{p_y n^{(\varepsilon/\rho)-1} \rho} \right)^{\varepsilon/(1-\varepsilon)} - n^{\varepsilon/\rho} \right]^{-1/\varepsilon} H , \quad \forall j ,$$

$$\overline{p} = \frac{w^L b}{\rho} , \quad \forall j .$$

Since the price does not depend on the number of varieties n, the price when the profit of each variety becomes zero by the free entry and exit is also given by $\overline{p} = w^L b / \rho$, and the zero profit condition $\overline{p}\overline{x} - b\overline{x} - f = 0$ gives the output $\overline{x}$ of each variety. The equality of labor demand and supply in intermediate goods sector, $\overline{n}(b\overline{x} + f) = L^S$, gives the number of varieties $\overline{n}$. Thus, the price $\overline{p}$ and output $\overline{x}$ of each variety and the number of varieties $\overline{n}$ are given by:

$$\overline{p} = \frac{w^L b}{\rho} , \quad \forall j ,$$

12 More detailed solutions in the intermediate goods sector are shown in Appendix A.

$$\bar{x} = \frac{f\rho}{b(1-\rho)} \quad , \quad \forall j \, ,$$

$$\bar{n} = \frac{L^S(1-\rho)}{f} \, .$$

We next derive the solutions in the final good sector.[13]

In our model with the CES production function, it is not difficult to obtain an explicit solution for the demand for each variety by the final good sector, but we solve the maximization problem for the final good sector by means of the following short-cut method. Define a new good $X = \left(\int_0^n x(j)^\rho dj \right)^{1/\rho}$ and its price p_X, and we can show desired results more easily.

The profit of the final good sector now becomes:

$$p_y \left(X^\varepsilon + H^\varepsilon \right)^{1/\varepsilon} - p_X X - w^H H \, .$$

First, by solving the cost minimization problem for the good X, we find that the price of X is:

(1)
$$p_X = \left(\int_0^n p(j)^{\rho/(\rho-1)} dj \right)^{(\rho-1)/\rho} .$$

By symmetry $p(j) = \bar{p}$, (1) becomes:

$$p_X = n^{(\rho-1)/\rho} \bar{p} \, .$$

Second, we solve for X. Since the technology of the final good shows the constant returns to scale with X and H, we have the following equality:

$$y = \frac{p_X X + w^H H}{p_y} \, .$$

On the other hand, the demand for the final good is given by:

$$c = \frac{w^H H^S + w^L L^S}{p_y} \, .$$

The final good market clearing $y = c$ and the feasible condition for the high skill $H = H^S$ then give:

13 More detailed solutions in the final good sector are shown in Appendix B.

(2) $$X = \frac{w^L L^S}{p_X}.$$

Third, we solve for the relative wage of high-skilled to low-skilled labor w^H / w^L. The first order conditions with respect to X and H for the final sector give:

$$\left(\frac{X}{H}\right)^{\varepsilon-1} = \frac{p_X}{w^H}.$$

By using (2) and $H = H^S$, in autarky equilibrium the relative wage of high-skilled labor w^H / w^L is given by:

(3) $$\frac{w^H}{w^L} = \left(\frac{p_X}{w^L}\right)^{\varepsilon} \left(\frac{L^S}{H^S}\right)^{1-\varepsilon}.$$

This autarky equilibrium is represented in Figures 3-a and 3-b. The demand for high skill and low skill by the production side, H and L, is represented by the isoquant curve of the final good: $y = \left[\left(w^L L / p_X\right)^{\varepsilon} + H^{\varepsilon}\right]^{1/\varepsilon}$ which is given by $y = \left(X^{\varepsilon} + H^{\varepsilon}\right)^{1/\varepsilon}$ and (2). On the other hand, the supply of labor for each sector, H^S and L^S, is represented by AB. The autarky equilibrium is then achieved at A in Figure 3-a or C in Figure 3-b, and thus the relative wage of high skill w^H / w^L, given by the slope of the isoquant curve, is greater than or equal to one before trade.

Since the focus of this paper is on the skill premium, in the following main text we concentrate on the interesting case as shown in Figure 3-a, in which the relative wage of high skill given by (3) is greater than one. Thus the high skill and low skill each do their own task, letting $H^S = \overline{H}$ and $L^S = \overline{L}$. In Appendix C, we briefly analyze the case as shown Figure 3-b, in which the relative wage of high skill given by (3) is one and the high skill is doing both high-skill and low-skill tasks.

C. *Trade Equilibrium and the Elimination of Trade-Wage Inequality Anomaly*

Consider two countries: country 1 and country 2. They have identical technologies and preferences. They can be different in their endowments of high-skilled and low-skilled labor. We assume that the relative wage of high-skilled to low-skilled labor is greater than one in both countries before trade as shown in Figure 3-a.

From the derived solutions in the intermediate goods, we easily get the following information. The output $\bar{x}$ of each variety is not changed before and after trade in intermediate goods, and the supply of labor for the intermediate goods sector, which is given by $L^S = \bar{L}$ before trade, cannot fall below this $\bar{L}$ after trade. This implies that the number of varieties produced within each country, which is given by $\bar{n} = \bar{L}(1-\rho)/f$ before trade, does not decrease after trade. Thus the total number of varieties, which is available to the final sector after trade, surely increases since it is given by the sum of the number of varieties produced within each country after trade.

Given this information, we show the following results. Here, let us focus only on country 1.

First, (1) now becomes:

$$p_{X1} = \left(\int_0^{n_1} p(j)^{\rho/(\rho-1)} dj + \int_{n_1}^{n_1+n_2} p(j)^{\rho/(\rho-1)} dj \right)^{(\rho-1)/\rho}.$$

By the symmetry $p(j) = \bar{p}_1$ for $j \in [0, n_1]$ and $p(j) = \bar{p}_2$ for $j \in [n_1, n_1 + n_2]$, this p_{X1} becomes:

$$p_{X1} = \left(n_1 \bar{p}_1{}^{\rho/(\rho-1)} + n_2 \bar{p}_2{}^{\rho/(\rho-1)} \right)^{(\rho-1)/\rho},$$

where $\bar{p}_1 = w_1^L b/\rho$ and $\bar{p}_2 = w_2^L b/\rho$.

Dividing both sides by w_1^L gives:

$$\text{(1)'} \qquad \frac{p_{X1}}{w_1^L} = \left(n_1 + n_2 \left(\frac{w_2^L}{w_1^L} \right)^{\rho/(\rho-1)} \right)^{(\rho-1)/\rho} \frac{b}{\rho}.$$

Thus we see that the trading level of p_{X1}/w_1^L given by (1)' becomes lower than the autarky level $p_{X1}/w_1^L = \bar{n}_1{}^{(\rho-1)/\rho} b/\rho$ since the coefficient of b/ρ is smaller due to $n_1 \geq \bar{n}_1$ and $(\rho-1)/\rho < 0$.

Second, from (2) we see that X_1 increases after trade since p_{X1}/w_1^L decreases and L_1^S, which is $\bar{L}_1$ before trade, does not decrease. This implies that the marginal product of high-skilled labor given by $MPH_1 = \left(X_1{}^{\varepsilon} + H_1{}^{\varepsilon} \right)^{(1/\varepsilon)-1} H_1{}^{\varepsilon-1}$ increases for any H_1. That is, the demand for high skill by the final good shifts upward. Since the supply of high skill for the final good, which is $\bar{H}_1$ before trade, does not increase, this implies that the real wage of high skill w_1^H / p_{y_1} increases.

Finally, from (3) we see that since $\varepsilon < 0$ ($\sigma < 1$), that is, since the varieties and high skill are complements, the relative wage of high skill w_1^H / w_1^L —the skill premium—increases after trade. This is because $\left(p_{X1} / w_1^L\right)^{\varepsilon}$ increases and $\left(L_1^S / H_1^S\right)^{1-\varepsilon}$, which is $\left(\overline{L}_1 / \overline{H}_1\right)^{1-\varepsilon}$ before trade, does not decrease.

Thus it follows that the high skill and low skill each do their own task after trade as well. That is, the supply of labor for the final and intermediate sectors remains at $H_1^S = \overline{H}_1$ and $L_1^S = \overline{L}_1$, respectively. Hence, the number of varieties produced within country 1 after trade remains at the autarky level $\overline{n}_1 = \overline{L}_1(1-\rho)/f$.

We note that the above results are also obtained in country 2. Hence, we get the following results.

The intra-industry trade in intermediate goods causes the total number of varieties available to the final good sector to simply increase from $\overline{n}_i$ to $\overline{n}_1 + \overline{n}_2$, the sum of the autarky levels, in each country i, $i = 1,2$. This causes p_{Xi} / w_i^L to decline and thus causes X_i to increase in both countries. Consequently, the demand for high skill shifts upward, thus increasing the real wage of high skill w_i^H / p_{y_i} in both countries (Figure 4). Moreover, since the varieties and high skill are complements, the decrease in p_{Xi} / w_i^L also increases the relative wage of high skill w_i^H / w_i^L —the skill premium—in both countries. Thus the trade-wage inequality anomaly has been eliminated in our model.

Let us derive more implications from the above argument. First, since the number of varieties before trade is given by $\overline{n}_i = \overline{L}_i(1-\rho)/f$ in each country i, $i = 1,2$, the ratio of the number of varieties produced within each country before trade is given by $\overline{n}_1 / \overline{n}_2 = \overline{L}_1 / \overline{L}_2$. This implies that the rate of increase in $\overline{n}_i$ is smaller in a country with the larger size of $\overline{L}_i$, and, therefore, the rate of decrease in p_{Xi} / w_i^L is also smaller as can be seen in (1)’. Hence, the rise in the relative wage of high skill w_i^H / w_i^L is smaller in a country with the larger size of $\overline{L}_i$ as can be seen in (3).[14]

Second, if $\varepsilon = 0$ ($\sigma = 1$), that is, if the production function of the final good is given by the Cobb-Douglas function, from (3) we see that the relative wage of high skill w_i^H / w_i^L is not affected by the decrease in $p_{X\,i} / w_i^L$ and therefore does not change after trade in either country.

D. *Economic Reasons for the Results*

Before going to Section II, we need to consider economic reasons for some of the results which have been shown in I-C on the basis of the explicit solutions to the model. First, we explain the economic reason why the good X increases after trade, that is, why the MPH increases after trade.

As we have seen, the activities in the intermediate goods sector never change at all in each country after trade. Some changes, however, do occur after trade. The number of varieties used by the final good sector increases, while the input quantity of each variety used by the final good sector decreases in each country since each variety is shared by two countries.

Can the effect of increase in the number of varieties be canceled by the effect of decrease in the input quantity of each variety? The answer is No. This is because the effect of increase in the number of varieties is greater than the effect of decrease in the input quantity of each variety. This is the crucial effect in the variety trade models which Ethier (1982) called the “international returns to scale.” That is, the increased number of inputs translates into higher productivity. Thus the good X increases after trade, that is, the MPH increases after trade.

We next explain the economic reason why the relative wage of high skill can rise after trade. Now the final good market clearings $y = c$ in each country i, $i = 1,2$, before trade are given by:

$$y_i = \frac{w_i^H \overline{H}_i + w_i^L \overline{L}_i}{p_{y\,i}} .$$

14 In fact, this prediction is consistent with the following observations: The number of production workers in manufacturing industries was much greater in the U.S. than in Mexico during the period 1980-1994. As shown in Figure 1, the U.S. skill premium increased by 12.5 percent from 1980 to 1994, while the Mexican skill premium increased by 48.9 percent.

Since $w_i^H / p_{yi} = MPH_i$, this becomes the following:

$$y_i = MPH_i \cdot \overline{H}_i + \frac{w_i^L}{p_{yi}} \overline{L}_i .$$

As we have seen, the marginal product of high skill increases in each country i, $i = 1,2$, after trade. For the same reason, the output of final good also increases in each country after trade.

Since $MPH_i = \left(X_{\mathrm{i}}^{\ \varepsilon} + \overline{H}_i^{\ \varepsilon}\right)^{(1/\varepsilon)-1} \overline{H}_i^{\ \varepsilon-1}$ and $y_i = \left(X_{\mathrm{i}}^{\ \varepsilon} + \overline{H}_i^{\ \varepsilon}\right)^{1/\varepsilon}$, it can be shown that the rate of increase in MPH_i is greater than the rate of increase in y_i since $\varepsilon < 0$, that is, since the varieties and high skill are complements. This relationship and the final good market clearing condition $y_i = MPH_i \cdot \overline{H}_i + w_i^L / p_{yi} \cdot \overline{L}_i$ imply that the rate of increase in MPH_i should be greater than the rate of change in w_i^L / p_{yi}. In other words, the rate of increase in the real wage of high skill $w_i^{\ H} / p_{yi}$ is greater than the rate of change in the real wage of low skill w_i^L / p_{yi} . Thus the relative wage of high skill can increase in each country i, $i = 1,2$.

II. Evidence

In this section, we show that the idea presented in this paper is consistent with available empirical evidence, and that the movements of the relative price of high-skill intensive good and the relative wage of high-skilled labor are consistent with the observations.

A. *Intra-industry Trade and the Relative Wage of High-Skilled Labor*

Let us recall the idea presented in this paper. We have linked the intra-industry trade in differentiated varieties to the wage inequality through the variety-skill complementarity. Hence, the main implications of the model are that the intra-industry trade should be extensive and should be positively correlated with the relative wage of high-skilled to low-skilled labor, and that the varieties and high-skilled labor should be complements.

Table 1 lists the U.S. exports to and U.S. imports from Mexico in 1985 and 1994.

The data is obtained from the International Trade Administration. As can be seen, in 1985 three SITC product categories (6, 7, and 8) appear in the top five in both lists, and machinery and transport equipment is 49 percent of U.S. export to and 29 percent of U.S. import from Mexico. As can also be seen, in 1994 four SITC product categories (0, 6, 7, and 8) appear in the top five in both lists, and machinery and transport equipment is 47 percent of U.S. export to and 54 percent of U.S. import from Mexico. This indicates that intra-industry trade (IIT) between the U.S. and Mexico was extensive in 1985, around when these two countries showed a surprisingly similar timing in the rise in skill premium. This extensiveness of intra-industry trade became stronger in 1994.

Figures 5-a and 5-b then plot the U.S.-Mexican manufacturing IIT (as a percent of U.S. manufacturing GDP) and the relative wage of high-skilled to low-skilled labor in U.S. and Mexican manufacturing industries during the period 1980-1994, respectively. This U.S.-Mexican manufacturing IIT is defined by multiplying the U.S.-Mexican manufacturing trade and the U.S.-Mexican manufacturing IIT index.

The U.S.-Mexican manufacturing IIT index is a weighted average over SITC 3-digit manufacturing industries. IIT index for industry i is defined by the following Grubel-Lloyd index:

$$1-\frac{|X_i - M_i|}{(X_i + M_i)} \text{ for industry } i,$$

where X_i and M_i represent export and import of industry i. In order to find this index for a country, we compute a weighted average over all the industries as follows[15]:

$$1-\frac{\sum_i |X_i - M_i|}{\sum_i (X_i + M_i)}.$$

The data is obtained from the OECD International Trade by Commodities Statistics (ITCS) and the OECD Structural Analysis (STAN).

On the other hand, the average annual wage of non-production relative to production workers is used as an index for this relative wage of high-skilled to low-skilled labor in U.S. and Mexican manufacturing industries. The source of data for the U.S. and Mexican relative wage is the same as for Figure 1.

15 It is possible to relate our model to the work by Herbert G. Grubel and Peter J. Lloyd (1975). We can express their IIT index in terms of the solutions in our model. In fact, the IIT index in our model is simply one.

As can be seen, the U.S.-Mexican IIT and the relative wage of high-skilled labor showed surprisingly similar movements in both U.S. and Mexican manufacturing industries during the period 1980-1994. In fact, the correlation between the U.S.-Mexican IIT and the relative wage of high skill was high: it was 0.983 and 0.986 in U.S. and Mexican manufacturing industries, respectively.

Thus the linking of the intra-industry trade to the relative wage of high skill is consistent with this evidence in both U.S and Mexican manufacturing industries.

B. *Variety-Skill Complementarity*

In our model, we have represented the variety of inputs as the variety of tasks which workers need to handle. Thus it is plausible to assume that the increased variety of inputs—the increased variety of tasks to be handled—translates into higher demand for high-skilled workers. In fact, this assumption of variety-skill complementarity is consistent with the facts about U.S. production organization.

During the first half of the 20th century, the spread of mass production, which is characterized by Ford's factories, led to the larger size of manufacturing plants. On the other hand, during the second half of the century, flexible machine tools have allowed plants to operate at a smaller scale. The organization of production has changed from mass production with a traditional assembly line to smaller customized batches, thus making the size of plants smaller.[16]

Workers on the assembly line have a single routine task to perform; however, workers in each batch are no longer as highly specialized in a single routine task. Each batch is highly customizable and requires a worker who can handle a wide variety of tasks depending on the custom features of the batch. The change in the production organization therefore affected the number of tasks and therefore affected the importance of skills. As the tasks shifted from a single routine task to a wide variety of tasks, the required skill shifted from low skill to high skill. Thus the varieties and high skill have been complements in the history of U.S. production.[17]

16 Paul Milgrom and John Roberts (1990) present the empirical facts on a change in the size of U.S. manufacturing plants.

17 Matthew F. Mitchell (2001) relates a plant size to skills, and he shows how much the change in the plant size can account for the movement in the skill premium over the century.

C. *Relative Price of High-Skill Intensive Good*

The standard H-O model predicts the same direction of movement of the relative price of high-skill intensive good and the relative wage of high-skilled labor since the rise in the relative wage of high skill should be driven by the rise in the relative price of high-skill intensive good in the high-skill abundant U.S. However, data shows that the relative price of high-skill intensive good was declining or constant during the 1980s while the relative wage of high skill was increasing in the U.S. (Robert Lawrence and Matthew J. Slaughter, 1993).

Our model demonstrates price movement consistent with this observed fact whereas the H-O model cannot. In I-D, it has been shown that the rate of change in w_i^L / p_{yi} should be smaller than the rate of increase in MPH_i since $\varepsilon < 0$. This implies that w_i^L / p_{yi} can rise (but it should rise less than MPH_i), and, therefore, the price of high-skill intensive final good relative to the low-skill wage, $p_{yi} \big/ w_i^L$, can decline. Here, let us recall that the price of the low-skill intensive variety relative to the low-skill wage, $\bar{p}_i \big/ w_i^L$, is constant at $b \big/ \rho$ before and after trade. Hence, the relative price of high-skill to low-skill intensive goods can decline while the relative wage of high skill rises, letting $\varepsilon < 0$. Thus the rise in the relative wage of high skill can happen without the rise in the relative price of high-skill intensive good.[18]

III. Numerical Experiments

We have shown that trade—in particular, intra-industry trade—can theoretically cause the increase in skill premium in two countries, and that our model is consistent with available empirical evidence. This section quantitatively tests this hypothesis, that is, we show how much the increase in variety trade can account for the increase in skill premium in U.S. and Mexican manufacturing industries without technological change for a reasonable parameterization of the model.

An increase in variety trade is here represented as a tariff reduction, for a tariff

18 We note that the price of final good can be constant or increase if $\varepsilon << 0$.

reduction in each country can mean that each country can use more foreign varieties.[19] Technological change, on the other hand, is here represented as a decrease in fixed cost f, for a decrease in f can cause an increase in the number of varieties, $n = \overline{L}(1-\rho)/f$, without an increase in variety trade and thus can cause an increase in the demand for the high skill.[20]

A. *Model with Tariffs*

We introduce tariffs into our simple model and assume that each county i, $i = us, mex$, imposes *iceberg* tariffs τ_i on imports from the other country, that is, the import quantity of a foreign variety is equal to the sum of the input quantity of the foreign variety used by the final good and the *iceberg* tariffs. We also introduce the share parameter α, $0 < \alpha < 1$, into the production function of the final good:

$$y_i = \left[\alpha \left(\int_0^{n_{us}+n_{mex}} x(j)_i^{\rho}\, dj \right)^{\varepsilon/\rho} + (1-\alpha) H_i^{\varepsilon} \right]^{1/\varepsilon}, \quad i = us, mex.$$

We note that the definition of an equilibrium with tariffs and all the derivations of equations below are shown in Appendix D.

The relative wages of high skill are now given by:

$$(4) \quad \frac{w_{us}^H}{w_{us}^L} = \frac{1-\alpha}{\alpha} \left(\frac{(1-\rho)}{f} \left(\frac{b}{\rho} \right)^{\rho/(\rho-1)} \left(\overline{L}_{us} + \overline{L}_{mex} \left((1+\tau_{us}) \frac{w_{mex}^L}{w_{us}^L} \right)^{\rho/(\rho-1)} \right) \right)^{\varepsilon(\rho-1)/\rho} \left(\frac{\overline{L}_{us}}{\overline{H}_{us}} \right)^{1-\varepsilon},$$

$$(5) \quad \frac{w_{mex}^H}{w_{mex}^L} = \frac{1-\alpha}{\alpha} \left(\frac{(1-\rho)}{f} \left(\frac{b}{\rho} \right)^{\rho/(\rho-1)} \left(\overline{L}_{us} \left((1+\tau_{mex}) \frac{w_{us}^L}{w_{mex}^L} \right)^{\rho/(\rho-1)} + \overline{L}_{mex} \right) \right)^{\varepsilon(\rho-1)/\rho} \left(\frac{\overline{L}_{mex}}{\overline{H}_{mex}} \right)^{1-\varepsilon}.$$

U.S.-Mexican intra-industry trade (IIT) is now given by[21]:

$$(6) \qquad \frac{\overline{L}_{us} w_{us}^L \overline{L}_{mex} (1+\tau_{us})^{\rho/(\rho-1)}}{\overline{L}_{us} \left(w_{us}^L / w_{mex}^L \right) + \overline{L}_{mex} (1+\tau_{us})^{\rho/(\rho-1)}} + \frac{\overline{L}_{mex} w_{mex}^L \overline{L}_{us} (1+\tau_{mex})^{\rho/(\rho-1)}}{\overline{L}_{us} (1+\tau_{mex})^{\rho/(\rho-1)} + \overline{L}_{mex} \left(w_{mex}^L / w_{us}^L \right)},$$

19 In Section I, we have looked at the movement from autarky to trade in order to show our idea in the simplest way. However, we here begin with trade equilibrium in order to compare our model with actual trade data.

20 We note that in our model "technological change" refers to non-trade-based technological change which can occur without trade, although it is possible to interpret the increased number of inputs due to trade as trade-based technological change.

21 We note that in our model the volume of trade is equivalent to the volume of IIT since in the model all trade is intra-industry trade.

where the balance of trade requires the following equality:

$$(7) \qquad \frac{\overline{L}_{us} w_{us}^{L} \overline{L}_{mex} \left(1+\tau_{us}\right)^{\rho/(\rho-1)}}{\overline{L}_{us}\left(w_{us}^{L} \big/ w_{mex}^{L}\right)+\overline{L}_{mex}\left(1+\tau_{us}\right)^{\rho/(\rho-1)}} = \frac{\overline{L}_{mex} w_{mex}^{L} \overline{L}_{us} \left(1+\tau_{mex}\right)^{\rho/(\rho-1)}}{\overline{L}_{us}\left(1+\tau_{mex}\right)^{\rho/(\rho-1)}+\overline{L}_{mex}\left(w_{mex}^{L} \big/ w_{us}^{L}\right)}.$$

Thus from (6) and (7), the U.S.-Mexican IIT is simply given by:

$$(8) \qquad 2\frac{\overline{L}_{us} w_{us}^{L} \overline{L}_{mex} \left(1+\tau_{us}\right)^{\rho/(\rho-1)}}{\overline{L}_{us}\left(w_{us}^{L} \big/ w_{mex}^{L}\right)+\overline{L}_{mex}\left(1+\tau_{us}\right)^{\rho/(\rho-1)}}.$$

U.S. GDP is now given by:

$$(9) \qquad w_{us}^{H} \overline{H}_{us} + w_{us}^{L} \overline{L}_{us}.$$

Thus (8) and (9) give the ratio of the U.S.-Mexican IIT to U.S. GDP by:

$$(10) \qquad 2\frac{\overline{L}_{us} \overline{L}_{mex} \left(1+\tau_{us}\right)^{\rho/(\rho-1)}}{\overline{L}_{us}\left(w_{us}^{L} \big/ w_{mex}^{L}\right)+\overline{L}_{mex}\left(1+\tau_{us}\right)^{\rho/(\rho-1)}} \Bigg/ \left(w_{us}^{H} \big/ w_{us}^{L}\right)\overline{H}_{us} + \overline{L}_{us},$$

where $w_{us}^{H} \big/ w_{us}^{L}$ is given by (4).

B. *Numerical Experiments: Intra-Industry Trade and the Skill Premium*

We test our model by calibrating it to 1994 data and then "backcasting" to 1987 to see what changes in U.S. and Mexican skill premium between 1987 and 1994 are predicted by the model.[22]

We first give appropriate values to some parameters. The value of $\rho = 0.833$ (=1/1.2) is chosen so that the markups charged by each variety is 20 percent, which is consistent with evidence in OECD countries presented by Joaquim O. Martins et al. (1996). We normalize $b = 10$ and $f = 100$, the choice of which leaves our results (percent changes in skill premium) unchanged. We note that by keeping f constant from 1987 to 1994, we assume that no technological change occurs. The labor endowments $\overline{L}_i$ and $\overline{H}_i$, $i = us, mex$, are constructed from the OECD STAN, the ASM, and the EIM data. U.S. endowments are first chosen from the data. We then calibrate $\overline{L}_{mex}$ so that the ratio $\overline{L}_{us} \big/ \overline{L}_{mex}$ matches with the observed ratio $w_{us}^{L}\overline{L}_{us} \big/ w_{mex}^{L}\overline{L}_{mex}$ in each year. This is because, as will be shown later, the balance of

22 Due to data constraint, we use data since 1987. It is, however, fortunate that Mexico acceded to the General Agreement on Tariffs and Trade (GATT) in 1986, and it agreed to a major liberalization of bilateral trade relations with the U.S. in 1987.

trade (7) holds at $w_{us}^L / w_{mex}^L = 1$ in each year under our choice of parameters. We also calibrate $\overline{H}_{mex}$ so that the ratio $\overline{H}_{mex} / \overline{L}_{mex}$ matches with the observed ratio.[23]

We then perform our numerical experiments with the following method.

Step 1: We choose the value of ε.

Step 2: We calibrate our model to 1994 data. We set the values of tariffs $\tau_{us,1994}$ and $\tau_{mex,1994}$ and α so that U.S. relative wage in 1994 given by (4) matches with the corresponding data, satisfying the balance of trade (7) in 1994 at $w_{us}^L / w_{mex}^L = 1$.

Step 3: We "backcast" to 1987. We set the values of tariffs $\tau_{us,1987}$ and $\tau_{mex,1987}$ so that the change in (10) between 1987 and 1994 is the same as the observed change in the ratio of U.S.-Mexican manufacturing IIT to U.S. manufacturing GDP, satisfying the balance of trade (7) in 1987 at $w_{us}^L / w_{mex}^L = 1$ as well.

Step 4: We calculate how much the U.S. and Mexican relative wages (4) and (5) increase from 1987 to 1994.

Table 2-a reports results of our benchmark numerical experiments in which $\varepsilon = -1.0$ ($\sigma = 0.5$). The data for the U.S. and Mexican relative wages and the ratio of U.S.-Mexican manufacturing IIT to U.S. manufacturing GDP is an extract from Figures 5-a and 5-b.

As can be seen, U.S. relative wage in 1994 is the same as the observed data, 1.780, and the ratio of U.S.-Mexican manufacturing IIT to U.S. manufacturing GDP increases by 158.2 percent as the corresponding data does. As a result, U.S. relative wage increases by 6.8 percent from 1987 to 1994 while the data shows the 9.2 percent increase, and Mexican relative wage increases by 34.2 percent while the data shows the 43.6 percent increase.

Thus the results indicate that increased intra-industry trade accounts for 73.8 percent of the change in U.S. skill premium and accounts for 78.5 percent of the change in Mexican skill premium in the manufacturing industries during the period 1987-1994.

23 U.S. endowments are: $\overline{H}_{us,1987} = 6707.6$, $\overline{L}_{us,1987} = 12242.7$, $\overline{H}_{us,1994} = 6274.3$, $\overline{L}_{us,1994} = 11845.3$ (in thousands of workers). Mexican endowments are: $\overline{H}_{mex,1987} = 94.6$, $\overline{L}_{mex,1987} = 222.5$, $\overline{H}_{mex,1994} = 210.0$, $\overline{L}_{mex,1994} = 481.2$, which satisfy: $\overline{L}_{us,1987} / \overline{L}_{mex,1987} = 55.03$, $\overline{L}_{us,1994} / \overline{L}_{mex,1994} = 24.61$, $\overline{H}_{mex,1987} / \overline{L}_{mex,1987} = 0.425$, $\overline{H}_{mex,1994} / \overline{L}_{mex,1994} = 0.436$.

Unlike Krugman's (1995, 2000) criticism, we have here seen that U.S.-Mexican manufacturing IIT, which is a small fraction of U.S. manufacturing GDP, can account for much of the increase in wage inequality.

We note, however, that U.S.-Mexican manufacturing IIT is not small from the Mexican view point. In fact, U.S.-Mexican manufacturing IIT as a fraction of Mexican manufacturing GDP was 50.2 percent in 1987 and 75.5 percent in 1994 as shown in the table. The table also shows the corresponding results in the model, but the results are far from the data in terms of the percent change. This is because much of the fluctuations in the trade to GDP ratio in Mexico were caused by fluctuations in GDP and in the real exchange rate. Our model cannot capture these fluctuations.

Table 2-b reports the results of numerical experiments in which the reduction in f —technological change—occurs together with the tariff reduction from 1987 to 1994. The results indicate that if f decreases by 10.6 percent together with the same tariff reduction as in the previous benchmark experiments, then it can cause U.S. skill premium to increase by the same as data and can account for 85.4 percent of the increase in Mexican skill premium.[24]

Thus the results indicate that trade and technological change are complementary to each other in that they both can make contributions to increased skill premium in both countries.

C. *Sensitivity Analysis*

The results obviously depend on the values of ε and ρ. We present some calculations for a variety of ε and ρ.

Table 3-a reports the results of numerical experiments in which $\varepsilon = -0.5$ ($\sigma = 0.666$) and $\varepsilon = -1.5$ ($\sigma = 0.4$) with $\rho = 0.833$ unchanged, respectively. The results indicate that a more negative value of ε—a smaller elasticity of substitution between the varieties and high skill, σ—is accompanied by a larger change in skill premium in both countries.

The final set of results reported in Table 3-b are for numerical experiments in which

24 We note that the 10.6 percent decrease in f is equivalent to the 10.6 percent increase in the number of firms, $n = \overline{L}(1-\rho)/f$, in each country.

$\rho = 0.7$ and $\rho = 0.9$ with $\varepsilon = -1.0$ unchanged, respectively. The results indicate that a change in the value of ρ—the elasticity of substitution between varieties—has larger effects on skill premium in a smaller country, Mexico.

IV. Conclusion and Future Research

The main purpose of this paper has been to eliminate the trade-wage inequality anomaly with a much simpler trade model consistent with empirical evidence.

Section I has presented a simple theoretical resolution of the anomaly. We have shown that the intra-industry trade increases the variety of intermediate goods used by the final good in both countries; as a result, since the varieties and high skill are complements, the skill premium rises in both countries after trade. Thus intra-industry trade can stimulate variety-skill complementarity.

Section II has shown that our model is consistent with empirical evidence. The U.S.-Mexican intra-industry trade was extensive, and the correlation between the U.S.-Mexican IIT and the relative wage of high-skilled labor was high, over 0.98, in both U.S. and Mexican manufacturing industries during the period 1980-1994. The variety-skill complementarity is an innocuous assumption as shown by the facts about U.S. production organization, and the rise in the relative wage of high skill can happen without the rise in the relative price of high-skill intensive good, which is also consistent with the observed fact in the U.S.

Section III has quantitatively tested our hypothesis. Our numerical experiments have shown that increased intra-industry trade is capable of explaining much of the increase in skill premium in both U.S. and Mexican manufacturing industries from 1987 to 1994 for a reasonable parameterization of the model.

It is true that the standard H-O model and its applications are inconsistent with data which shows a rising wage inequality across countries, and, therefore, most economists have rejected increased trade as an explanation of increased wage inequality. However, we can now show in a simple way that trade—in, particular, intra-industry trade—is a possible explanation of increased wage inequality across countries. We note that the result that trade can theoretically increase wage inequality is not necessarily negative, for our model shows that the real wage of both high skill and low skill can rise despite the increase in inequality.[25]

Of course, room for future research still exists. First, this paper has hypothesized in a very simple form that one of the possible causes for the rising wage inequality across countries is intra-industry trade and the variety-skill complementarity. Formulating a more general version of the model and quantitatively testing it is consequently the next step. This is because (a) not all trade is intra-industry trade, (b) much of output is services, which is largely non-traded but ignored in this paper, (c) capital is also ignored in this paper, and (d) trade is not balanced in data. In another paper, we shall calibrate a static applied general equilibrium model, which can resolve problems (a)-(d), to U.S. and Mexican input-output matrices in order to show how much of the rise in wage inequality is accounted for by the intra-industry trade under the assumption of variety-skill complementarity.

Second, we can analyze the relationship between competition policies and wage inequality. In our model, the change in the number of varieties is related to wage inequality. This implies that government can affect wage inequality by entry policies which adjust the number of firms. Third, our model has been applied to the problems of trade between the U.S. and Mexico, but we can also directly apply it to the problems of intra-trade among EU nations.

Finally, the focus of this paper has been on the elimination of the discrepancy between the standard H-O model and the data since the late 1980s until 1994, when the NAFTA was enacted. We should next consider whether this discrepancy remained or not after 1994. Unfortunately, the movements of the Mexican skill premium after 1994 are unclear. Raymond Robertson (2004) argues that the skill premium in Mexico significantly declined from 1994 to 1998 on the basis of the Mexican Industrial Census. Unlike the observations before 1994, this finding seems consistent with the predictions of the Stolper-Samuelson theorem. However, it can also be shown on the basis of the Mexican Monthly Industrial Survey (EIM) that the Mexican skill premium actually increased over the same period. Robertson (2004) and the EIM thus show movements in the opposite direction over the period 1994-1998, whereas both show a rising trend since the late 1980s until 1994. It would seem, therefore, that further investigation is

25 In fact, the real wage of non-production labor has increased, and, further, the real wage of production workers have slightly increased since the 1980s.

needed in order to analyze the movements of the Mexican skill premium after the NAFTA.

Appendix

A. *Intermediate Goods*

Step 1: Given arbitrary n, derive the indirect demand and $MR = MC$ and find $x(j)$ and $p(j)$.

1: Derive the indirect demand of intermediate good j.

From the problem of the final good, we get:

$$p(j) = p_y \frac{1}{\varepsilon}\left[\left(\int_0^n x(j)^\rho dj\right)^{\varepsilon/\rho} + H^\varepsilon\right]^{(1/\varepsilon)-1} \frac{\varepsilon}{\rho}\left(\int_0^n x(j)^\rho dj\right)^{(\varepsilon/\rho)-1} \rho x(j)^{\rho-1}.$$

2: $MR = MC$.

The differentiated intermediate goods sector is monopolistically competitive with Cournot pricing rules.

Solve the following problem:

$$\max_{x(j)} p(j)x(j) - w^L bx(j) - w^L f .$$

The first order condition w.r.t. $x(j)$ is given by:

$$p_y\left[\left(\int_0^n x(j)^\rho dj\right)^{\varepsilon/\rho} + H^\varepsilon\right]^{(1/\varepsilon)-1}\left(\int_0^n x(j)^\rho dj\right)^{(\varepsilon/\rho)-1} \rho x(j)^{\rho-1} = w^L b .$$

3: Find $x(j)$ and $p(j)$.

By using the symmetry $x(j) = \bar{x}$, we get:

$$\bar{x} = \left[\left(\frac{w^L b}{p_y n^{(\varepsilon/\rho)-1}\rho}\right)^{\varepsilon/(1-\varepsilon)} - n^{\varepsilon/\rho}\right]^{-1/\varepsilon} H, \quad \forall j ,$$

$$\bar{p} = \frac{w^L b}{\rho}, \quad \forall j .$$

Step 2: Zero profit condition $\overline{px} - b\bar{x} - f = 0$ with $\bar{p} = w^L b/\rho$ gives the following output $\bar{x}$ of each variety:

$$\bar{x} = \frac{f\rho}{b(1-\rho)} \quad , \quad \forall j .$$

With $\bar{x} = f\rho/b(1-\rho)$, the labor market clearing in the intermediate goods sector, $\bar{n}(b\bar{x} + f) = L^S$, gives the number of varieties, $\bar{n}$:

$$\overline{n} = \frac{L^S(1-\rho)}{f}.$$

B. ***Final Good***

Define a new good $X = \left(\int_0^n x(j)^\rho dj\right)^{1/\rho}$ and its price p_X. Then the profit of the final good sector becomes:

$$p_y\left(X^\varepsilon + H^\varepsilon\right)^{1/\varepsilon} - p_X X - w^H H.$$

This new good X shows the constant returns to scale with varieties $x(j)$, and, therefore, we have the following equality:

$$p_X X = \int_0^n p(j)x(j)dj.$$

Step 1: p_X.

By solving the following cost minimization problem for the good X, we can find that the price of X is $p_X = \left(\int_0^n p(j)^{\rho/(\rho-1)}dj\right)^{(\rho-1)/\rho}$.

$$\min \int_0^n p(j)x(j)dj$$
$$s,t,\ \left(\int_0^n x(j)^\rho dj\right)^{1/\rho} \geq X.$$

Define the Lagrangian L:

$$L = \int_0^n p(j)x(j)dj + \lambda\left[\left(\int_0^n x(j)^\rho dj\right)^{1/\rho} - X\right].$$

Then the first order condition w.r.t. $x(j)$ gives:

$$\lambda\left(\int_0^n x(j)^\rho dj\right)^{1/\rho} = \int_0^n p(j)x(j)dj.$$

Since $p_X X = \int_0^n p(j)x(j)dj$, this implies λ is equivalent to p_X. By solving for λ, we get:

(1) $$\lambda = p_X = \left(\int_0^n p(j)^{\rho/(\rho-1)}dj\right)^{(\rho-1)/\rho}.$$

Step 2: X .

Since the technology of the final good shows the constant returns to scale with X and H , we have the following equality:

$$y = \frac{p_X X + w^H H}{p_y} .$$

On the other hand, the demand for the final good is given by:

$$c = \frac{w^H H^S + w^L L^S}{p_y} .$$

Hence, the final good market clearing $y = c$ and $H = H^S$ give:

$$p_X X = w^L L^S .$$

Thus X is given by:

(2) $$X = \frac{w^L L^S}{p_X} .$$

Step 3: w^H / w^L .

The first order conditions w.r.t. X and H for the final sector are given by:

$$p_y \frac{1}{\varepsilon}\left(X^{\varepsilon} + H^{\varepsilon}\right)^{(1/\varepsilon)-1} \varepsilon X^{\varepsilon-1} = p_X ,$$

$$p_y \frac{1}{\varepsilon}\left(X^{\varepsilon} + H^{\varepsilon}\right)^{(1/\varepsilon)-1} \varepsilon H^{\varepsilon-1} = w^H .$$

These give the following:

$$\left(\frac{X}{H}\right)^{\varepsilon-1} = \frac{p_X}{w^H} .$$

By solving for w^H with (2) and $H = H^S$, w^H is given by:

$$w^H = p_X{}^{\varepsilon}\left(\frac{w^L L^S}{H^S}\right)^{1-\varepsilon} .$$

The relative wage of high-skilled labor w^H / w^L is then given by:

(3) $$\frac{w^H}{w^L} = \left(\frac{p_X}{w^L}\right)^{\varepsilon}\left(\frac{L^S}{H^S}\right)^{1-\varepsilon} .$$

C. *The Movement of High-Skilled Labor*

In Section I, we have focused on the interesting case in which the relative wage w^H / w^L given by (3) is greater than one before trade. Thus the high skill and low skill each do their own task, letting $H^S = \overline{H}$ and $L^S = \overline{L}$. In this appendix, we briefly analyze the other case in which the relative wage w^H / w^L given by (3) is one and the high skill is doing both high-skill and low-skill tasks before trade.

In the autarky equilibrium as shown in Figure 3-b, the relative wage w^H / w^L given by (3) is one at C, and part of high skill is doing the low-skill task in the intermediate goods sector. This movement of high skill from A to C maximizes the output of final good, that is, the consumer's utility.

As we have seen in I-C, the case as shown in Figure 3-a let us conclude that the skill premium rises after trade. On the other hand, if it is one before trade as shown in Figure 3-b, it can be shown that the relative wage w^H / w^L rises or remains after trade, and, in any case, the number of varieties used by the final good surely increases.

D. *Model with Tariffs*

Equilibrium

Definition: An equilibrium is prices $p_{y,us}$, $p_{y,mex}$, $p(j)$, $j \in [0, n_{us} + n_{mex}]$, w_{us}^H, w_{mex}^H, w_{us}^L, w_{mex}^L, and quantities c_{us}, c_{mex}, y_{us}, y_{mex}, $x(j)_{us}$, $x(j)_{mex}$, $x(j)$, $j \in [0, n_{us} + n_{mex}]$, H_{us}, H_{mex}, $l(j)$, $j \in [0, n_{us} + n_{mex}]$, H_{us}^S, H_{mex}^S, L_{us}^S, L_{mex}^S, and the number of firms in the intermediate sectors n_{us}, n_{mex}, given *iceberg* tariffs τ_{us} and τ_{mex}, such that

1. Final good: Given p_{yi}, $p(j)$, and w_i^H,
y_i, $x(j)_{us}$, and H_i solve
(a) U.S.

$$\max\ p_{yus} y_{us} - \int_0^{n_{us}} p(j) x(j)_{us}\, dj - \int_{n_{us}}^{n_{us}+n_{mex}} p(j)(1+\tau_{us}) x(j)_{us}\, dj - w_{us}^H H_{us}$$

$$\text{s,t,} \quad y_{us} = \left[\alpha \left(\int_0^{n_{us}+n_{mex}} x(j)_{us}{}^{\rho}\, dj \right)^{\varepsilon/\rho} + (1-\alpha) H_{us}{}^{\varepsilon} \right]^{1/\varepsilon},$$

(b) Mexico

$$\max\ p_{ymex} y_{mex} - \int_0^{n_{us}} p(j)(1+\tau_{mex}) x(j)_{mex}\, dj - \int_{n_{us}}^{n_{us}+n_{mex}} p(j) x(j)_{mex}\, dj - w_{mex}^{H} H_{mex}$$

$$\text{s,t,} \quad y_{mex} = \left[\alpha \left(\int_0^{n_{us}+n_{mex}} x(j)_{mex}{}^{\rho}\, dj \right)^{\varepsilon/\rho} + (1-\alpha) H_{mex}{}^{\varepsilon} \right]^{1/\varepsilon};$$

2. Intermediate goods: Given w_i^L,

$x(j)$ solves

(a) U.S. $j \in [0, n_{us}]$

$$\max_{x(j)}\ p(j)x(j) - w_{us}^{L} b x(j) - w_{us}^{L} f\ ,$$

where $x(j) = x(j)_{us} + (1+\tau_{mex}) x(j)_{mex}$,

(b) Mexican $j \in [n_{us}, n_{us} + n_{mex}]$

$$\max_{x(j)}\ p(j)x(j) - w_{mex}^{L} b x(j) - w_{mex}^{L} f\ ,$$

where $x(j) = (1+\tau_{us}) x(j)_{us} + x(j)_{mex}$;

3. Consumer: Given $p_{y,i}$, w_i^H, and w_i^L,

c_i, H_i^S, L_i^S solve

(a) U.S.

$$\max c_{us}$$

$$s,t,\ p_{y,us} c_{us} = w_{us}^{H} H_{us}^{S} + w_{us}^{L} L_{us}^{S},$$

(b) Mexico

$$\max c_{mex}$$

$$s,t,\ p_{y,mex} c_{mex} = w_{mex}^{H} H_{mex}^{S} + w_{mex}^{L} L_{mex}^{S};$$

4. Market clearing:

$$c_{us} = y_{us}\,,\quad c_{mex} = y_{mex}\,,$$

$$x(j)_{us}+(1+\tau_{mex})x(j)_{mex}=x(j) \quad \text{for} \quad j\in[0,n_{us}],$$
$$(1+\tau_{us})x(j)_{us}+x(j)_{mex}=x(j) \quad \text{for} \quad j\in[n_{us},n_{us}+n_{mex}],$$
$$H_{us}=H_{us}^{S}, \quad H_{mex}=H_{mex}^{S},$$
$$\int_0^{n_{us}} l(j)dj=L_{us}^{S} \quad \text{for} \quad j\in[0,n_{us}],$$
$$\int_{n_{us}}^{n_{us}+n_{mex}} l(j)dj=L_{mex}^{S} \quad \text{for} \quad j\in[n_{us},n_{us}+n_{mex}].$$

Remarks:

1. $(1+\tau_{mex})x(j)_{mex}$, $j\in[0,n_{us}]$, means that the imports of a U.S. variety by the Mexican final good, and $(1+\tau_{us})x(j)_{us}$, $j\in[n_{us},n_{us}+n_{mex}]$, means that the imports of a Mexican variety by the U.S. final good. We note that the U.S. and Mexican final good can use only $x(j)_{us}$ and $x(j)_{mex}$ as input, respectively.

2. We focus on $w_i^H / w_i^L > 1$, thus $H_i^S=\overline{H}_i$ and $L_i^S=\overline{L}_i$, $i=us,mex$.

Solutions

Intermediate Goods

Introducing tariffs doe not change the solutions in the intermediate goods sector.

By the symmetry $p(j)=\overline{p}_{us}$ for $j\in[0,n_{us}]$ and $p(j)=\overline{p}_{mex}$ for $j\in[n_{us},n_{us}+n_{mex}]$, the price and output of each variety and the number of varieties in each country are now given by:

$$\overline{p}_{us}=\frac{w_{us}^{L}b}{\rho} \quad \text{for} \quad j\in[0,n_{us}], \quad \overline{p}_{mex}=\frac{w_{mex}^{L}b}{\rho} \quad \text{for} \quad j\in[n_{us},n_{us}+n_{mex}],$$
$$\overline{x}_{us}=\frac{f\rho}{b(1-\rho)} \quad \text{for} \quad j\in[0,n_{us}], \quad \overline{x}_{mex}=\frac{f\rho}{b(1-\rho)} \quad \text{for} \quad j\in[n_{us},n_{us}+n_{mex}],$$
$$\overline{n}_{us}=\frac{\overline{L}_{us}(1-\rho)}{f}, \quad \overline{n}_{mex}=\frac{\overline{L}_{mex}(1-\rho)}{f}.$$

Final Good

The profit of the final good sector now becomes:

$$p_{yi}\left(\alpha X_i^{\ \varepsilon}+(1-\alpha)H_i^{\ \varepsilon}\right)^{1/\varepsilon}-p_{Xi}X_i-w_i^H H_i,\ \ i=us,mex.$$

By solving the cost minimization problem for the good X, we can find that the price of X in each country is:

$$p_{X\,us}=\left(\int_0^{n_{us}}p(j)^{\rho/(\rho-1)}dj+\int_{n_{us}}^{n_{us}+n_{mex}}\left((1+\tau_{us})p(j)\right)^{\rho/(\rho-1)}dj\right)^{(\rho-1)/\rho},$$

$$p_{X\,mex}=\left(\int_0^{n_{us}}\left((1+\tau_{mex})p(j)\right)^{\rho/(\rho-1)}dj+\int_{n_{us}}^{n_{us}+n_{mex}}p(j)^{\rho/(\rho-1)}dj\right)^{(\rho-1)/\rho}.$$

By the symmetry $p(j)=\overline{p}_{us}$ for $j\in[0,n_{us}]$ and $p(j)=\overline{p}_{mex}$ p_X for $j\in[n_{us},n_{us}+n_{mex}]$,

$$p_{X\,us}=\left(n_{us}\overline{p}_{us}^{\ \rho/(\rho-1)}+n_{mex}\left((1+\tau_{us})\overline{p}_{mex}\right)^{\rho/(\rho-1)}\right)^{(\rho-1)/\rho},$$

$$p_{X\,mex}=\left(n_{us}\left((1+\tau_{mex})\overline{p}_{us}\right)^{\rho/(\rho-1)}+n_{mex}\overline{p}_{mex}^{\ \rho/(\rho-1)}\right)^{(\rho-1)/\rho}.$$

The good X in each country is now given by:

$$X_{us}=\frac{w_{us}^L\overline{L}_{us}}{p_{X\,us}},\ \ X_{mex}=\frac{w_{mex}^L\overline{L}_{mex}}{p_{X\,mex}}.$$

The relative wage of high-skilled to low-skilled labor in each country is now given by:

$$\frac{w_{us}^H}{w_{us}^L}=\frac{1-\alpha}{\alpha}\left(\frac{p_{X\,us}}{w_{us}^L}\right)^{\varepsilon}\left(\frac{\overline{L}_{us}}{\overline{H}_{us}}\right)^{1-\varepsilon}\text{ and }\frac{w_{mex}^H}{w_{mex}^L}=\frac{1-\alpha}{\alpha}\left(\frac{p_{X\,mex}}{w_{mex}^L}\right)^{\varepsilon}\left(\frac{\overline{L}_{mex}}{\overline{H}_{mex}}\right)^{1-\varepsilon}.$$

By substituting p_{Xi}, n_i, and $\overline{p}_i$, $i=us,mex$, the equilibrium relative wages are rewritten as follow:

(4) $$\frac{w_{us}^H}{w_{us}^L}=\frac{1-\alpha}{\alpha}\left(\frac{(1-\rho)}{f}\left(\frac{b}{\rho}\right)^{\rho/(\rho-1)}\left(\overline{L}_{us}+\overline{L}_{mex}\left((1+\tau_{us})\frac{w_{mex}^L}{w_{us}^L}\right)^{\rho/(\rho-1)}\right)\right)^{\varepsilon(\rho-1)/\rho}\left(\frac{\overline{L}_{us}}{\overline{H}_{us}}\right)^{1-\varepsilon}$$

(5) $$\frac{w_{mex}^H}{w_{mex}^L}=\frac{1-\alpha}{\alpha}\left(\frac{(1-\rho)}{f}\left(\frac{b}{\rho}\right)^{\rho/(\rho-1)}\left(\overline{L}_{us}\left((1+\tau_{mex})\frac{w_{us}^L}{w_{mex}^L}\right)^{\rho/(\rho-1)}+\overline{L}_{mex}\right)\right)^{\varepsilon(\rho-1)/\rho}\left(\frac{\overline{L}_{mex}}{\overline{H}_{mex}}\right)^{1-\varepsilon}.$$

Trade and GDP

Trade

Step1: Balance of trade.

The balance of trade—U.S. exports = U.S. imports (or Mexican imports = Mexican exports)—is given by the following:

$$\overline{n}_{us}\,\overline{p}_{us}\left(1+\tau_{mex}\right)\overline{x}_{us,mex} = \overline{n}_{mex}\,\overline{p}_{mex}\left(1+\tau_{us}\right)\overline{x}_{mex,us}\,,$$

where $\left(1+\tau_{mex}\right)\overline{x}_{us,mex}$ means that the imports of a U.S. variety by the Mexican final good, and $\left(1+\tau_{us}\right)\overline{x}_{mex,us}$ means that the imports of a Mexican variety by the U.S. final good.

The ratio of U.S. exports to imports (or the ratio of Mexican imports to exports) is then given by:

$$\frac{\left(1+\tau_{mex}\right)\overline{x}_{us,mex}}{\left(1+\tau_{us}\right)\overline{x}_{mex,us}} = \frac{\overline{n}_{mex}\,\overline{p}_{mex}}{\overline{n}_{us}\,\overline{p}_{us}}\,.$$

Step 2: The first order conditions for each variety by the final good.

The first order conditions for each variety by the final good give:

$$\overline{x}_{mex,us} = \left(1+\tau_{us}\right)^{1/(\rho-1)} x_{us,us}\,,\quad \overline{x}_{us,mex} = \left(1+\tau_{mex}\right)^{1/(\rho-1)} x_{mex,mex}\,.$$

Step 3: The ratio of each country's share in each variety.

From Steps 1 and 2, the ratio of the demand for a U.S. variety by the U.S. to the demand for a U.S. variety by Mexico is given by:

$$\frac{\left(1+\tau_{us}\right)\left(1+\tau_{us}\right)^{1/(\rho-1)}\overline{x}_{us,us}}{\left(1+\tau_{mex}\right)\overline{x}_{us,mex}} = \frac{\overline{n}_{us}\,\overline{p}_{us}}{\overline{n}_{mex}\,\overline{p}_{mex}}\,.$$

Similarly, the ratio of the demand for a Mexican variety by the U.S. to the demand for a Mexican variety by Mexico is given by:

$$\frac{\left(1+\tau_{us}\right)x_{mex,us}}{\left(1+\tau_{mex}\right)\left(1+\tau_{mex}\right)^{1/(\rho-1)} x_{mex,mex}} = \frac{\overline{n}_{us}\,\overline{p}_{us}}{\overline{n}_{mex}\,\overline{p}_{mex}}\,.$$

Thus by substituting n_i and $\overline{p}_i$, $i = us, mex$, the ratio of the demand for a U.S. variety by the U.S. to the demand for a U.S. variety by Mexico becomes:

$$\overline{x}_{us,us}\Big/\left(1+\tau_{mex}\right)\overline{x}_{us,mex} = \overline{L}_{us} w_{us}^{L}\Big/\overline{L}_{mex} w_{mex}^{L}\left(1+\tau_{us}\right)^{\rho/(\rho-1)}\,.$$

The ratio of the demand for a Mexican variety by the U.S. to the demand for a Mexican variety by Mexico also becomes:

$$\left(1+\tau_{us}\right)\overline{x}_{mex,us}\Big/\overline{x}_{mex,mex} = \overline{L}_{us} w_{us}^{L}\left(1+\tau_{mex}\right)^{\rho/(\rho-1)}\Big/\overline{L}_{mex} w_{mex}^{L}\,.$$

We see that a reduction in τ_{us} and τ_{mex} increases the share of Mexico in a U.S.

variety and the share of U.S. in a Mexican variety.

Step 4: Trade.

U.S.-Mexican trade is represented as the sum of U.S. exports and imports:

$$\overline{n}_{us}\,\overline{p}_{us}\left(1+\tau_{mex}\right)\overline{x}_{us,mex}+\overline{n}_{mex}\,\overline{p}_{mex}\left(1+\tau_{us}\right)\overline{x}_{mex,us}\,.$$

From Step 3, this becomes:

$$\overline{n}_{us}\,\overline{p}_{us}\,\frac{\overline{L}_{mex}w^{L}_{mex}\left(1+\tau_{us}\right)^{\rho/(\rho-1)}}{\overline{L}_{us}w^{L}_{us}+\overline{L}_{mex}w^{L}_{mex}\left(1+\tau_{us}\right)^{\rho/(\rho-1)}}\,\overline{x}_{us}+\overline{n}_{mex}\,\overline{p}_{mex}\,\frac{\overline{L}_{us}w^{L}_{us}\left(1+\tau_{mex}\right)^{\rho/(\rho-1)}}{\overline{L}_{us}w^{L}_{us}\left(1+\tau_{mex}\right)^{\rho/(\rho-1)}+\overline{L}_{mex}w^{L}_{mex}}\,\overline{x}_{mex}\,.$$

By substituting n_i, $\overline{p}_i$ and $\overline{x}_i$, $i=us,mex$, the U.S.-Mexican trade is given by:

$$\text{(6)}\qquad \frac{\overline{L}_{us}w^{L}_{us}\overline{L}_{mex}\left(1+\tau_{us}\right)^{\rho/(\rho-1)}}{\overline{L}_{us}\left(w^{L}_{us}/w^{L}_{mex}\right)+\overline{L}_{mex}\left(1+\tau_{us}\right)^{\rho/(\rho-1)}}+\frac{\overline{L}_{mex}w^{L}_{mex}\overline{L}_{us}\left(1+\tau_{mex}\right)^{\rho/(\rho-1)}}{\overline{L}_{us}\left(1+\tau_{mex}\right)^{\rho/(\rho-1)}+\overline{L}_{mex}\left(w^{L}_{mex}/w^{L}_{us}\right)},$$

where the balance of trade requires the following equality:

$$\text{(7)}\qquad \frac{\overline{L}_{us}w^{L}_{us}\overline{L}_{mex}\left(1+\tau_{us}\right)^{\rho/(\rho-1)}}{\overline{L}_{us}\left(w^{L}_{us}/w^{L}_{mex}\right)+\overline{L}_{mex}\left(1+\tau_{us}\right)^{\rho/(\rho-1)}}=\frac{\overline{L}_{mex}w^{L}_{mex}\overline{L}_{us}\left(1+\tau_{mex}\right)^{\rho/(\rho-1)}}{\overline{L}_{us}\left(1+\tau_{mex}\right)^{\rho/(\rho-1)}+\overline{L}_{mex}\left(w^{L}_{mex}/w^{L}_{us}\right)}\,.$$

Thus from (6) and (7), the U.S.-Mexican IIT is simply given by:

$$\text{(8)}\qquad 2\,\frac{\overline{L}_{us}w^{L}_{us}\overline{L}_{mex}\left(1+\tau_{us}\right)^{\rho/(\rho-1)}}{\overline{L}_{us}\left(w^{L}_{us}/w^{L}_{mex}\right)+\overline{L}_{mex}\left(1+\tau_{us}\right)^{\rho/(\rho-1)}}\,.$$

We note that in our model trade refers to intra-industry trade (IIT).

GDP

By the equality $p_{y,us}y_{us}=p_{y,us}c_{us}=w^{H}_{us}\overline{H}_{us}+w^{L}_{us}\overline{L}_{us}$, U.S. GDP is given by:

$$\text{(9)}\qquad w^{H}_{us}\overline{H}_{us}+w^{L}_{us}\overline{L}_{us}\,.$$

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Table 1. U.S. Exports to and Imports from Mexico in 1985 and 1994

1985

U.S. Exports to Mexico			U.S. Imports from Mexico	
Rank	SITC category	Percent	SITC category	Percent
1	<u>7 - Machinery and Transport Equipment</u>	<u>49</u>	3 - Mineral Fuels, Lubricants and Related Materials	41
2	5 - Chemicals and Related Products	11	<u>7 - Machinery and Transport Equipment</u>	<u>29</u>
3	6 - Manufactured Goods Classified Chiefly by Material	10	0 - Food and Live Animals	8
4	2 - Crude Materials, Inedible, except Fuels	9	6 - Manufactured Goods Classified Chiefly by Material	6
5	8 - Miscellaneous Manufactured Articles	7	8 - Miscellaneous Manufactured Articles	6
6	0 - Food and Live Animals	7	5 - Chemicals and Related Products	3
7	3 - Mineral Fuels, Lubricants and Related Materials	4	9 - Commodities & Transact not Class Elsewhere	3
8	9 - Commodities & Transact not Class Elsewhere	3	2 - Crude Materials, Inedible, except Fuels	2
9	4 - Animal and Vegetable Oils, Fats and Waxes	1	1 - Beverages and Tobacco	1
10	1 - Beverages and Tobacco	0	4 - Animal and Vegetable Oils, Fats and Waxes	0
	Total	100	Total	100

1994

U.S. Exports to Mexico			U.S. Imports from Mexico	
Rank	SITC category	Percent	SITC category	Percent
1	<u>7 - Machinery and Transport Equipment</u>	<u>47</u>	<u>7 - Machinery and Transport Equipment</u>	<u>54</u>
2	6 - Manufactured Goods Classified Chiefly by Material	13	8 - Miscellaneous Manufactured Articles	14
3	8 - Miscellaneous Manufactured Articles	13	3 - Mineral Fuels, Lubricants and Related Materials	10
4	5 - Chemicals and Related Products	9	6 - Manufactured Goods Classified Chiefly by Material	7
5	0 - Food and Live Animals	6	0 - Food and Live Animals	6
6	9 - Commodities & Transact not Class Elsewhere	4	9 - Commodities & Transact not Class Elsewhere	4
7	2 - Crude Materials, Inedible, except Fuels	4	5 - Chemicals and Related Products	2
8	3 - Mineral Fuels, Lubricants and Related Materials	2	2 - Crude Materials, Inedible, except Fuels	2
9	4 - Animal and Vegetable Oils, Fats and Waxes	0	1 - Beverages and Tobacco	1
10	1 - Beverages and Tobacco	0	4 - Animal and Vegetable Oils, Fats and Waxes	0
	Total	100	Total	100

Source: The International Trade Administration.

Table 2-a. Results for Benchmark Numerical Experiments

	1987	1994	Change
Data (Figures 5-a and 5-b)			
Manuf. IIT/U.S. Manf. GDP	0.018	0.046	**158.2%**
Manuf. IIT/Mex. Manf. GDP	0.502	0.755	50.4%
U.S. Skill Premium	1.630	**1.780**	9.2%
Mexican Skill Premium	2.020	2.900	43.6%
$\varepsilon = -1.0, \rho = 0.833, \alpha = 0.55$			
$\tau_{us,1987} = 0.048, \tau_{us,1994} = 0.010, \tau_{mex,1987} = 0.729, \tau_{mex,1994} = 0.177$			
Manuf. IIT/U.S. Manf. GDP	0.015	0.038	**158.2%**
Manuf. IIT/Mex. Manf. GDP	0.912	0.924	1.4%
U.S. Skill Premium	1.667	**1.780**	6.8%
Mexican Skill Premium	1.678	2.252	34.2%

Table 2-b. Results for Benchmark Numerical Experiments with Technological Change

	1987	1994	Change
Data (Figures 5-a and 5-b)			
Manuf. IIT/U.S. Manf. GDP	0.018	0.046	**158.2%**
Manuf. IIT/Mex. Manf. GDP	0.502	0.755	50.4%
U.S. Skill Premium	**1.630**	**1.780**	**9.2%**
Mexican Skill Premium	2.020	2.900	43.6%
$\varepsilon = -1.0, \rho = 0.833, \alpha = 0.55, f_{1987} = 111.8, f_{1994} = 100.0$			
$\tau_{us,1987} = 0.048, \tau_{us,1994} = 0.019, \tau_{mex,1987} = 0.729, \tau_{mex,1994} = 0.177$			
Manuf. IIT/U.S. Manf. GDP	0.015	0.038	**158.2%**
Manuf. IIT/Mex. Manf. GDP	0.920	0.924	0.4%
U.S. Skill Premium	**1.630**	**1.780**	**9.2%**
Mexican Skill Premium	1.641	2.252	37.2%

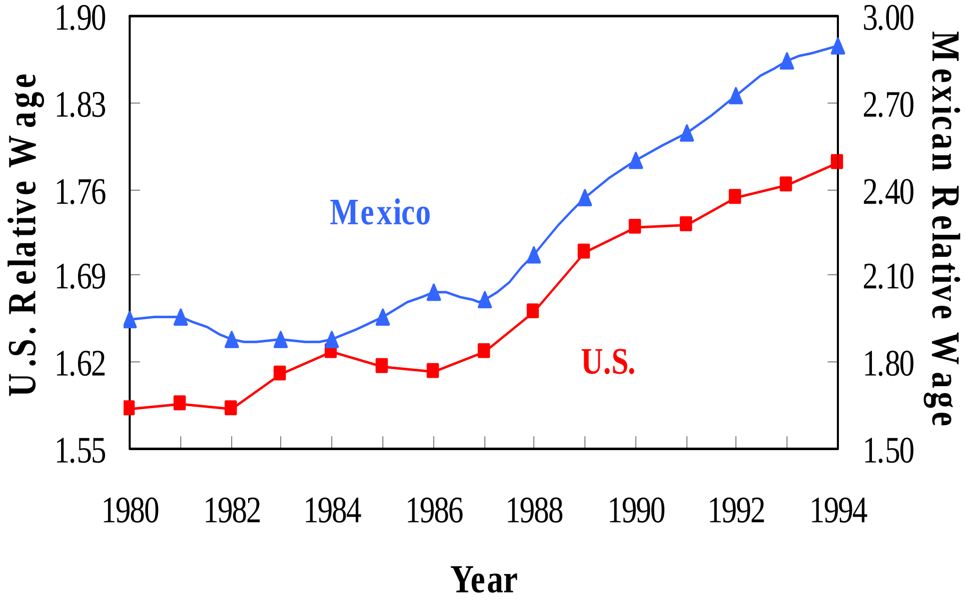
Table 3-a. Results for Numerical Experiments with Different ε

	1987	1994	Change
Data (Figures 5-a and 5-b)			
Manuf. IIT/U.S. Manf. GDP	0.018	0.046	**158.2%**
Manuf. IIT/Mex. Manf. GDP	0.502	0.755	50.4%
U.S. Skill Premium	1.630	**1.780**	9.2%
Mexican Skill Premium	2.020	2.900	43.6%
$\varepsilon = -1.0, \rho = 0.833, \alpha = 0.55$			
$\tau_{us,1987} = 0.048, \tau_{us,1994} = 0.010, \tau_{mex,1987} = 0.729, \tau_{mex,1994} = 0.177$			
Manuf. IIT/U.S. Manf. GDP	0.015	0.038	**158.2%**
Manuf. IIT/Mex. Manf. GDP	0.912	0.924	1.4%
U.S. Skill Premium	1.667	**1.780**	6.8%
Mexican Skill Premium	1.678	2.252	34.2%
$\varepsilon = -0.5, \rho = 0.833, \alpha = 0.53$			
$\tau_{us,1987} = 0.046, \tau_{us,1994} = 0.010, \tau_{mex,1987} = 0.716, \tau_{mex,1994} = 0.177$			
Manuf. IIT/U.S. Manf. GDP	0.015	0.038	**158.2%**
Manuf. IIT/Mex. Manf. GDP	0.864	0.934	8.1%
U.S. Skill Premium	1.694	**1.780**	5.1%
Mexican Skill Premium	1.935	2.206	14.0%
$\varepsilon = -1.5, \rho = 0.833, \alpha = 0.57$			
$\tau_{us,1987} = 0.049, \tau_{us,1994} = 0.010, \tau_{mex,1987} = 0.741, \tau_{mex,1994} = 0.177$			
Manuf. IIT/U.S. Manf. GDP	0.015	0.038	**158.2%**
Manuf. IIT/Mex. Manf. GDP	0.960	0.915	-4.7%
U.S. Skill Premium	1.640	**1.780**	8.5%
Mexican Skill Premium	1.448	2.299	58.7%

Table 3-b. Results for Numerical Experiments with Different ρ

	1987	1994	Change
Data (Figures 5-a and 5-b)			
Manuf. IIT/U.S. Manf. GDP	0.018	0.046	**158.2%**
Manuf. IIT/Mex. Manf. GDP	0.502	0.755	50.4%
U.S. Skill Premium	1.630	**1.780**	9.2%
Mexican Skill Premium	2.020	2.900	43.6%
$\varepsilon = -1.0, \rho = 0.833, \alpha = 0.55$			
$\tau_{us,1987} = 0.048, \tau_{us,1994} = 0.010, \tau_{mex,1987} = 0.729, \tau_{mex,1994} = 0.177$			
Manuf. IIT/U.S. Manf. GDP	0.015	0.038	**158.2%**
Manuf. IIT/Mex. Manf. GDP	0.912	0.924	1.4%
U.S. Skill Premium	1.667	**1.780**	6.8%
Mexican Skill Premium	1.678	2.252	34.2%
$\varepsilon = -1.0, \rho = 0.7, \alpha = 0.93$			
$\tau_{us,1987} = 0.092, \tau_{us,1994} = 0.010, \tau_{mex,1987} = 2.060, \tau_{mex,1994} = 0.216$			
Manuf. IIT/U.S. Manf. GDP	0.015	0.039	**158.2%**
Manuf. IIT/Mex. Manf. GDP	1.129	0.963	-14.6%
U.S. Skill Premium	1.670	**1.780**	6.6%
Mexican Skill Premium	0.990	2.179	120.0%
$\varepsilon = -1.0, \rho = 0.9, \alpha = 0.34$			
$\tau_{us,1987} = 0.031, \tau_{us,1994} = 0.010, \tau_{mex,1987} = 0.380, \tau_{mex,1994} = 0.142$			
Manuf. IIT/U.S. Manf. GDP	0.014	0.037	**158.2%**
Manuf. IIT/Mex. Manf. GDP	0.800	0.876	9.5%
U.S. Skill Premium	1.666	**1.780**	6.9%
Mexican Skill Premium	2.066	2.320	12.3%

Figure 1. Relative Wage of High-Skilled to Low-Skilled Labor in U.S. and Mexican Manufacturing Industries

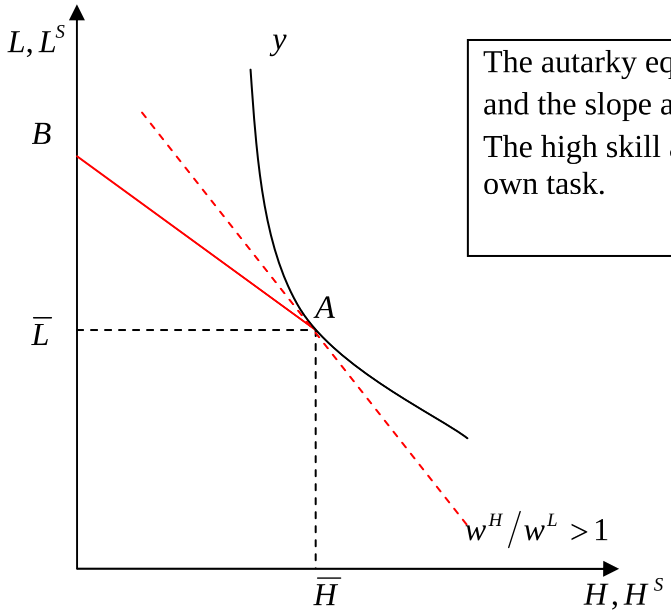


Source: Author's calculations based on the ASM and the EIM.

Figure 2. U.S.-Mexican Trade as Percent of U.S. GDP

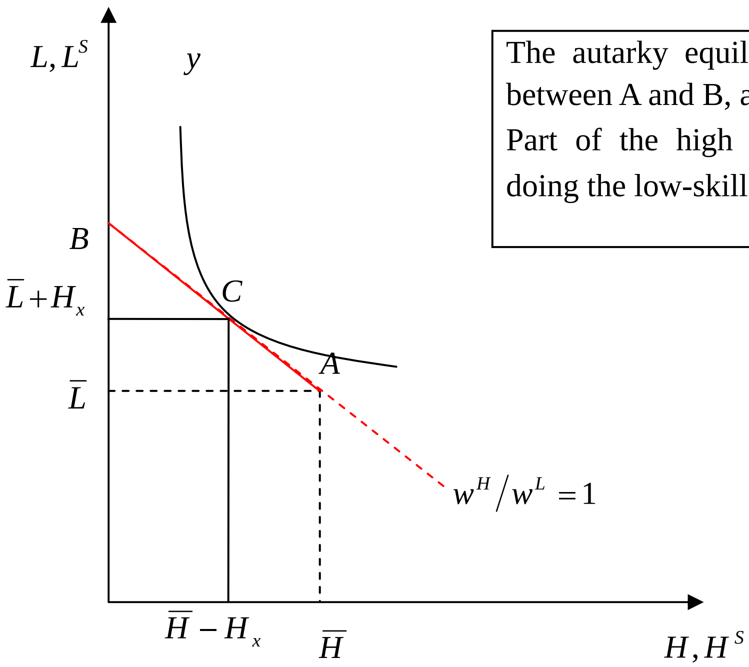
Note: U.S.-Mexican trade is defined by the sum of U.S. exports to and U.S. imports from Mexico.
Source: Author's calculations based on the International Trade Administration and the Bureau of Economic Analysis.

Figure 3-a. Autarky Equilibrium with $w^H / w^L > 1$



The autarky equilibrium is achieved at A, and the slope at A is $w^H / w^L > 1$.
The high skill and low skill each do their own task.

Figure 3-b. Autarky Equilibrium with $w^H / w^L = 1$



The autarky equilibrium is achieved at C between A and B, and $w^H / w^L = 1$.
Part of the high skill denoted by H_x is doing the low-skill task.

Figure 4. Labor Market for High-Skilled Labor

In **BOTH** Countries

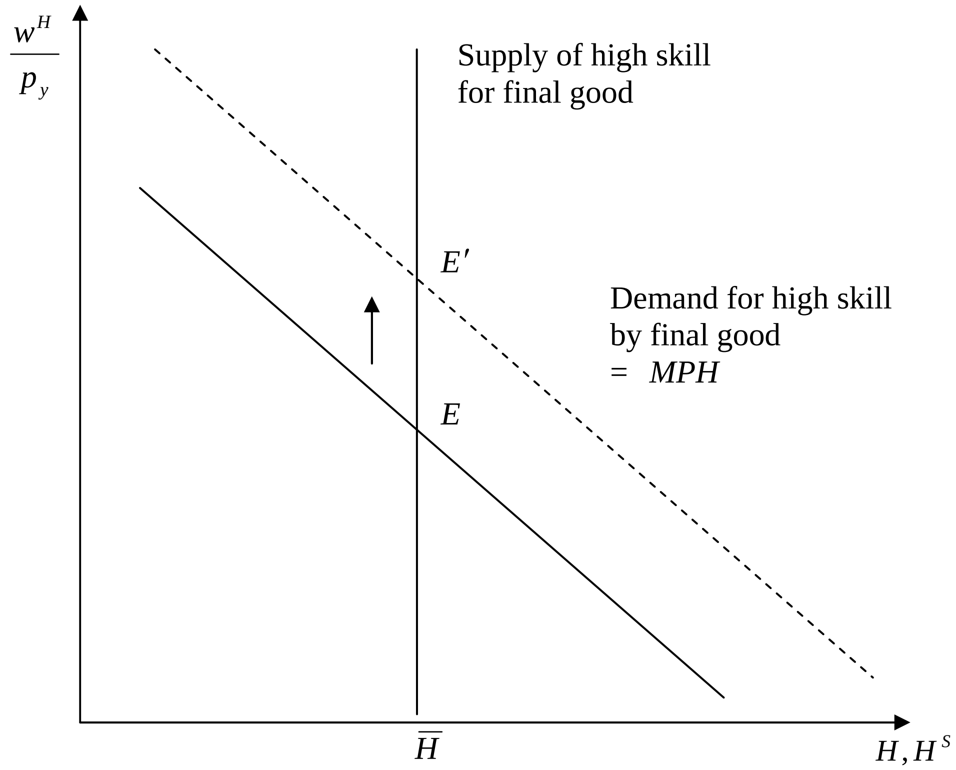
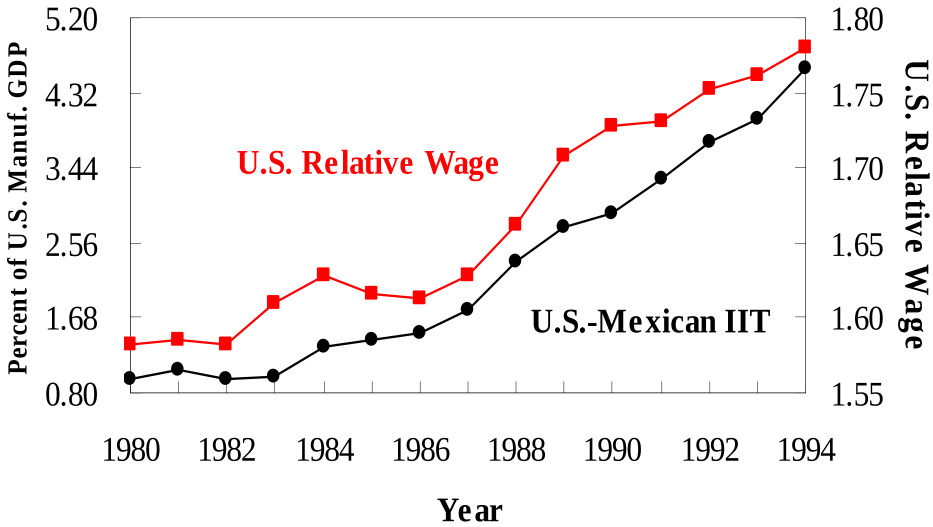
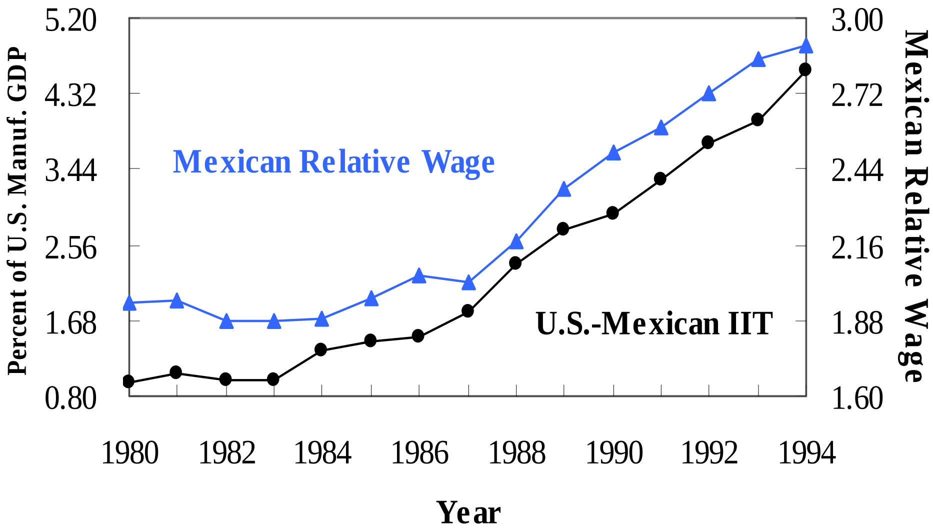


Figure 5-a. U.S.-Mexican IIT and Relative Wage of High-Skilled Labor in U.S. Manufacturing Industries



Source: Author's calculations based on the OECD ITCS and STAN and the ASM.

Figure 5-b. U.S.-Mexican IIT and Relative Wage of High-Skilled Labor in Mexican Manufacturing Industries



Source: Author's calculations based on the OECD ITCS and STAN and the EIM.