Import Variety and Skill Premium in a Calibrated General Equilibrium Model: The Case of Mexico[*]

Manoj Atolia Yoshinori Kurokawa

Florida State University[†] University of Tsukuba[‡]

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Abstract

It can be theoretically shown that imports of new foreign varieties—the extensive margin—can be a possible source of increased skill premium in wages. No past studies, however, have quantified how much of the increase in skill premium can be accounted for by the increase in the extensive margin. This paper now formulates a static applied 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 extensive margin growth in Mexican manufactured imports from the U.S. can account for 6-13 percent of the actual increase in skill premium in Mexico from 1987 to 1994.

Keywords: Variety Trade, Extensive Margin, Skill Premium, Variety-Skill Complementarity, Applied General Equilibrium, Mexico

JEL Classifications: F12, F16

1 Introduction

It can be theoretically shown that imports of new foreign varieties—the extensive margin—can be a possible source of an increase in the relative wage of high-skilled to low-skilled workers—the skill premium—in each of the trading countries.[1] Kurokawa (2011), 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. By extending the well-known model of variety trade in intermediate goods advanced by Ethier (1982), he shows that imports of new foreign varieties increases the number of inputs used by the final goods and thus widens the gap between the marginal products of high-skilled and low-skilled workers through the variety-skill complementarity.[2] This raises the relative wage of high-skilled to low-skilled workers and generates skill premium in both countries.[3]

While the variety-skill complementarity mechanism is intuitively appealing, no past studies have quantified how much of the increase in skill premium is accounted for by the change in the extensive margin.[4] This paper now formulates a static applied general equilibrium model and calibrates it to Mexican data for 1987 to quantify the impact of the extensive margin growth in Mexican manufactured imports from the U.S. on the skill premium in Mexico. Here, applied general equilibrium analysis is defined to be the numerical implementation of general equilibrium models calibrated to data (Kehoe and Prescott, 1995).[5]

We use a static applied general equilibrium model which allows us to perform a full-scale calibration.[6] There are two countries and three sectors—primaries, man-

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[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] Ethier's (1982) model is an intermediate-good version of Krugman's (1979) model of variety trade in final goods.

[3] Dinopoulos et al. (2009) also link variety 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—not an increase in the number of variety—to an increase in the relative demand for high-skilled labor by each variety.

[4] Although Kurokawa (2011) has provided several numerical examples to show that the variety-skill complementarity mechanism can be potentially important, it does not produce a more comprehensive quantitative analysis since its purpose is to use a simple model to highlight the existence of such a mechanism.

[5] See Kehoe and Prescott (1995) for the discipline and history of applied general equilibrium analysis. Due to data constraint, here we use data from 1987. Fortunately, however, Mexico acceded to the General Agreement on Tariffs and Trade (GATT) in 1986 and signed a framework agreement on trade and investment with the U.S. in 1987.

[6] Our model extends Bergoeing and Kehoe's (2003) applied general equilibrium model by distin-

ufactures, 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. The production of each good uses high- and low-skilled workers, primaries, services, and a variety of manufactures. The technology in each sector displays the variety-skill complementarity mentioned above. 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 extensive margin growth on the skill premium in Mexico—a small country relative to the U.S. Thus, for our numerical analysis, we specialize the model to a small open economy.

We calibrate our theoretical model to the Mexican input-output matrix for 1987. It is worth noting that as will be shown in the matrix, much of output is services which are non-traded and trade is not balanced in the data, which can be captured by our calibrated model. In the calibrated model, we conduct numerical experiments to see how much of the increase in Mexican skill premium can be accounted for by the extensive margin growth in Mexican manufactured imports from the U.S. Here, the growth in the extensive margin is measured by the growth in what Kehoe and Ruhl (2009) call the "least traded goods." Kehoe and Ruhl classify the set of goods which accounts for only 10 percent of trade as the least traded goods.

Figure 1 plots the 1987-2000 data on the growth in the least traded goods in Mexican manufactured imports from the U.S. and on the relative wage of high-skilled to low-skilled labor in Mexican manufacturing industries.[7] Figure 1 reveals that the least traded goods that account for 10 percent of Mexican manufactured imports from the U.S. in 1987 account for 19.5 percent in 1994. This indicates that over this period, Mexico started importing U.S. manufactured goods that it had not imported before or had imported only in small quantities, thus indicating that the variety of Mexican manufactured imports from the U.S. increased. The figure also reveals that

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guishing high- and low-skilled labor, thus relating an increase in extensive margin into an increase in skill premium.

[7]The data for the least traded goods growth are the Standard International Trade Classification (SITC) (revision 2) 4-digit manufacturing data from the OECD International Trade by Commodities Statistics (ITCS). See Kehoe and Ruhl (2009) for the detailed procedure used to construct Figure 1. The data for the Mexican relative wage is from the Mexican Monthly Industrial Survey (*Encuesta Industrial Mensual*, or EIM). 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 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.

the growth in the least traded goods was highly correlated with the growth in the relative wage in Mexico over 1987-2000. In fact, the correlation between these two series was high, 0.926, over the period. As can be seen, the extensive margin was drastically growing before the North American Free Trade Agreement (NAFTA) was enacted in 1994, and it became stable after the NAFTA. Similarly, the Mexican skill premium was also drastically increasing before the NAFTA and became stable (with a slight decrease) after the NAFTA.[8]

Accordingly, our numerical experiments will focus on the period 1987-1994, when both the extensive margin and the skill premium were drastically increasing. Then we will see how much of the increase in Mexican skill premium can be accounted for by the extensive margin growth in Mexican manufactured imports from the U.S. over the period. We find that the relative wage of high- to low-skilled labor can increase by 2.6-5.6 percent if the extensive margin increases according to the data. Hence, the extensive margin growth over 1987-1994 can raise Mexican skill premium by 2.6-5.6 percent. On the other hand, the data show that Mexican skill premium increased from 2.021 to 2.899 over 1987-1994, which is a 43.4 percent increase. Thus the results indicate that the extensive margin growth in Mexican manufactured imports from the U.S. can account for 6-13 percent of the change in Mexican skill premium over 1987-1994.[9] We, therefore, illustrate that the extensive margin is possibly a factor significantly contributing to the increase in wage inequality in Mexico; however, it still does not appear to be the major cause. It should be noted that here we look 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 1994 supplied 69 percent of Mexico's imports and attracted 85 percent of its exports.[10]

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[8]Esquivel and Rodríguez-López (2003) also show the same movements of Mexican wages. Robertson (2004) argues, using the Mexican Industrial Census, that the Mexican skill premium declined from 1994 to 1998.

[9]Note that, as we work with a structural model, our quantitative 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 quantitative 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 experiments ask precisely these two questions posed by Deardorff and Hakura.

[10]In 1994, Japan provided 6 percent of Mexico's imports, Germany 4 percent, Canada 2 percent, and France 2 percent. Canada was the second largest destination for Mexican products, accounting for 2 percent of exports. Outside the NAFTA, no individual country absorbed more than 2 percent of total Mexican exports.

Of course, other mechanisms which can account for the increase in skill premium have also been proposed and tested. One set of studies highlights 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.[11] 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 accounted for by this capital-skill complementarity hypothesis.[12]

Another set of studies concentrates 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 accounted for by the increasing import share.[13] Zhu and Trefler (2005) demonstrate that the product shifting highlighted by Feenstra and Hanson, which leads to a rise in wage inequality, can also result from technological catch-up in the South.[14]

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

[12]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.

[13]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.

[14]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.

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.[15] 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.[16]

In this line of literature, our paper makes the following contributions. First, this paper puts the contribution of the extensive margin to the increase in skill premium in perspective relative to the other channels investigated in the literature. We find that while extensive margin is important in its own right, it seems not so important as skill-biased technological change or foreign direct investment. Second, from a methodological viewpoint, while applied general equilibrium models have been used in trade studies, in particular, for analyses of the impact of the NAFTA, ours is a first application to the analysis of the impact of trade on skill premium.[17]

Our paper also makes a contribution to the extensive margin of trade literature. While the extensive margin have recently been proven useful in understanding firm-level export patterns (Melitz, 2003) and the growth in aggregate trade volumes (Yi, 2003), our paper now quantifies the possible importance of the extensive margin in understanding the increase in skill premium.

The rest of this paper is organized as follows. In Section 2, we formulate our static applied 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.

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[15] 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.

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

[17] According to Kehoe (2005), three of the most prominent applied general equilibrium models for the NAFTA analysis are the Brown-Deardorff-Stern model of all three North American economies, the Cox-Harris model of Canada, and the Sobarzo model of Mexico. See, for example, Francois and Shiells (1994) for applied general equilibrium models of the impact of the NAFTA.

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 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.[18]

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

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

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 $D^w = [0, n^1 + n^2]$ 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

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[18]It should be noted that by introducing primary and service goods in the present paper, we have generalized Kurokawa's model (2011) that has only manufactured goods produced by high- and low-skilled labor. In addition, we have also allowed trade in final goods which is absent in Kurokawa's model.

constant returns production functions

$$y_p^j = \gamma_p \left[a_p \left\{ b_p (x_{m,p}^j)^\varepsilon + (1 - b_p) (H_p^j)^\varepsilon \right\}^{\frac{\mu}{\varepsilon}} + (1 - a_p) (L_p^j)^\mu \right]^{\frac{\alpha_{p1}}{\mu}} (x_{p,p}^j)^{\alpha_{p2}} (x_{s,p}^j)^{\alpha_{p3}} (4)$$

$$y_s^j = \gamma_s \left[a_s \left\{ b_s (x_{m,s}^j)^\varepsilon + (1 - b_s) (H_s^j)^\varepsilon \right\}^{\frac{\mu}{\varepsilon}} + (1 - a_s) (L_s^j)^\mu \right]^{\frac{\alpha_{s1}}{\mu}} (x_{p,s}^j)^{\alpha_{s2}} (x_{s,s}^j)^{\alpha_{s3}}, (5)$$

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 $x_{h,i}^j$ refers to factor h used in sector i. 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

$$y_{mz}^j = \max \left\{ \gamma_m \left[\begin{array}{c} a_m \left\{ b_m (x_{m,mz}^j)^\varepsilon + (1 - b_m) (H_{mz}^j)^\varepsilon \right\}^{\frac{\mu}{\varepsilon}} + \\ (1 - a_m) (L_{mz}^j)^\mu \end{array} \right]^{\frac{\alpha_{m1}}{\mu}} (x_{p,mz}^j)^{\alpha_{m2}} (x_{s,mz}^j)^{\alpha_{m3}} - F, 0 \right\}, \tag{7}$$

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,

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

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

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 with a nested-CES technology, where substitution parameters ε and μ are the same across all sectors. The nested-CES specification allows us to introduce variety-skill complementarity in production in the most natural and parsimonious manner. This is achieved by setting $\varepsilon < \mu$ which makes the varieties of manufactured goods relatively more complementary to high-skilled labor than to low-skilled one.[19]

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[19]Kurokawa (2011) 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.

Let $\tilde{c}_{mz}^j(q_m^j, w_H^j, w_L^j, q_p^j, q_s^j; y_{mz} + F)$ 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:

$$
\begin{aligned}
\tilde{c}_{mz}^j \left(q_m^j, w_H^j, w_L^j, q_p^j, q_s^j; y_{mz} + F \right) &= \tilde{c}_{mz}^j \left(\tilde{c}_{A,m}^j \left(q_m^j, w_H^j, w_L^j \right), q_p^j, q_s^j; y_{mz} + F \right), \\
&= \tilde{c}_{mz}^j \left(\tilde{c}_{A,m}^j \left(\tilde{c}_{B,m}^j \left(q_m^j, w_H^j \right), w_L^j \right), q_p^j, q_s^j; y_{mz} + F \right), \\
&= \frac{1}{\gamma_m} \left(\frac{\tilde{c}_{A,m}^j}{\alpha_{i1}} \right)^{\alpha_{i1}} \left(\frac{q_p}{\alpha_{i2}} \right)^{\alpha_{i2}} \left(\frac{q_s}{\alpha_{i3}} \right)^{\alpha_{i3}} (y_{mz} + F) \quad (9)
\end{aligned}
$$

where $z \in D^1 = [0, n^1]$ or $z \in D^2 = [n^1, n^1 + n^2]$, and the sub-cost functions are

$$
\tilde{c}_{A,mz}^j \left(q_m^j, w_H^j, w_L^j \right) = \left[a_m^{\frac{1}{1-\mu}} \tilde{c}_{B,mz}^j \left(q_m^j, w_H^j \right)^{-\frac{\mu}{1-\mu}} + (1 - a_m)^{\frac{1}{1-\mu}} \left(w_L^j \right)^{-\frac{\mu}{1-\mu}} \right]^{-\frac{1-\mu}{\mu}} \quad (10)
$$

$$
\tilde{c}_{B,mz}^j \left(q_m^j, w_H^j \right) = \left[b_m^{\frac{1}{1-\varepsilon}} \left(q_m^j \right)^{-\frac{\varepsilon}{1-\varepsilon}} + (1 - b_m)^{\frac{1}{1-\varepsilon}} \left(w_H^j \right)^{-\frac{\varepsilon}{1-\varepsilon}} \right]^{-\frac{1-\varepsilon}{\varepsilon}}. \quad (11)
$$

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

$$
\tilde{c}_{mz}^j \left(q_m^j, w_H^j, w_L^j, q_p^j, q_s^j; y_{mz} + F \right) = G^j \left(y_{mz} + F \right), \qquad z \in D^j, \quad j = 1, 2. \quad (12)
$$

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_{mz}^j to maximize profits:

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

taking all other prices as given.

Let us derive the demand for each variety z. 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:

$$
c_{mz}^j = \left(\frac{q_{mz}^j}{q_m^j} \right)^{-\frac{1}{1-\rho}} \frac{\beta_m \left(w_H^j H^j + w_L^j L^j \right)}{q_m^j}, \qquad z \in D^j, \quad (14)
$$

$$
c_{mz}^j = \left(\frac{q_{mz}^{-j}}{q_m^j} \right)^{-\frac{1}{1-\rho}} \frac{\beta_m \left(w_H^j H^j + w_L^j L^j \right)}{q_m^j}, \qquad z \in D^{-j}, \quad (15)
$$

where q_{mz}^j is the price in country j of variety $z \in D^j$ and q_{mz}^{-j} the price in country $-j$ of variety $z \in D^{-j}$. One can show that q_m^j can be written as an exact consumption-based

price index of the prices of individual varieties as follows:

$$q_m^j = \left[\int_{D^j} (q_{mz}^j)^{-\frac{\rho}{1-\rho}} dz + \int_{D^{-j}} (q_{mz}^{-j})^{-\frac{\rho}{1-\rho}} dz \right]^{-\frac{1-\rho}{\rho}}. \tag{16}$$

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

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

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

Thus, the total consumption demand varies with price q_{mz}^j with elasticity $-1/(1-\rho)$. One can show that the same holds true for the total consumption and input 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 $D^w = [0, n^1 + n^2]$, and a measure of firms for each country $D^1 = [0, n^1]$ and $D^2 = [n^1, n^1 + n^2]$ 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,*

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

$$c_s^j + x_{s,p}^j + x_{s,s}^j + \int_{D^j} x_{s,mz}^j dz = y_s^j, \quad j = 1, 2, \qquad (25)$$

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

6. *The factor markets clear,*

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

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

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 extensive margin growth 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 an 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

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

where

$$\tilde{c}_{A,i}\left(q_m, w_H, w_L\right) = \left[a_i^{\frac{1}{1-\mu}} \tilde{c}_{B,i}\left(q_m, w_H\right)^{-\frac{\mu}{1-\mu}} + (1-a_i)^{\frac{1}{1-\mu}} w_L^{-\frac{\mu}{1-\mu}}\right]^{-\frac{1-\mu}{\mu}},$$

$$\tilde{c}_{B,i}\left(q_m, w_H\right) = \left[b_i^{\frac{1}{1-\varepsilon}} q_m^{-\frac{\varepsilon}{1-\varepsilon}} + (1-b_i)^{\frac{1}{1-\varepsilon}} w_H^{-\frac{\varepsilon}{1-\varepsilon}}\right]^{-\frac{1-\varepsilon}{\varepsilon}}, \qquad (32)$$

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

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

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

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

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

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

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

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

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

The condition for profit maximization by the firms producing manufactured varieties has already been derived (see (21)).[20] Profit maximization by firms implies that in the primary and service sectors, price equals marginal cost which also equals the

---

[20]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.

unit cost

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

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 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

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

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

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

where

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

is the price index for the domestically produced varieties and

$$\bar{q}_{mz^*} = \left(n^* \right)^{-\frac{1-\rho}{\rho}} q_{mz^*} \qquad (43)$$

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

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

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

4   Calibration of the Model

We test the ability of the model to account for the rise in skill premium in Mexico over the period 1987-1994. The choice of 1987 comes from data constraint. However, this is not a serious limitation since Mexico acceded to the GATT in 1986 and signed a framework agreement on trade and investment 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 $(X_{h,i})$ where i stands for sector and h 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

$$Y_i = \sum_h X_{h,i}, \qquad i = p, m, s, \tag{46}$$

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 manufactured varieties and low-skilled labor and between the manufactured varieties and high-skilled labor, respectively. Due to the uncertainty about these elasticities, we set μ and ε as free parameters. Here, as a benchmark case, we choose the elasticity of substitution for low-skilled labor to be 2 and for high-skilled labor to be 0.5.[21] This implies $\mu = 1/2$ and $\varepsilon = -1$. In Section 5.2, we will do our sensitivity analysis for a variety of values of μ and ε to test the robustness of our quantitative results.

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[22]

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

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 h, define the cost share of that factor in sector i as $\theta_{h,i}$ and denote by $\mathbf{w}_h$ the price of factor $h = p, s, m, L, H$.[23] Then, from the demand functions derived above, we get

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

---

[21] Although our focus is on variety-skill complementarity, it is worth noting that a number of studies report evidence on capital-skill complementarity. For example, see Griliches (1969), Berndt and Christensen (1974), Fallon and Layard (1975), and Brown and Christensen (1981). 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 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."

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

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

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

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

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 $\theta_{H,i}/\theta_{L,i} = \theta_{H,m}/\theta_{L,m}$, $i = p, s$.[24]

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.

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

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

4.2.1 Remaining Calibration

To complete the calibration we still need to find values for

$$q_{mz}, \ q_{mz^*}, \ \gamma_m, \ n, \ n^*, x_{mz}, \ x_{mz^*}. \tag{61}$$

---

[24]In Section 5.3, for the primary and service sectors, we will use the break-up in Chile in 1992.

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[25]

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

Similarly,

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

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

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

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

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

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

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

which can be used to write (66) as

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

Finally, we impose the normalization

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

---

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

and calibrate 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 in the model, the ratio n/n^* equals the ratio of the total labor compensations in the Mexican and U.S. manufactures $(X_{H,m} + X_{L,m})/(X_{H,m}^* + X_{L,m}^*)$, which is approximately 3/97 in the data for 1987.

It is possible to solve (21), $(63 - 65)$, and $(68 - 70)$ for q_{mz}, 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   Extensive Margin and Skill Premium

We have calibrated the static applied general equilibrium model to the Mexican economy. In the calibrated model, we quantitatively evaluate the ability of the variety-skill complementarity hypothesis to account for the rise in skill premium in Mexico over the period 1987-1994. To do so, we change the number of foreign varieties—the extensive margin—in the calibrated model as in the Mexican data from 1987 to 1994.

Here, as we have seen in Figure 1, the growth in the extensive margin is measured by the growth in what Kehoe and Ruhl (2009) call the "least traded goods." Kehoe and Ruhl classify the set of goods which accounts for only 10 percent of trade as the least traded goods. As shown in Figure 1, the least traded goods that account for 10 percent of Mexican manufactured imports from the U.S. in 1987 account for 19.5 percent in 1994, which is a 95 percent increase in the extensive margin. This indicates that over this period, Mexico started importing U.S. manufactured goods that it had not imported before or had imported only in small quantities, thus indicating that the variety of Mexican manufactured imports from the U.S. increased.

It is worth noting that the method by Kehoe and Ruhl (2009) used in our paper for measuring the extensive margin is different from methods used in the few previous studies of the extensive margin. Broda and Weinstein (2006), for example, classify a good as not traded if the value of trade is zero, and Evenett and Venables (2002) classify a good as not traded if its yearly value of trade is less than or equal to 50,000 1985 U.S. dollars, regardless of the country to be studied. In Kehoe and Ruhl's definition of a non-traded good, on the other hand, goods with very small but non-

zero amounts of trade can also be considered, and the actual dollar value of the cutoff can differ across countries. In fact, the method by Kehoe and Ruhl has been widely used. Mukerji (2009) and Sandrey and van Seventer (2004), for example, use the method to measure the extensive margin of trade as does our paper.

Before presenting the results, here we briefly sketch the procedure for solving for the new equilibrium. To obtain the new values of 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). In the consumer's budget constraints, total net exports adjust freely in the new equilibrium.

5.1 Numerical Experiment - Extensive Margin and the Skill Premium

In this experiment, as mentioned above, we increase the number of foreign varieties n^* by 95 percent as in the Mexican data over 1987-1994. Thus it is anticipated that 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 manufactured varieties 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—the skill premium. In other words, the increase in the available number of foreign varieties will lower the price of the composite manufactured input, which in turn will raise the relative wage 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 1994 in Table 2. The number of imported varieties n^* rises from 97 to 189.15, which is a 95 percent increase in the number of foreign varieties. The price index of the composite manufactured good falls from 1 to 0.9572. As a result, we can see that the wage of the high-skilled labor increases from 1 to 1.0152 and that of the low-skilled labor decreases from 1 to 0.9988. Thus the relative wage w_H/w_L increases from 1 to 1.0164, which is a 1.64 percent increase.

It is worth noting that while the number of imported varieties n^* increases, the quantity of each imported variety x_{mz^*} actually falls from 34.47 to 28.67. This is an

interesting and important point in variety-trade models emphasized by Ethier (1982). 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 imported variety but does not completely offset it. Other changes in the equilibrium are also worth noting. While q_{mz^*} does not change in the new equilibrium, q_{mz} does fall, in this case, from 1.2870 to 1.2743. Besides the manufacturing sector, the service sector also expands whereas the primary sector shrinks.

The effect on skill premium of the extensive margin growth in manufactured imports seems to be small compared to the data. The data show that the Mexican skill premium increased from 2.021 to 2.899 during the period 1987-1994, which is a 43.4 percent increase. Thus the extensive margin growth in Mexican manufactured imports from the U.S. accounts for approximately 3.8 percent of the change in Mexican skill premium over 1987-1994. 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 1994 supplied 69 percent of Mexico's imports and attracted 85 percent of its exports.

It should be also noted that one of the most salient characteristics of the Mexican economy is *maquiladoras*. This export-processing sector imports intermediate inputs and then assemble them into final goods in a similar way as modeled in this paper. In fact, our assumption (manufactured imported inputs and high-skilled workers are complements) can be compatible with the observations in *maquiladoras* emphasized by Feenstra and Hanson (1997): both the imports from the U.S. and the demand for high-skilled workers increased in *maquiladoras*.[26]

5.2   Sensitivity Analysis

The basic mechanism underlying the variety-skill complementarity hypothesis is the difference in the relative ease of the substitution of manufactured varieties and high-skilled labor versus low-skilled labor. It, therefore, appears that the elasticity of substitution between manufactured varieties and high-skilled labor and between man-

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[26]Of course, low-skilled workers would be used more intensively than high-skilled workers in *maquiladoras*, but it is still possible that the demand for high-skilled workers increases more than that for low-skilled workers (complementarity). In fact, our experiments successfully capture both the intensity and the complementarity.

ufactured varieties and low-skilled labor would be important to the quantitative effect of change in the extensive margin in manufactured imports on skill premium. The sensitivity analysis is thus very important, and 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 experiment in Section 5.1 has 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. Here, we do our sensitivity analysis for two sets of value of ε and μ so that the two elasticities of substitution take extreme 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 accounted for by the extensive margin growth in Mexican manufactured imports from the U.S.

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. The rise in skill premium is still small but is much stronger (a 2.13 percent increase) compared to the benchmark case (the 1.64 percent increase). We can now account for 4.9 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 (a 2.28 percent increase).

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 (1.64, 2.13, and 2.28 percent) do not make a significant difference in that they are small compared to the 43.4 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 approximately 6 percent of the actual increase of 43.4 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.

5.3 Sectoral Variation in Skill Intensity of Employment and Skill Premium

There is another reason why we have underestimated the increase in skill premium due to the increase in extensive margin 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.[27] 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 assumption and leads us to underestimate the effect of the extensive margin growth 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, 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.[28] 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

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[27]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.

[28]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).

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 as shown in Table 5, the extensive margin growth over 1987-1994 gives rise to a 5.39 percent increase in skill premium for the benchmark values of ε and μ, which is much greater than the 1.64 percent change in the absence of sectoral variations in skill intensity. This 5.39 percent increase is 12.4 percent of the actual 43.4 percent increase. In fact, it can be shown that the increase in skill premium for these benchmark values of ε and μ is close to the maximum. The upper bound of increase is thus approximately 13 percent of the actual rise.

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, as shown in Table 6 the skill premium now increases by 5.16 percent for the benchmark values of ε and μ. This number (5.16 percent) is 11.9 percent of the actual observed rise in skill premium. In fact, it can be again shown that the increase in skill premium for these benchmark values of ε and μ is close to the maximum, thus indicating that the upper bound of increase is approximately 12 percent of the actual rise in this second case.

6 Conclusion

The main purpose of this paper has been to quantitatively evaluate the ability of the variety-skill complementarity hypothesis to account for the rise in skill premium in Mexico over the period 1987-1994. The results of our numerical experiments indicate that the extensive margin growth in Mexican manufacturing imports from the U.S. has the capability of accounting for 6-13 percent of the change in Mexican skill premium during this period. Here, we have illustrated the possibility that the extensive margin growth can significantly contribute to the increase in wage inequality in Mexico, although it appears not to be the major cause. This is compatible with past results indicating that trade is not the major cause of increased skill premium while

technological change is. Thus, using an applied general equilibrium model, this paper has been successful in adding a new quantitative result to the literature.

It may be noted that while the increase in extensive margin is large, the rise in wage inequality in Mexico is modest in our experiments. A factor causing this modesty is that in our model, the marginal products of both high- and low-skilled labor rise due to the increased number of inputs, but the former rises disproportionately more than the latter. Thus the relative demand for high- to low-skilled labor does not rise as much, thereby mitigating the rise in wage inequality.

Looking forward, we can say that this paper's methodology can be used to derive further quantitative 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 quantify the effects of the extensive margin growth on skill premium in each of them.

Finally, this paper has focused on the extensive margin of imports. It would also be interesting to introduce tariffs into the model and then exogenously change the tariffs to change the intensive margin of imports—the import volumes of existing foreign varieties—in the model as in available data.

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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-outpút 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).
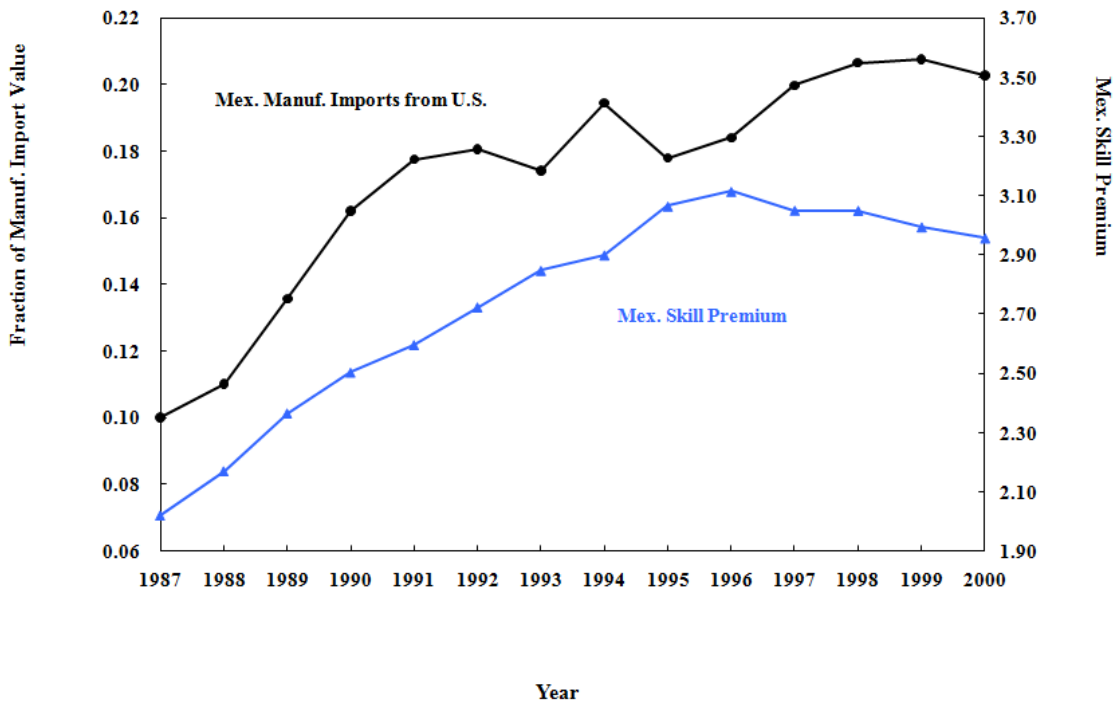
Figure 1: Least traded goods growth in Mexican manufactured imports from U.S. and Mexican skill premium, 1987-2000.

Preference parameters
$\beta_p = 0.035$ $\qquad \beta_s = 0.673$ $\qquad \beta_m = 0.292$

Technology: CES aggregator parameters
$b_p = 0.088$ $\qquad b_s = 0.154$ $\qquad b_m = 0.659$
$a_p = 0.569$ $\qquad a_s = 0.591$ $\qquad a_m = 0.665$
$\varepsilon = -1$ $\qquad \mu = \frac{1}{2}$ $\qquad \rho = \frac{5}{6}$

Technology: productivity parameters
$\gamma_p = 3.688$ $\qquad \gamma_s = 3.697$ $\qquad \gamma_m = 4.387$

Technology: cost shares
$\alpha_{p1} = 0.853$ $\qquad \alpha_{p2} = 0.102$ $\qquad \alpha_{p3} = 0.045$
$\alpha_{s1} = 0.856$ $\qquad \alpha_{s2} = 0.013$ $\qquad \alpha_{s3} = 0.131$
$\alpha_{m1} = 0.736$ $\qquad \alpha_{m2} = 0.163$ $\qquad \alpha_{m3} = 0.101$

Endowments
$L = 74936.415$ $\quad H = 63613.585$

Manufactured varieties
$F = 4285.095$
$n = 3$ $\qquad n^* = 97$
$q_{mz} = 1.2870$ $\quad q_{mz^*} = 3.6483$
$x_{mz} = 17,892$ $\quad x_{mz^*} = 34.47$

Table 1: The parameterization of the model.

$\varepsilon = -1, \mu = \frac{1}{2}$	Initial equilibrium 1987	New equilibrium 1994
n	3	3.1980
n^*	97	189.15
x_{mz}	17,892	15,786
x_{mz^*}	34.47	28.67
q_{mz}	1.2870	1.2743
q_{mz^*}	3.6483	3.6483
q_m	1	0.9572
q_p	1	1
q_s	1	0.9982
w_H	1	1.0152
w_L	1	0.9988
w_H/w_L	1	1.0164
y_p	26,625	18,827
y_s	113,835	119,757
y_m	82,718	87,315

Table 2: The results for the benchmark numerical experiment with epsilon = -1 and mu = (1/2).

$\varepsilon = -3, \mu = \frac{3}{4}$	Initial equilibrium 1987	New equilibrium 1994
n	3	3.1937
n^*	97	189.15
x_{mz}	17,892	15,800
x_{mz^*}	34.47	28.71
q_{mz}	1.2870	1.2744
q_{mz^*}	3.6483	3.6483
q_m	1	0.9575
q_p	1	1
q_s	1	0.9982
w_H	1	1.0177
w_L	1	0.9965
w_H/w_L	1	1.0213
y_p	26,625	17,754
y_s	113,835	120,539
y_m	82,718	87,205

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

$\varepsilon = -9, \mu = \frac{9}{10}$	Initial equilibrium 1987	New equilibrium 1994
n	3	3.1978
n^*	97	189.15
x_{mz}	17,892	15,772
x_{mz^*}	34.47	28.64
q_{mz}	1.2870	1.2743
q_{mz^*}	3.6483	3.6483
q_m	1	0.9572
q_p	1	1
q_s	1	0.9983
w_H	1	1.0186
w_L	1	0.9959
w_H/w_L	1	1.0228
y_p	26,625	18,303
y_s	113,835	120,046
y_m	82,718	87,312

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

$\varepsilon = -1, \mu = \frac{1}{2}$	Initial equilibrium 1987	New equilibrium 1994
n	3	3.1822
n^*	97	189.15
x_{mz}	17,892	15,672
x_{mz^*}	34.47	29.94
q_{mz}	1.2870	1.2852
q_{mz^*}	3.6483	3.6483
q_m	1	0.9641
q_p	1	1
q_s	1	1.0107
w_H	1	1.0469
w_L	1	0.9934
w_H/w_L	1	1.0539
y_p	26,625	17,151
y_s	113,835	120,993
y_m	82,718	87,621

Table 5: The results for the benchmark numerical experiment with sectoral variations in skill intensity: the first case.

	Initial equilibrium	New equilibrium
$\varepsilon = -1, \mu = \frac{1}{2}$	1987	1994
n	3	3.1845
n^*	97	189.15
x_{mz}	17,892	15,674
x_{mz^*}	34.47	29.85
q_{mz}	1.2870	1.2844
q_{mz^*}	3.6483	3.6483
q_m	1	0.9636
q_p	1	1
q_s	1	1.0089
w_H	1	1.0451
w_L	1	0.9938
w_H/w_L	1	1.0516
y_p	26,625	17,123
y_s	113,835	121,025
y_m	82,718	87,637

Table 6: The results for the benchmark numerical experiment with sectoral variations in skill intensity: the second case.