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Abstract

It can be theoretically shown that variety trade can be a possible source of increased skill premium in wages. No past studies, however, have empirically quantified how much of the increase in skill premium can be accounted for by the increase in variety trade. This paper now formulates a static general equilibrium model and then calibrates it to the Mexican input-output matrix for 1987. In the calibrated model, our numerical experiments show that the increase in U.S.-Mexican variety trade can explain approximately 12 percent of the actual increase in skill premium in Mexico from 1987 to 2000.

Keywords: Variety Trade, Skill Premium, Variety-Skill Complementarity, Calibrated General Equilibrium Model, Mexico

JEL Classifications: F12, F16

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1 Introduction

It can be theoretically shown that the variety trade between two countries can be a possible source of an increase in the relative wage of high-skilled to low-skilled workers—the skill premium—in both countries.[1] Kurokawa (2008), for example, proposes a simple theoretical framework to illustrate the possibility of an increase in skill premium in each of the trading countries as a result of variety trade. Upon application of the well-known variety-trade models (Krugman, 1979; Dixit and Norman, 1980; Ethier, 1982), he shows 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 an increase in the variety of tasks to be handled and thus correspond to a higher demand for the high-skilled labor. Through this variety-skill complementarity, the relative wage of high skill—the skill premium—can rise in both countries.[2]

A serious empirical challenge, however, is imposed because no past studies have empirically quantified how much of the increase in skill premium can be accounted for by the increase in variety trade. This paper now formulates a static general equilibrium model and then calibrates it to Mexican data for 1987. In the calibrated model, our numerical experiments show how much of the increase in Mexican skill premium from 1987 to 2000 can be explained by the increase in U.S.-Mexican variety trade.[3]

We first present our theoretical model. The model is a static general equilibrium model which allows us to perform a full-scale calibration.[4] There are two countries and three sectors—primaries, manufactures, and services. While primaries and services are produced under constant returns and perfect competition, manufactures are differentiated goods produced under increasing returns and monopolistic competition.

[1] There are other trade-based explanations for an increase in skill premium in each of the trading countries. One explanation is based on outsourcing (Feenstra and Hanson, 1996). Another explanation is based on the Schumpeterian mechanism (Dinopoulos and Segerstrom, 1999; Acemoglu, 2003).

[2] 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 production of each variety, thus relating an increase in the output of each variety to an increase in the relative demand for high-skilled labor by each variety.

[3] Due to data constraint, here we use data from 1987 to 2000. Fortunately, however, Mexico acceded to the General Agreement on Tariffs and Trade (GATT) in 1986 and agreed to a major liberalization of bilateral trade relations with the U.S. in 1987.

[4] Our model extends Bergoeing and Kehoe's (2003) model by distinguishing high- and low-skilled labor and introducing tariffs on the imports of manufactured varieties, thus relating an increase in variety trade due to a tariff reduction into an increase in skill premium.

The production of each good uses high- and low-skilled workers, primaries, services, and a variety of manufactures. Primaries and manufactures are tradable goods, while services are non-tradable goods. In each country, a representative consumer with homothetic preferences consumes these primaries, manufactures, and services. While our model specification is very general, in this paper, we are interested in assessing the impact of the U.S.-Mexican variety trade on the skill premium in Mexico—a small country relative to the U.S. Thus, for our numerical analysis, we specialize the model to the small open economy case.

We calibrate our theoretical model to the Mexican input-output matrix for 1987. In the calibrated model, we conduct numerical experiments to see how much of the increase in skill premium in Mexico from 1987 to 2000 can be explained by the increase in U.S.-Mexican variety trade. For this purpose, we consider two alternative plausible experiments. In one experiment, we assume that trade liberalization in Mexico over 1987-2000 resulted in a lower tariff and thus reduced the price of foreign varieties in Mexico but the number of imported varieties remained unchanged. In the other experiment, we assume that the increase in manufactured imports in Mexico was accompanied by an increase in the number of varieties but the tariff remained unchanged.

Both of the experiments show that the relative wage of high- to low-skilled labor can increase by approximately 4 percent. On the other hand, the data show that Mexican skill premium increased from 1.666 to 2.208 over 1987-2000, which is a 32.5 percent increase.[5] Thus the results indicate that increased U.S.-Mexican variety trade can account for approximately 12 percent of the change in Mexican skill premium over 1987-2000.[6] Hence, we illustrate the possibility that the U.S.-Mexican variety trade, which is a small fraction of Mexican GDP, is a factor contributing to the increase in wage inequality in Mexico; however, it appears not to be the major cause. It should be noted that here we look at Mexican trade with the U.S. alone. Our results,

[5] Here we use non-production and production workers as an index for high-skilled and low-skilled workers (Berman et al., 1994; Robertson, 2004). We calculate the Mexican relative wage on the basis of the Mexican Monthly Industrial Survey (*Encuesta Industrial Mensual*, or EIM) by first calculating the monthly income per person of non-production relative to production labor. The annual average is then produced by averaging this monthly relative wage.

[6] Note that, as we work with a structural model, our empirical analysis of trade and skill premium avoids the pitfalls that Deardorff and Hakura (1994) point out. Since both trade and wages are endogenous variables, it is not meaningful to ask if trade causes skill premium to rise. They thus formulate questions for empirical analysis that are theoretically meaningful. Among them, two questions are (1) what would be or would have been the wage effects of a particular trade liberalization; and (2) what are the wage effects in one country for a particular change such as a productivity improvement in another country, these effects presumably being transmitted through trade. Our two experiments ask precisely these two questions posed by Deardorff and Hakura.

however, would be little changed even if Mexican trade with other trade partners of Mexico is also included. This is because Mexico's principal trade partner is by far the U.S., which in 2000 supplied approximately 73 percent of Mexico's imports and attracted approximately 89 percent of its exports.[7]

Of course, other mechanisms which can explain the increase in skill premium have also been proposed and empirically tested. One set of studies highlight the influence of technological change on skill premium. Berman et al. (1994) argue that skill-biased technological change caused the shift in demand away from low-skilled and toward high-skilled labor in U.S. manufacturing during the 1980s. Their regression results show that 40 percent of this shift can be accounted for by skill-biased technological change.[8] Krusell et al. (2000) argue that 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. They find, using a calibrated model, that most of the wage inequality shift of the last 30 years in the U.S. can be explained by this capital-skill complementarity hypothesis.[9]

Another set of studies concentrate on the effect of trade on rising skill premium as does our paper. Feenstra and Hanson (1996) claim 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 of the low-skill intensive goods to the South, but these goods are high-skill intensive goods by the standards of the South. Thus, the skill intensity of production rises in both the North and the South. While trade-based explanations have often been criticized due to the small volume of trade (Krugman, 1995), their regression results indicate that 15-33 percent of shifts towards high-skilled workers within U.S. manufacturing industries during the period 1979-1985 can be explained by the increasing import share.[10] Zhu and Trefler (2005) demonstrate that the product shifting highlighted by Feenstra and Hanson,

[7]In 2000, Canada was the second largest destination for Mexican products, accounting for approximately 2 percent of exports. Outside the North American Free Trade Agreement (NAFTA), no individual country absorbed more than 1 percent of total Mexican exports.

[8]Katz and Murphy (1992), Katz and Autor (1999), and Berman et al. (1998) also relate technological change to wage inequality.

[9]The hypothesis of capital-skill complementarity was first formalized by Griliches (1969). Goldin and Katz (1998) document the importance of capital-skill complementarity during the period 1909-1929. Lindquist (2001) has recently replicated the research by Krusell et al. (2000) for Sweden.

[10]It should be noted that Krugman (2008) argues that, due to the increase in U.S. trade with poor countries and the growing fragmentation of production, it is no longer safe to assume that the effect of trade on wage inequality is very minor, although he admits that it is hard to prove the actual effect.

which leads to a rise in wage inequality, can also result from technological catch-up in the South.[11]

On a different note, Hanson and Harrison (1999) link the increase in Mexican wage inequality over the period 1984-1990 to changes in trade policy. They find, using regressions, that the reduction in tariff protection in 1985 disproportionately affected low-skilled industries and that the goods from this sector may have fallen in price and wage because of competition from economies with reserves of cheaper low-skilled labor than Mexico's.[12] In contrast, using numerical simulations, Atolia (2007) shows that the rise in wage inequality in Latin America can be rationalized as a short-run response to trade liberalization. In particular, he shows a short-run rise in wage inequality, despite a long-run decline, can occur due to asymmetries in the speed of adjustment in different sectors and capital-skill complementarity in production.[13]

In this line of empirical studies, our paper adds a new quantitative result using a different methodology. To our knowledge, this paper is the first to use a calibrated general equilibrium model to show how much of the increase in Mexican skill premium can be accounted for by trade.

The rest of this paper is organized as follows. In Section 2, we formulate our static general equilibrium model of trade. We solve the model in Section 3. Section 4 calibrates the model to the Mexican input-output matrix for 1987. Using the calibrated model, we present our numerical experiments in Section 5. Finally, Section 6 summarizes main results and mentions future research.

2 The Model

Consider a world in which there are two countries: country 1 and country 2. In each country j, $j = 1, 2$, there are three types of goods, a primary good that is tradable and homogeneous, varieties of a manufactured good that are tradable and differentiated by the firm that produces them, and a service good that is homogeneous

[11] Xu (2003) extends Feenstra and Hanson (1996) by introducing endogenously determined non-traded goods, thus showing that trade liberalization in the South can reduce wage inequality when trade barriers start at a high level. Many papers relate trade to wage inequality in the U.S. Borjas and Ramey (1994) show how trade volumes can be linked to wage inequality in the U.S. Harrigan and Balaban (1999) estimate an econometric general equilibrium model of U.S. wages as a function of prices, technology, and factor supplies.

[12] There are many papers focusing on Mexico. Revenga (1997) also relates changes in Mexican wage inequality to changes in trade policy. Robertson (2004) investigates the link between relative goods prices and relative wages in Mexico, and Verhoogen (2008) links quality upgrading for export to skill premium in Mexico.

[13] See also Robbins (1996) for discussions on increased skill premium in Latin America.

and non-tradable. The varieties of the manufactured good are combined to produce a composite manufactured good. Each country j has a given endowment of high-skilled labor and low-skilled labor, H^j and L^j.

A representative consumer in country j solves the problem of maximizing

$$\beta_p \log c_p^j + \beta_m \log c_m^j + \beta_s \log c_s^j, \tag{1}$$

subject to

$$\begin{aligned} q_p^j c_p^j + q_m^j c_m^j + q_s^j c_s^j &\leq w_H^j H^j + w_L^j L^j \\ c_p^j, c_m^j, c_s^j &\geq 0. \end{aligned} \tag{2}$$

Here c_p^j is the consumption of the primary good and q_p^j is its price; c_m^j is the consumption of the composite manufactured good and q_m^j is its price; c_s^j is the consumption of the service good and q_s^j is its price; and w_H^j and w_L^j are the wages for the high- and the low-skilled labor. The composite manufactured goods is a CES aggregate of different varieties given by

$$c_m^j = \left(\int_{D^w} (c_{mz}^j)^\rho dz \right)^{\frac{1}{\rho}}, \tag{3}$$

where parameter ρ, $\rho < 1$, governs the elasticity of substitution, $1/(1-\rho)$, between any two differentiated varieties in the interval $D^w = [0, d^w]$ of the varieties of the manufactured good produced throughout the world. On the other hand, note that the elasticity of substitution between primaries, services, and composite manufactures is 1.

Both the primary and the service good in country j are produced according to constant returns production functions

$$\begin{aligned} y_p^j &= \gamma_p \left[a_p \left\{ b_p (x_{m,p}^j)^\varepsilon + (1-b_p)(H_p^j)^\varepsilon \right\}^{\frac{\mu}{\varepsilon}} + (1-a_p)(L_p^j)^\mu \right]^{\frac{\alpha_{p1}}{\mu}} (x_{p,p}^j)^{\alpha_{p2}} (x_{s,p}^j)^{\alpha_{p3}} \quad (4) \\ y_s^j &= \gamma_s \left[a_s \left\{ b_s (x_{m,s}^j)^\varepsilon + (1-b_s)(H_s^j)^\varepsilon \right\}^{\frac{\mu}{\varepsilon}} + (1-a_s)(L_s^j)^\mu \right]^{\frac{\alpha_{s1}}{\mu}} (x_{p,s}^j)^{\alpha_{s2}} (x_{s,s}^j)^{\alpha_{s3}}, \quad (5) \end{aligned}$$

where $0 < a_i,\ b_i < 1$, $\gamma_i > 0$, and $0 < \alpha_{ik} < 1$ are sector-specific parameters with $\alpha_{i1} + \alpha_{i2} + \alpha_{i3} = 1$, and the composite manufactured inputs are

$$x_{m,p}^j = \left(\int_{D^w} x_{mz,p}^j{}^\rho dz \right)^{\frac{1}{\rho}} \quad \text{and} \quad x_{m,s}^j = \left(\int_{D^w} x_{mz,s}{}^\rho dz \right)^{\frac{1}{\rho}}. \tag{6}$$

In contrast, the technology for producing manufactured goods exhibits increasing returns to scale because of the presence of fixed costs. Specifically, every firm z, $z \in D^w$, has the production function

$$y^j_{mz} = \max\left\{\gamma_m \left[\begin{array}{c} a_m\left\{b_m(x^j_{m,mz})^{\varepsilon} + (1-b_m)\left(H^j_{mz}\right)^{\varepsilon}\right\}^{\frac{\mu}{\varepsilon}} + \\ (1-a_m)\left(L^j_{mz}\right)^{\mu}\end{array}\right]^{\frac{\alpha_{m1}}{\mu}} (x^j_{p,mz})^{\alpha_{m2}}(x^j_{s,mz})^{\alpha_{m3}} - F, 0\right\}, \tag{7}$$

where as in other sectors $0 < a_m, b_m < 1$, $\gamma_m > 0$, $0 < \alpha_{mk} < 1$, and $\alpha_{m1}+\alpha_{m2}+\alpha_{m3} = 1$. Also,

$$x^j_{m,mz} = \left(\int_{D^w}\left(x^j_{mz',mz}\right)^{\rho} dz'\right)^{\frac{1}{\rho}}, \tag{8}$$

and $F > 0$ is the level of fixed costs.

Thus, in each sector, production requires primaries, services, and a composite good as inputs. The composite input is produced by combining the manufactured good, high-skilled labor, and low-skilled labor using a nested-CES technology. The substitution parameters of this technology, ε and μ, are the same across all sectors. Further, we assume $\varepsilon < \mu$ and define this as the case where the varieties or manufactured goods are relatively more complementary to the high-skilled labor than the low-skilled labor (variety-skill complementarity).[14]

Let $\tilde{c}^j_{mz}(q^j_m, w^j_H, w^j_L, q^j_p, q^j_s; y_{mz}+F)$ be the solution to the cost minimization problem for firm z. As the manufacturing sector produces output using a nested-CES technology with primaries, services, and a composite input made from manufactured good, high-skilled labor, and low-skilled labor as inputs, the cost function can be written in terms of the sub-cost functions as follows:

$$\begin{aligned}
\tilde{c}^j_{mz}\left(q^j_m, w^j_H, w^j_L, q^j_p, q^j_s; y_{mz}+F\right) &= \tilde{c}^j_{mz}\left(\tilde{c}^j_{A,m}\left(q^j_m, w^j_H, w^j_L\right), q^j_p, q^j_s; y_{mz}+F\right), \\
&= \tilde{c}^j_{mz}\left(\tilde{c}^j_{A,m}\left(\tilde{c}^j_{B,m}\left(q^j_m, w^j_H\right), w^j_L\right), q^j_p, q^j_s; y_{mz}+F\right), \\
&= \frac{1}{\gamma_m}\left(\frac{\tilde{c}^j_{A,m}}{\alpha_{i1}}\right)^{\alpha_{i1}}\left(\frac{q_p}{\alpha_{i2}}\right)^{\alpha_{i2}}\left(\frac{q_s}{\alpha_{i3}}\right)^{\alpha_{i3}}(y_{mz}+F)
\end{aligned} \tag{9}$$

[14] Kurokawa (2008) formalizes the hypothesis of variety-skill complementarity. In some papers, the number of inputs plays a related role. Blanchard and 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.

where $z \in D^j$, $j = 1, 2$, and the sub-cost functions are

$$\tilde{c}^j_{A,mz}\left(q^j_m, w^j_H, w^j_L\right) = \left[a_m^{\frac{1}{1-\mu}} \tilde{c}^j_{B,mz}\left(q^j_m, w^j_H\right)^{-\frac{\mu}{1-\mu}} + (1-a_m)^{\frac{1}{1-\mu}} \left(w^j_L\right)^{-\frac{\mu}{1-\mu}}\right]^{-\frac{1-\mu}{\mu}} \quad (10)$$

$$\tilde{c}^j_{B,mz}\left(q^j_m, w^j_H\right) = \left[b_m^{\frac{1}{1-\varepsilon}} \left(q^j_m\right)^{-\frac{\varepsilon}{1-\varepsilon}} + (1-b_m)^{\frac{1}{1-\varepsilon}} \left(w^j_H\right)^{-\frac{\varepsilon}{1-\varepsilon}}\right]^{-\frac{1-\varepsilon}{\varepsilon}}. \quad (11)$$

Thus, we can write $\tilde{c}^j_{mz}(.)$ as a linear function of $y_{mz} + F$:

$$\tilde{c}^j_{mz}\left(q^j_m, w^j_H, w^j_L, q^j_p, q^j_s; y_{mz} + F\right) = G^j\left(y_{mz} + F\right), \qquad z \in D^j, \quad j = 1, 2. \quad (12)$$

The firms in the manufacturing sector are monopolistic competitors and face a downward sloping demand curve and firm $z \in D^w$ in country j sets its price q^j_{mz} to maximize profits:

$$\max \pi^j_{mz} = q^j_{mz} y_{mz} - G^j\left(y_{mz} + F\right), \quad (13)$$

taking all other prices as given.

To derive the demand for each variety, assume each country j levies an *iceberg* tariff τ^j on the imports of the manufactured goods from country $-j$. Then, the demand by the consumer in country j for the domestic variety $z \in D^j$ and the foreign variety $z \in D^{-j}$ is:

$$c^j_{mz} = \left(\frac{q^j_{mz}}{q^j_m}\right)^{-\frac{1}{1-\rho}} \frac{\beta_m\left(w^j_H H^j + w^j_L L^j\right)}{q^j_m}, \qquad z \in D^j, \quad (14)$$

$$c^j_{mz} = \left(\frac{\left(1+\tau^j\right) q^{-j}_{mz}}{q^j_m}\right)^{-\frac{1}{1-\rho}} \frac{\beta_m\left(w^j_H H^j + w^j_L L^j\right)}{q^j_m}, \qquad z \in D^{-j}, \quad (15)$$

where q^j_{mz} is the price in country j of variety $z \in D^j$ and q^{-j}_{mz} the price in country $-j$ of variety $z \in D^{-j}$. One can show that q^j_m can be written as an exact consumption-based price index of the prices of individual varieties as follows:

$$q^j_m = \left[\int_{D^j} \left(q^j_{mz}\right)^{-\frac{\rho}{1-\rho}} dz + \int_{D^{-j}} \left[\left(1+\tau^j\right) q^{-j}_{mz}\right]^{-\frac{\rho}{1-\rho}} dz\right]^{-\frac{1-\rho}{\rho}}. \quad (16)$$

Thus, the total consumption demand for variety $z \in D^j$ faced by the firm is:

$$\begin{aligned} c_{mz}^j + \left(1+\tau^{-j}\right) c_{mz}^{-j} &= \left(\frac{q_{mz}^j}{q_m^j}\right)^{-\frac{1}{1-\rho}} \frac{\beta_m \left(w_H^j H^j + w_L^j L^j\right)}{q_m^j} + \\ &\quad \left(1+\tau^{-j}\right) \left(\frac{\left(1+\tau^{-j}\right) q_{mz}^j}{q_m^{-j}}\right)^{-\frac{1}{1-\rho}} \frac{\beta_m \left(w_H^{-j} H^{-j} + w_L^{-j} L^{-j}\right)}{q_m^{-j}} \\ &= E q_{mz}^{-\frac{1}{1-\rho}}, \qquad z \in D^j, \quad j = 1,2, \end{aligned} \tag{17}$$

where

$$E = \frac{\beta_m \left(w_H^j H^j + w_L^j L^j\right)}{\left(q_m^j\right)^{-\frac{\rho}{1-\rho}}} + \frac{\beta_m \left(w_H^{-j} H^{-j} + w_L^{-j} L^{-j}\right)}{\left(q_m^{-j} / \left(1+\tau^{-j}\right)\right)^{-\frac{\rho}{1-\rho}}}. \tag{18}$$

Thus, the total consumption demand varies with price q_{mz}^j with elasticity $-1/\left(1-\rho\right)$. One can show that the same holds true for the total demand for variety z which can be expressed as

$$y_{mz} = T q_{mz}^{-\frac{1}{1-\rho}}, \qquad z \in D^j, \quad j = 1,2, \tag{19}$$

for some constant $T > 0$.

Hence, given the number of varieties, the profit of firm z can be rewritten as:

$$\pi_z^j = q_{mz}^j T q_{mz}^{-\frac{1}{1-\rho}} - G^j T q_{mz}^{-\frac{1}{1-\rho}} - G^j F. \tag{20}$$

The first order condition for profit maximization with respect to q_{mz} then gives:

$$q_{mz} = \frac{G^j}{\rho}, \qquad z \in D^j, \quad j = 1,2. \tag{21}$$

Further, by the zero profit condition for this q_{mz}:

$$\pi_z^j = \frac{G^j}{\rho} y_{mz} - G^j \left(y_{mz} + F\right) = 0, \tag{22}$$

we obtain

$$y_{mz}^j = \frac{\rho}{1-\rho} F, \qquad z \in D^w. \tag{23}$$

Definition 1 *An* ***equilibrium*** *is a vector of prices* q_p^j, q_s^j, q_{mz}^j, w_H^j, w_L^j, *and quantities* c_p^j, c_s^j, c_{mz}^j, y_p^j, y_s^j, y_{mz}^j, $x_{mz,p}^j$, $x_{p,p}^j$, $x_{s,p}^j$, H_p^j, L_p^j, $x_{mz,s}^j$, $x_{p,s}^j$, $x_{s,s}^j$, H_s^j, L_s^j, $x_{mz,mz}^j$, $x_{p,mz}^j$, $x_{s,mz}^j$, H_{mz}^j, L_{mz}^j, $z \in D^j$, $j = 1,2$, *an interval* D^w, *and a measure of firms for each country* D^j, $j = 1,2$, *such that*

1. *Given the prices, the consumption plans* c_p^j, c_{mz}^j, c_s^j *solve the utility maximization*

problem of consumer j;

2. *Given factor prices, the production plans (including the factor demands) for the primary and service good satisfy the conditions for zero profit and cost minimization;*

3. *Given factor prices and demand, price* q_{mz}^j *and production plans (including the factor demands) of the manufacturing firm* z *in country* j *maximize profits and minimize costs;*

4. *Every firm* $z \in D^w$ *earns zero profits;*

5. *The markets for goods clear,*

$$\sum_{j=1}^{2}\left(c_p^j + x_{p,p}^j + x_{p,s}^j + \int_{D^j} x_{p,mz}^j dz\right) = \sum_{j=1}^{2} y_p^j, \tag{24}$$

$$c_s^j + x_{s,p}^j + x_{s,s}^j + \int_{D^j} x_{s,mz}^j dz = y_s^j, \; j = 1, 2, \tag{25}$$

$$\left[\begin{array}{c} c_{mz}^j + x_{mz,p}^j + x_{mz,s}^j + \int_{D^j} x_{mz',mz}^j dz' + \\ (1+\tau^{-j})\left(c_{mz}^{-j} + x_{mz,p}^{-j} + x_{mz,s}^{-j} + \int_{D^{-j}} x_{mz',mz}^j dz'\right) \end{array}\right] = y_{mz}^j, \; j = 1, 2 \tag{26}$$

6. *The factor markets clear,*

$$H_p^j + \int_{D^j} H_{mz}^j dz + H_s^j = H^j, \quad j = 1, 2, \tag{27}$$

$$L_p^j + \int_{D^j} L_{mz}^j dz + L_s^j = L^j, \quad j = 1, 2; \tag{28}$$

7. *The number of available varieties for consumption is the number of varieties produced,*

$$D^w = D^1 \cup D^2.$$

3 Solving the Model

In the previous section, we have laid out the model in the two-country setting. We, however, are interested in assessing the impact of the U.S.-Mexican variety trade on the skill premium in Mexico—a small country relative to the U.S. Thus, in our simulations, we will concentrate on the small open economy case. Therefore, we will omit country superscripts from this section onwards. To solve the model, we begin with the consumer's problem.

3.1 Consumption

With the Cobb-Douglas utility function, the consumer's optimal decision is to spend a constant fraction β_i of his income on good $i = p, m, s$. Thus utility maximization yields the following demand functions for the consumption of the different goods:

$$c_i(q_i, E) = \frac{\beta_i E}{q_i}, \qquad i = p, m, s, \tag{29}$$

where E is the total consumption expenditure and q_i is the price of good i. From (2), we have that the consumption expenditure equals the wage income. However, with a eye on calibration to data wherein a country may not have the balanced current account, we allow for net exports (NX) and E to be given by

$$E = w_H H + w_L L - NX. \tag{30}$$

Accordingly, in the demand for each individual manufacturing variety in $(14 - 15)$, $w_H H + w_L L$ is replaced by E.

3.2 Production

Turning to the production, we start with the primary and service sectors. Similar to (9), we can write the cost functions for the primary and service sectors as

$$\begin{aligned} \tilde{c}_i(q_m, w_H, w_L, q_p, q_s; y_i) &= \tilde{c}_i(\tilde{c}_{A,i}(q_m, w_H, w_L), q_p, q_s; y_i) \\ &= \tilde{c}_i(\tilde{c}_{A,i}(\tilde{c}_{B,i}(q_m, w_H), w_L), q_p, q_s; y_i) \\ &= \frac{1}{\gamma_i}\left(\frac{\tilde{c}_{A,i}(q_m, w_H, w_L)}{\alpha_{i1}}\right)^{\alpha_{i1}}\left(\frac{q_p}{\alpha_{i2}}\right)^{\alpha_{i2}}\left(\frac{q_s}{\alpha_{i3}}\right)^{\alpha_{i3}} y_i, \end{aligned} \tag{31}$$

where

$$\begin{aligned} \tilde{c}_{A,i}(q_m, w_H, w_L) &= \left[a_i^{\frac{1}{1-\mu}}\tilde{c}_{B,i}(q_m, w_H)^{-\frac{\mu}{1-\mu}} + (1-a_i)^{\frac{1}{1-\mu}} w_L^{-\frac{\mu}{1-\mu}}\right]^{-\frac{1-\mu}{\mu}}, \\ \tilde{c}_{B,i}(q_m, w_H) &= \left[b_i^{\frac{1}{1-\varepsilon}} q_m^{-\frac{\varepsilon}{1-\varepsilon}} + (1-b_i)^{\frac{1}{1-\varepsilon}} w_H^{-\frac{\varepsilon}{1-\varepsilon}}\right]^{-\frac{1-\varepsilon}{\varepsilon}}, \end{aligned} \tag{32}$$

and, $i = p, s$.

Using these cost functions, it is easy to derive the input demands using Shephard's lemma. For example, the demand of primaries is

$$x_{p,i}\left(q_m, w_H, w_L, q_p, q_s; y_i\right) = \frac{\partial \tilde{c}_i}{\partial q_p} = \frac{\alpha_{i2}\tilde{c}_i}{q_p}, \qquad i = p, s, \tag{33}$$

$$x_{p,mz}\left(q_m, w_H, w_L, q_p, q_s; y_{mz} + F\right) = \frac{\partial \tilde{c}_{mz}}{\partial q_p} = \frac{\alpha_{m2}\tilde{c}_{mz}}{q_p}, \tag{34}$$

where the numerator is the factor payment to the primaries for the relevant good or variety, and the demand for service input is

$$x_{s,i}\left(q_m, w_H, w_L, q_p, q_s; y_i\right) = \frac{\partial \tilde{c}_i}{\partial q_s} = \frac{\alpha_{i3}\tilde{c}_i}{q_s}, \qquad i = p, s, \tag{35}$$

$$x_{s,mz}\left(q_m, w_H, w_L, q_p, q_s; y_{mz} + F\right) = \frac{\partial \tilde{c}_{mz}}{\partial q_s} = \frac{\alpha_{m3}\tilde{c}_{mz}}{q_s}, \tag{36}$$

Similarly, we can derive the demand for low-skilled labor $\left(L_i\left(q_m, w_H, w_L, q_p, q_s; y_i\right)\right)$ and high-skilled labor $\left(H_i\left(q_m, w_H, w_L, q_p, q_s; y_i\right)\right)$ and the composite manufactured input $\left(x_{m,i}\left(q_m, w_H, w_L, q_p, q_s; y_i\right)\right)$ by differentiating the cost function with respect to w_L, w_H, and q_m. Finally, the input demand for a particular variety z of manufactures is

$$x_{mz,i} = \left(\frac{q_{mz}}{q_m}\right)^{-\frac{1}{1-\rho}} x_{m,i}, \qquad i = p, s, \tag{37}$$

$$x_{mz,mz} = \left(\frac{q_{mz}}{q_m}\right)^{-\frac{1}{1-\rho}} x_{m,mz}. \tag{38}$$

The condition for profit maximization by the firms producing manufactured varieties has already been derived (see (21)).[15] Profit maximization by firms implies that in the primary and service sectors, price equals marginal cost which also equals the unit cost

$$q_i = \frac{1}{\gamma_i}\left(\frac{\tilde{c}_{A,i}\left(q_m, w_H, w_L\right)}{\alpha_{i1}}\right)^{\alpha_{i1}}\left(\frac{q_p}{\alpha_{i2}}\right)^{\alpha_{i2}}\left(\frac{q_s}{\alpha_{i3}}\right)^{\alpha_{i3}}, \qquad i = p, s. \tag{39}$$

3.3 Production and Use of Manufactures

The maximization problem for a firm manufacturing a particular variety has already been solved in Section 2. We now proceed to further derive the aggregate variables for the manufacturing sector or good. For this we begin by imposing symmetry in

[15] Even though the country is small, every firm producing a variety z of manufactured good possesses marketing power and faces same elasticity of demand in domestic and foreign markets. So, equation (21) still applies.

the manufacturing sector so that the price of all domestic varieties and hence their quantities produced as well as domestically used are all the same. Similarly, the price and quantities used of the imported varieties are the same as well.

Let n be the number of domestic varieties and n^* be the number of foreign varieties. Further, let x_{mz} be the quantity of a representative variety that is domestically used and similarly define x_{mz^*}. Then we can write the price (q_m) of the composite manufactured good that is used in production and for consumption as a use- or consumption-based price index

$$q_m = \left[n q_{mz}^{-\frac{\rho}{1-\rho}} + n^* [(1+\tau) q_{mz^*}]^{-\frac{\rho}{1-\rho}} \right]^{-\frac{1-\rho}{\rho}}. \tag{40}$$

It is instructive to rewrite this index as a combination of the price indices for the domestic and foreign varieties

$$q_m = \left[\bar{q}_{mz}^{-\frac{\rho}{1-\rho}} + \bar{q}_{mz^*}^{-\frac{\rho}{1-\rho}} \right]^{-\frac{1-\rho}{\rho}}, \tag{41}$$

where

$$\bar{q}_{mz} = n^{-\frac{1-\rho}{\rho}} q_{mz}, \tag{42}$$

is the price index for the domestically produced varieties and

$$\bar{q}_{mz^*} = (n^*)^{-\frac{1-\rho}{\rho}} (1+\tau) q_{mz^*} \tag{43}$$

is the price index for the foreign produced varieties. The corresponding quantity indices for their *use* in the domestic economy are

$$\bar{x}_{mz} = n^{\frac{1}{\rho}} x_{mz}, \tag{44}$$

$$\bar{x}_{mz^*} = (n^*)^{\frac{1}{\rho}} x_{mz^*}. \tag{45}$$

4 Calibration of the Model

We test the ability of the model to explain the rise in skill premium in Mexico over the period 1987-2000. The choice of 1987 comes from data constraint. However, this is not a serious limitation since Mexico acceded to the GATT only in 1986 and agreed to a major liberalization of bilateral trade relations with the U.S. in 1987. Accordingly, the model is calibrated to the input-output matrix for Mexico for the year 1987.

4.1 Data

The input-output matrix for Mexico for 1987 is given in Appendix A. This matrix contains the information on the factor costs in each sector ($X_{j,i}$) where i stands for sector and j stands for the factor; the value of output for each sector, Y_i; the value of exports and imports for each sector, EX_i and IM_i; and the value of consumption of each good, C_i. All of the steps to construct this input-output matrix and the sources of the data are shown in Appendix A. Note that we do not have data on the break-up of the cost share of labor between low-skilled and high-skilled labor for the primary and service sectors for Mexico. In the benchmark simulations, we assume the share to be the same as in the manufacturing sector. In an alternative scenario, we use the break-up for Chile for 1992.

As shown in the matrix, much of output is services which are non-traded, and trade is not balanced in the data. We can also see that the gross value added in each sector equals its factor payments

$$Y_i = \sum_j X_{j,i}, \qquad i = p, m, s, \tag{46}$$

and that the total use of each good equals its net supply

$$\sum_k X_{i,k} + C_i = Y_i + IM_i - EX_i \qquad i = p, m, s. \tag{47}$$

4.2 Calibration

We begin our calibration by choosing the values of the three substitution parameters in the model, ρ, μ, and ε. The parameter ρ governs the elasticity of substitution among manufactured varieties. Recall that the elasticity of substitution between the primaries, the services, and the manufactures is already set to 1. The value of ρ determines the markup over cost charged by the firm. We set $\rho = 5/6$ which yields a 20 percent markup. This is in accordance with evidence in OECD countries presented by Martins et al. (1996).

Parameters μ and ε set the elasticity of substitution between the manufactures and low-skilled labor and between the manufactures and high-skilled labor, respectively. A number of studies report evidence in favor of capital-skill complementarity.[16] As Krusell et al. (2000) document, the majority of the estimates for the elasticity of substitution between low-skilled labor and capital lie between 0.5 and 3 whereas

[16] For example, see Griliches (1969), Berndt and Christensen (1974), Fallon and Layard (1975), and Brown and Christensen (1981).

most estimates of the elasticity of substitution between high-skilled labor and capital are below 1.2, and as they note, "several are near zero." In accordance with this evidence, we choose the elasticity of substitution for low-skilled labor to be 2 and for high-skilled labor to be 0.5 in the benchmark case. This implies $\mu = 1/2$ and $\varepsilon = -1$.

We begin the calibration by setting

$$E = C_p + C_m + C_s. \tag{48}$$

Further, given that there are productivity parameters in the production functions, we can only normalize all domestic goods prices to 1, i.e., we set

$$q_p = q_m = q_s = 1. \tag{49}$$

Further, we can also independently set the wage rates. Hence, without loss of generality, let[17]

$$w_L = w_H = 1. \tag{50}$$

The calculation of $\beta' s$ is straightforward in our case

$$\beta_i = \frac{C_i}{E}, \qquad i = p, s, m. \tag{51}$$

For factor j, define the cost share of that factor in sector i as $\theta_{j,i}$ and denote by $\mathbf{w}_j$ the price of factor $j = p, s, m, L, H$.[18] Then, from the demand functions derived above, we get

$$\theta_{j,i}\left(q_m, w_H, w_L, q_p, q_s\right) = \frac{\mathbf{w}_j x_{j,i}\left(q_m, w_H, w_L, q_p, q_s\right)}{\tilde{c}_i\left(q_m, w_H, w_L, q_p, q_s\right)}. \tag{52}$$

Then, $b_i' s$ can be solved from the following equations

$$\frac{\theta_{m,i}}{\theta_{H,i}} = \frac{X_{m,i}}{X_{H,i}}, \qquad i = p, s, mz. \tag{53}$$

Each of these equations has only one unknown, b_i. Note that here we are using the fact that

$$\frac{X_{m,mz}}{X_{H,mz}} = \frac{X_{m,m}}{X_{H,m}}. \tag{54}$$

[17] It does not matter how big w_H is in relation to w_L.

[18] For example, $w_m = q_m$, $w_p = q_p$, and $w_s = q_s$.

Similarly, $a_i's$ solve the following equations

$$\frac{\theta_{m,i}+\theta_{H,i}}{\theta_{L,i}}=\frac{X_{m,i}+X_{H,i}}{X_{L,i}}, \qquad i=p,s,mz. \tag{55}$$

Recall, as we do not have data on the break-up of the cost share of labor between low-skilled and high-skilled labor for the primary and service sectors, in the benchmark calibration we set $\theta_{H,i}/\theta_{L,i}=\theta_{H,m}/\theta_{L,m}$, $i=p,s$.

The $\alpha_i's$ are easy to calculate as well

$$\alpha_{i1} = \frac{X_{m,i}+X_{H,i}+X_{L,i}}{Y_i}, \qquad i=p,s,mz, \tag{56}$$

$$\alpha_{i2} = \frac{X_{p,i}}{Y_i}, \qquad i=p,s,mz, \tag{57}$$

$$\alpha_{i3} = \frac{X_{s,i}}{Y_i}, \qquad i=p,s,mz. \tag{58}$$

With all goods prices (q_p,q_m,q_s) and factor prices (w_H,w_L) normalized to 1, factor costs equal factor demands, and it is easy to calibrate γ_p and γ_s by using the production functions $(4-5)$ in which the only remaining unknown is γ_i. Furthermore, by labor market clearing, the supply of low-skilled and high-skilled labor is simply equal to the factor payments of each labor.

$$L = \textstyle\sum_{i=p,m,s} X_{L,i}, \tag{59}$$

$$H = \textstyle\sum_{i=p,m,s} X_{H,i}. \tag{60}$$

4.2.1 Remaining Calibration

To complete the calibration we still need to find values for

$$q_{mz},\ (1+\tau)q_{mz^*},\ \gamma_m,\ n,\ n^*, x_{mz},\ x_{mz^*}. \tag{61}$$

We begin with the composite of the domestic traded varieties which can be expressed as

$$\bar{x}_{mz}=\frac{Y_m-EX_m}{\bar{q}_{mz}}=\frac{Y_m-EX_m}{n^{-\frac{1-\rho}{\rho}}q_{mz}}, \tag{62}$$

which in turn yields[19]

$$x_{mz}=\frac{\bar{x}_{mz}}{n^{\frac{1}{\rho}}}=\frac{Y_m-EX_m}{nq_{mz}}. \tag{63}$$

[19]We could have obtained this directly using symmetry.

Similarly,

$$x_{mz^*} = \frac{\bar{x}_{mz^*}}{(n^*)^{\frac{1}{\rho}}} = \frac{IM_m}{n^*(1+\tau)q_{mz^*}} \tag{64}$$

Since varieties are aggregated using a CES aggregator, it is easy to see from $(14-15)$ or $(37-38)$ that the relative demand for the domestic and foreign varieties is

$$\frac{x_{mz}}{x_{mz^*}} = \left(\frac{q_{mz}}{(1+\tau)q_{mz^*}}\right)^{-\frac{1}{1-\rho}}. \tag{65}$$

Further, from the price index of the manufactured good (40), we have

$$q_m = \left[n q_{mz}^{-\frac{\rho}{1-\rho}} + n^*[(1+\tau)q_{mz^*}]^{-\frac{\rho}{1-\rho}}\right]^{-\frac{1-\rho}{\rho}}, \tag{66}$$

which can be simplified using (65). For this, we use (65) to obtain

$$\frac{n q_{mz} x_{mz}}{n^*(1+\tau)q_{mz^*}x_{mz^*}} = \frac{n}{n^*}\left(\frac{q_{mz}}{(1+\tau)q_{mz^*}}\right)^{-\frac{\rho}{1-\rho}} = \frac{Y_m - EX_m}{IM_m}, \tag{67}$$

which can be used to write (66) as

$$\begin{aligned} q_m &= (n^*)^{-\frac{1-\rho}{\rho}}(1+\tau)q_{mz^*}\left[\left\{\frac{n}{n^*}\left(\frac{q_{mz}}{(1+\tau)q_{mz^*}}\right)^{-\frac{\rho}{1-\rho}}\right\}+1\right]^{-\frac{1-\rho}{\rho}} \\ &= (n^*)^{-\frac{1-\rho}{\rho}}(1+\tau)q_{mz^*}\left[\frac{Y_m - EX_m}{IM_m}+1\right]^{-\frac{1-\rho}{\rho}}. \end{aligned} \tag{68}$$

Finally, we impose the normalization

$$n + n^* = 100, \tag{69}$$

and obtain the ratio of varieties produced in Mexico and the U.S.

$$\frac{n}{n^*} \tag{70}$$

using the employment data. It can be shown that the ratio n/n^* equals the ratio of the total labor compensations in the Mexican and U.S. manufactures, which is approximately 3/97 in 1987.

It is possible to solve (21), $(63-65)$, and $(68-70)$ for q_{mz}, $(1+\tau)q_{mz^*}$, γ_m, n, n^*, x_{mz}, and x_{mz^*}. In order to complete the calibration of the model, we check the calibration by ensuring that all markets actually clear. The resulting calibration of the model is summarized in Table 1, and Table 2 lists the initial steady state values of the endogenous variables.

5 Variety Trade and Skill Premium

We have calibrated the static general equilibrium model to the Mexican economy. In the calibrated model, we quantitatively evaluate the ability of the variety-skill complementarity hypothesis to explain the rise in skill premium in Mexico over the period 1987-2000. To do so, we change the manufactured trade in the calibrated model as in the Mexican data from 1987 to 2000. Over this period, both the ratio of manufactured imports from the U.S. to GDP and the ratio of manufactured exports to the U.S. to GDP increased by over 100 percent.

There are two plausible exogenous changes that could have led to this increase in imports: reduction of trade barriers (τ) by Mexico or production of the increased number of varieties (n^*) in the U.S. We, therefore, consider two alternative plausible experiments that are consistent with the suggestions of Deardorff and Hakura (1994). In Experiment 1, the increase in manufactured imports arises solely from reduced trade barriers that we interpret as a reduction in a tariff. In Experiment 2, this increase is assumed to come entirely from an increase in the number of varieties being imported. In either case, we capture the change in availability of domestic varieties by letting their exports change as in the data.

While the reality perhaps lies somewhere in the middle, our simulations show that the effect of increased manufactured trade on skill premium is the same irrespective of the cause. In fact, the economy's equilibrium is the same in the two cases, except for the number of imported varieties and their price.

Before presenting the results, here we briefly sketch the procedure for solving for the new equilibrium. To obtain the new values of $[(1+\tau)q'_{mz^*}]$, q'_{mz}, n', q'_s, q'_m, w'_H, w'_L, y'_p, and y'_s, we solve zero profit conditions (39) for the primary and the service sectors; the profit maximization condition (21) for a representative domestic manufactured variety; the price index (66) for the domestic composite manufactured good, q_m; market clearing conditions $(59-60)$ for the two types of labor; the market clearing condition for the non-traded service good (25); the consumer's budget constraint (30); and the market clearing condition for the representative foreign variety (26).[20] In the consumer's budget constraints, total net exports adjust freely in the new equilibrium,

[20]This condition (26) is used to choose $(1+\tau)q_{mz^*}$ to match the manufactured imports/GDP ratio.

but the net exports of manufactures is at its value in the Mexican data for 2000 which is 20.98 percent of GDP. This is because both the manufactured imports/GDP ratio and the manufactured exports/GDP ratio increase as do the data.

5.1 Experiment 1 - Tariff Reduction and Skill Premium

In this experiment, as mentioned above, the rise in manufactured imports comes from reduced trade barriers. We estimate the reduction of trade barriers in Mexico by changing $(1+\tau)q_{mz^*}$ so that both the ratio of manufactured imports from the U.S. to GDP and the ratio of manufactured exports to the U.S. to GDP increase as do the Mexican data over 1987-2000. In particular, in our experiment, we increase these ratios by 103.4 percent (from 8.8 percent in 1987 to 17.9 percent in 2000) and by 114.3 percent (from 9.8 percent in 1987 to 20.98 percent in 2000), respectively. The calibration yields a decrease in $(1+\tau)q_{mz^*}$ from 3.6483 to 2.9600. Assuming an initial tariff rate of 25 percent, this is equivalent to reducing the tariff to 1.42 percent as shown in Table 2 for the new equilibrium in Experiment 1.[21]

The price of each foreign variety, therefore, falls by approximately 20 percent in Mexico. In our model, this would increase the quantity of each foreign variety that is imported. The increased availability of manufactured varieties would raise the demand for the high-skilled labor relative to that of the low-skilled labor since the high-skilled labor is more strongly complementary to manufactures than the low-skilled labor. This, in turn, will lead to the rise in the wage of the high-skilled labor relative to that of the low-skilled labor. In other words, the lowered price of imported varieties will lower the price of the composite manufactured input, which in turn will raise the relative demand of the high-skilled labor through the variety-skill complementarity mechanism.

This indeed is the case as shown by the new equilibrium for the year 2000 in Table 2. The quantity of each variety imported rises from 34.47 to 87.06. The price index of the composite manufactured good falls from 1 to 0.9368. As a result, we can see that the wage of the high-skilled labor increases from 1 to 1.0224 and that of the low-skilled labor decreases from 1 to 0.9983. Thus the relative wage w_H/w_L increases from 1 to 1.0241, which is a 2.41 percent increase. Other changes in the equilibrium are also worth noting. The change in the domestic production of manufactures occurs entirely through the change in the number of domestic varieties that are produced. The output of a domestic variety cannot change. This is an artifact of the facts that

[21] The price of a foreign variety in Mexico is $3.6483 = (1+0.250)2.9186$ in 1987 and $2.9600 = (1+0.0142)2.9186$ in 2000.

in the model the markup is constant and the fixed costs are fixed in units of output (see (23)). While n^* does not change in the new equilibrium, n does rise, in this case, from 3 to 3.1470. Besides the manufacturing sector, the service sector also expands whereas the primary sector shrinks.

The effect of variety trade on skill premium seems to be small compared to the data. The data show that the Mexican skill premium increased from 1.666 to 2.208 during the period 1987-2000, which is a 32.5 percent increase. Thus the increased U.S.-Mexican variety trade accounts for approximately 7.4 percent of the change in Mexican skill premium over 1987-2000. Yet, we here have illustrated the possibility that the variety trade can contribute to the increase in wage inequality; however, it might not be the major cause. It should be noted that here we have looked at Mexican trade with the U.S. alone. Our results, however, would be little changed even if Mexican trade with other trade partners of Mexico is also included. This is because Mexico's principal trade partner is by far the U.S., which in 2000 supplied approximately 73 percent of Mexico's imports and attracted approximately 89 percent of its exports.

5.2 Experiment 2 - Increase in Imported Varieties and Skill Premium

In this experiment, we assume that the increase in manufactured imports in Mexico was a result of the increase in the number of varieties alone. The increase in the available number of foreign varieties lowers the price of the composite manufactured input. Once again, it is anticipated that this lowered price would raise the demand for the high-skilled labor relative to that of the low-skilled labor as the high-skilled labor is more strongly complementary to manufactures than the low-skilled labor. This should then raise the wage of the high-skilled labor relative to that of the low-skilled labor.

The resulting new equilibrium is shown in Table 2. A look at Table 2 reveals that the entire equilibrium is the same as for Experiment 1 except that n^* is now changing instead of $(1+\tau)q_{mz^*}$. The number of imported varieties rises from 97 to 275.92, an almost 200 percent increase in the number of varieties. Note that the actual imports increase only by approximately 100 percent. Thus the quantity of each foreign variety that is imported actually falls from 34.47 to 24.83.

This is an interesting and important point. When the increased number of varieties become available, it is optimal to spread existing imports over these varieties to gain from the diversity of inputs. However, this also reduces the price of the composite manufactured input which then increases its usage. This increase in usage tends to mitigate the fall in quantity of each foreign variety that is imported but does not completely offset it.

As otherwise the equilibrium is unchanged, the interpretation of the results for Experiment 1 applies in this case as well.

5.3 Sensitivity Analysis

The basic mechanism underlying the variety-skill complementarity hypothesis is the difference in the relative ease of the substitution of manufactured input and high-skilled labor versus low-skilled labor. It, therefore, appears that the elasticity of substitution between manufactured input and high-skilled labor and between manufactured input and low-skilled labor would be important to the quantitative effect of change in manufactured imports and exports on skill premium. The sensitivity analysis is thus very important as there is considerable variation in the estimates of these elasticities in the literature as Krusell et al. (2000) note. These elasticities are governed by values of ε and μ. Here we do our sensitivity analysis for a variety of values of ε and μ.

The benchmark numerical experiments in Sections 5.1 and 5.2 have set $\varepsilon = -1$ and $\mu = 1/2$. This means that the elasticity of substitution between the varieties and high-skilled labor, $1/(1-\varepsilon)$, is 1/2 and that between the varieties and low-skilled labor, $1/(1-\mu)$, is 2. Recall, Krusell et al. (2000) report that the majority of the estimates for the elasticity of substitution between low-skilled labor and capital lie between 0.5 and 3. On the other hand, most estimates of the elasticity of substitution between high-skilled labor and capital are below 1.2, and, as they note, "several are near zero." Accordingly, we do our sensitivity analysis for two sets of value of ε and μ so that the two elasticities of substitution take extreme but plausible values. Given the uncertainty about these elasticities, the sensitivity analysis can test the robustness of our quantitative results. It can also provide an estimate of the upper bound on the amount of rise in skill premium in Mexico that can be explained by the Mexican-U.S. manufactured or variety trade.

Table 3 reports the results of the numerical experiments in which $\varepsilon = -3$ and $\mu = 3/4$, that is, the elasticity of substitution between the varieties and high-skilled labor is 1/4 and that between the varieties and low-skilled labor is 4. Note that these are plausible values. The rise in skill premium is still small but is much stronger (3.09

percent) compared to the benchmark case (2.41 percent). We can now explain 9.47 percent of the actual rise in skill premium.

In Table 4, we further increase the difference in the elasticities by letting $\varepsilon = -9$ and $\mu = 9/10$; the elasticity of substitution between the varieties and high-skilled labor is 1/10 and that between the varieties and low-skilled labor is 10. As we can see, the results indicate that the skill premium now increases slightly more (3.29 percent).

Qualitatively, these results are as expected. A more negative value of ε (a smaller elasticity of substitution between the varieties and high-skilled labor) and a greater value of μ (a greater elasticity of substitution between the varieties and low-skilled labor) are accompanied by a larger increase in skill premium. Quantitatively, however, all of these increases (2.41, 3.09, and 3.29 percent) do not make a significant difference in that they are small compared to the 32.5 percent increase shown in the data. In fact, it can be shown that in our numerical experiments, the upper bound for the increase in skill premium is 11-12 percent of the actual increase of 32.5 percent. However, the choice of elasticities of substitution may make a greater difference when the rise in skill premium is initially more significant in the benchmark case.

5.4 Sectoral Variation in Skill Intensity of Employment and Skill Premium

There is another reason why we have under-estimated the increase in skill premium due to the increase in variety trade in the previous sections. In the new equilibrium, manufacturing and service sectors expand at the expense of the primary sector. There is overwhelming evidence that manufacturing and service production is more skill intensive than the production of primaries (see Atolia, 2007). In fact, recent evidence in Bussolo et al. (2002) indicates that the service sector is the most skill-intensive sector followed by the manufacturing.[22] The upshot of these facts is that as manufactures and services expand, their resulting resource allocation further raises the relative demand of high-skilled labor through the Heckscher-Ohlin mechanism.

Due to lack of data on the skill intensity of employment in the primary and service sectors for Mexico, we have so far assumed the skill intensity to be the same as in manufacturing. However, as the above discussion shows, this is not an innocuous

[22]Note, this implies that by assuming the skill intensity of employment to be the same as the manufacturing sector for all sectors, we have not overestimated the overall skill intensity of employment in the economy. In fact, besides being the most skill-intensive sector, the service sector is also the biggest, accounting for almost half of the total output of the economy.

assumption and leads us to under-estimate the effect of variety trade on skill premium. The only virtue of this assumption is that it does not demand any additional data. It can, however, be argued that this virtue is also its weakness since it forces us to ignore evidence available on sectoral differences in skill intensity, albeit from other similar countries.

To rectify this shortcoming of the previous analysis as well as to check the robustness of our results, in this subsection we allow sectoral differences in the skill intensity of employment. In particular, we use the evidence in Bussolo et al. (2002) on the skill intensity of employment in Chile for 1992.[23] They provide the sectoral break-up of employment into seven categories. We present results for two different ways of aggregating these categories into high- and low-skilled employment.

In the first case, we aggregate workers by their skill level: managers and professionals, technicians, administrative workers, and skilled blue collar workers comprise the high-skilled category; commerical and service workers, un-skilled blue collar workers, and informal workers comprise the low-skilled. With this classification, the ratio of (share of) high-skilled workers in the primary sector to the manufacturing sector is 11/28. The number for the service sector is 32/28. We recalibrate the model taking these sectoral skill intensity variations into account.

In the recalibrated model, the change is that variety trade over 1987-2000 gives rise to a 2.66 percent increase in skill premium for the benchmark value of ε and μ, which is 10.4 percent greater than the 2.41 percent change in the absence of sectoral variations in skill intensity. For the other values of ε and μ considered in our sensitivity analysis, the skill premium rises by 3.28 percent and 3.46 percent compared to earlier increases of 3.09 and 3.29 percent.

In the first case, the classification of the workers as high- and low-skilled is not the same across all sectors. We have followed the skill classification of Bussolo et al. (2002) for the primary and service sectors, whereas for the manufacturing sector, we have used nonproduction-production classification based on Mexican data. To avoid this problem, in the second case, we aggregate employment in the primary and service sectors according to the white and blue collar classification of Bussolo et al. (2002) which corresponds more closely to the nonproduction-production classification. As a result, now the ratios of high-skilled workers in primaries and services are 22/48 and 49/48. In the recalibrated model, the skill premium now increases by 2.76 percent,

[23] Table 2 in their paper summarizes the structural features of the Chilean economy. They report the shares of gross output, value-added, total demand, trade flows, and employment for 24 sectors and three aggregate macro-sectors (primary, manufactures and services). These shares are calculated using the Social Accounting Matrix for Chile in Alonso and Roland-Holst (1995).

3.38 percent, and 3.54 percent for the three sets of elasticities of substitution, respectively. The last number (3.54 percent) is 10.90 percent of the actual observed rise in skill premium, and it can be shown that the upper bound of increase is now 12-13 percent of the actual rise, thus indicating that our results obtained in the previous sections are robust.

6 Conclusion

The main purpose of this paper has been to quantitatively evaluate the ability of the variety-skill complementarity hypothesis to explain the rise in skill premium in Mexico over the period 1987-2000. The results of our numerical experiments indicate that the increased U.S.-Mexican variety trade has the capability of accounting for approximately 12 percent of the change in Mexican skill premium during this period. Here we have illustrated the possibility that U.S.-Mexican variety trade, which is a small fraction of Mexican GDP, can contribute to the increase in wage inequality in Mexico, although it appears not to be the major cause. This is compatible with past empirical results indicating that trade is not the major cause of increased skill premium while technological change is.

Thus, using a calibrated general equilibrium model, this paper has been successful in adding a new quantitative result to the literature. Moreover, we can say that this paper's methodology can be used to derive further empirical implications. First, this paper has focused on the case where Mexico is a small open economy. We can also extend our model to a two-country model.

Second, our model can be directly applied to countries other than Mexico. We can calibrate our model to the input-output data for other countries and then empirically quantify the effects of variety trade on skill premium in each of them. For example, we have calibrated our model to the 1985 input-output data for Japan. In the calibrated model, the benchmark numerical experiment shows that the Japanese skill premium decreases by 4.77 percent when the manufacturing variety trade with the OECD countries changes (actually decreases) as in the data over 1985-1995. The data, however, show that the Japanese skill premium actually increased modestly during the 1980s and 1990s (Freeman and Katz, 1994). The results thus indicate that other factors such as technological change must have offset the decrease caused by the manufacturing variety trade in Japan. This provides a possible answer to why the increase in skill premium was drastic in Mexico but modest in Japan.

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Appendix A - Benchmark 1987 Mexican Data Set

The following is the input-output matrix for 1987 that is used to calibrate the model to the Mexican economy. All the numbers in the matrix are in millions of U.S. dollars. The steps following the matrix show the procedure for the construction of the input-output matrix and the sources of the data.

	Primaries	Manufactures	Services	Total
$X_{p,i}$	$2,712$	$13,485$	$1,533$	$17,730$
$X_{m,i}$	$2,836$	$23,704$	$15,939$	$42,479$
$X_{s,i}$	$1,190$	$8,355$	$14,874$	$24,419$
H_i	$9,131$	$17,068$	$37,414$	$63,613$
L_i	$10,756$	$20,106$	$44,075$	$74,937$
Y_i	$26,625$	$82,718$	$113,835$	$223,179$
C_i	$4,643$	$38,793$	$89,416$	$132,853$
NX_i	$4,252$	$1,446$	0	$5,698$
EX_i	$6,626$	$13,643$		
IM_i	$2,374$	$12,197$		

Step 1. Intermediate input and total production. This 1987 matrix is constructed from the 1980 input-output table provided by the *Instituto Nacional de Estadística Geografía e Informática* (INEGI) .

Step 2. Labor compensation. $Y_i - X_{p,i} - X_{m,i} - X_{s,i}$ in each sector. The compensation is then distributed into H_i and L_i according to the EIM: $w_H H/w_L L = 4185/4930$ in 1987.

Step 3. Net exports to the U.S. of primaries and manufactures. Source: The International Trade Administration.

Step 4. Consumption. Get from $Y_i - C_i - X_{i,p} - X_{i,m} - X_{i,s} = NX_i$. This consumption C corresponds to $c + i + g$+net exports to the rest of the world except the U.S.

Notes

1. 1 peso = 1000 old pesos.

2. The nominal exchange rate in 1987 = 1.37818 MXP/USD. Source: The International Financial Statistics (IFS).

Preference parameters		
$\beta_p = 0.035$	$\beta_s = 0.673$	$\beta_m = 0.292$
Technology: CES aggregator parameters		
$b_p = 0.088$	$b_s = 0.154$	$b_m = 0.659$
$a_p = 0.569$	$a_s = 0.591$	$a_m = 0.665$
$\varepsilon = -1$	$\mu = \frac{1}{2}$	$\rho = \frac{5}{6}$
Technology: productivity parameters		
$\gamma_p = 3.688$	$\gamma_s = 3.697$	$\gamma_m = 4.387$
Technology: cost shares		
$\alpha_{p1} = 0.853$	$\alpha_{p2} = 0.102$	$\alpha_{p3} = 0.045$
$\alpha_{s1} = 0.856$	$\alpha_{s2} = 0.013$	$\alpha_{s3} = 0.131$
$\alpha_{m1} = 0.736$	$\alpha_{m2} = 0.163$	$\alpha_{m3} = 0.101$
Endowments		
$L = 74936.415$	$H = 63613.585$	
Manufactured varieties		
$F = 4285.095$		
$n = 3$	$n^* = 97$	
$q_{mz} = 1.2870$	$(1+\tau)q_{mz^*} = 3.6483$	
$x_{mz} = 17,892$	$x_{mz^*} = 34.47$	

Table 1: The values of the calibrated parameters of the model.

$\varepsilon = -1, \mu = \frac{1}{2}$	Initial equilibrium 1987	Experiment 1 2000	Experiment 2 2000
n	3	3.1470	3.1470
n^*	97	97	275.92
x_{mz}	17,892	14,074	14,074
x_{mz^*}	34.47	87.06	24.83
q_{mz}	1.2870	1.2682	1.2682
$(1+\tau)\, q_{mz^*}$	3.6483	2.9600	3.6483
τ	0.25	0.0142	0.25
q_m	1	0.9368	0.9368
q_p	1	1	1
q_s	1	0.9973	0.9973
w_H	1	1.0224	1.0224
w_L	1	0.9983	0.9983
w_H/w_L	1	1.0241	1.0241
y_p	26,625	25,358	25,358
y_s	113,835	114,399	114,399
y_m	82,718	91,278	91,278

Table 2: The initial equilibrium (1987) with tariff (tau) normalized to .25. The new equilibrium (2000) when tariff falls (Experiment 1). The new equilibrium (2000) when the number of imported varieties increases (Experiment 2).

$\varepsilon = -3, \mu = \frac{3}{4}$	Initial equilibrium 1987	Experiment 1 2000	Experiment 2 2000
n	3	3.1244	3.1244
n^*	97	97	276.34
x_{mz}	17,892	14,025	14,025
x_{mz^*}	34.47	87.07	24.79
q_{mz}	1.2870	1.2686	1.2686
$(1+\tau)\, q_{mz^*}$	3.6483	2.9591	3.6483
τ	0.25	0.01386	0.25
q_m	1	0.9378	0.9378
q_p	1	1	1
q_s	1	0.9974	0.9974
w_H	1	1.0258	1.0258
w_L	1	0.9951	0.9951
w_H/w_L	1	1.0309	1.0309
y_p	26,625	25,220	25,220
y_s	113,835	114,313	114,313
y_m	82,718	90,554	90,554

Table 3: The results for the numerical experiment with epsilon = -3 and mu = (3/4).

$\varepsilon = -9, \mu = \frac{9}{10}$	Initial equilibrium 1987	Experiment 1 2000	Experiment 2 2000
n	3	3.1328	3.1328
n^*	97	97	276.29
x_{mz}	17,892	14,043	14,043
x_{mz^*}	34.47	87.08	24.80
q_{mz}	1.2870	1.2684	1.2684
$(1+\tau)\, q_{mz^*}$	3.6483	2.9592	3.6483
τ	0.25	0.01390	0.25
q_m	1	0.9374	0.9374
q_p	1	1	1
q_s	1	0.9975	0.9975
w_H	1	1.0270	1.0270
w_L	1	0.9943	0.9943
w_H/w_L	1	1.0329	1.0329
y_p	26,625	25,279	25,279
y_s	113,835	114,333	114,333
y_m	82,718	90,820	90,820

Table 4: The results for the numerical experiment with epsilon = -9 and mu = (9/10).