Heckscher-Ohlin and the global increase of skill premia: factor intensity reversals to the rescue*

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Abstract

By introducing skill-intensity reversals this paper shows that the Heckscher-Ohlin trade model captures the stylized facts of the global increase in skill premia, both in developed and in less-developed countries. The analysis also suggests an explanation for protection of skill-*un*intensive sectors in less-developed countries. The calibrated model is successful quantitatively: small changes in relative goods' prices are consistent with much larger increases in skill premia that have been observed in the data. This suggests that tariff reductions might have been a strong driving force behind the increase in global inequality and weakens the conclusion that other forces have been dominant.

Keywords: Heckscher-Ohlin, Factor intensity reversals, Skill premium, Trade liberalization, Tariff reduction.
JEL Classification: F11, F16

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1 Introduction

One of the most prevalent economic phenomena in the last two decades of the 20th century has been the global increase in wage inequality. Practically in every way it has been measured—e.g., Gini coefficients and skill premia—skilled workers have been receiving a higher share of income and higher wages relative to their less-skilled fellow workers. The magnitude of this increase varies considerably across countries, but is economically large everywhere. This phenomenon has indeed been global, as both developed and less-developed countries have experienced it; and as such, economists have attempted to find explanations for it that are global in scope.

This paper advances the claim that trade liberalization has been a strong force behind the increase in skill premia[1]. I present a simple general equilibrium model of international trade, based on the Heckscher-Ohlin-Samuelson (HOS) framework, that captures the stylized facts of global increases in skill premia. The standard Heckscher-Ohlin-Samuelson model has not been successful in explaining this trend in less-developed countries, despite its reasonable predictions for developed ones. However, by releasing the assumption of "no factor intensity reversals", this model becomes consistent with observation on skill premia, both in developed and less-developed countries, both qualitatively and, more importantly, quantitatively. Thus, the paper reconciles factor-endowment theory of comparative advantage with evidence on skill premia. Moreover, the model provides an explanation for why less-developed have protected low skill-intensity sectors.

Following the conclusion of the Tokyo GATT round in 1979, subscribing countries lowered their tariff and non-tariff barriers considerably. Heckscher-Ohlin trade theory relates goods' prices to wages (or, more generally, factor prices). The timing of the implementation of the aforementioned tariff reductions in many countries coincides with increases in their wage inequality, sometimes reversing previous trends[2]. Thus, it is only natural to suspect that tariff reductions caused the increases in skill premia.

According to Heckscher-Ohlin trade theory, skill-abundant (developed) countries have a comparative advantage in exporting skill-intensive goods, whereas skill-scarce (less-developed) countries have a comparative advantage in exporting skill-*un*intensive goods. Thus, falling trade barriers, namely

[1] The skill premium, i.e. the wage of skilled workers relative to their unskilled fellow workers, is one important dimension of wage inequality.

[2] E.g., in Mexico after the 1985 reforms. See Hanson and Harrison (1999).

tariffs, would induce an increase in the skill premium in developed countries, and a *fall* in the skill premium in less-developed countries—which is at strong odds with the evidence.

Based on empirical analysis in the U.S., some economists have discarded the trade-related explanation for the increase in the skill premium there. Katz and Murphy (1992) and Berman, Bound and Griliches (1994) have concluded that skill-biased technological change has been the source for the increase in wage inequality in the U.S. More recently, Acemoglu (1998 and 2002) has provided a theoretical framework that endogenizes such biased technical change; Acemoglu (2003) shows how increased openness might strengthen this mechanism and propagate its effects to less-developed countries.

Feenstra and Hanson (1996a) suggest that outsourcing of intermediate inputs is a different mechanism by which increased openness has increased wage inequality both in developed and less-developed countries. If developed countries transfer the production of their least skill-intensive activities to less-developed countries where these activities are relatively skill intensive, the result is an increase in skill intensity and skill premia in both country types. Feenstra and Hanson (1997) test their predictions on Mexican data and conclude that this effect is indeed economically important. Wood (1995, 1997) claims that the pronounced increase of importation of low skill-intensity goods in developed countries has expanded the effective supply of unskilled labor there. Thus, the factor content of those imports is the mechanism by which trade has caused the increase in wage inequality in developed countries.

Other economists have tried to reconcile the predictions of the HOS model with the facts by suggesting that other forces have increased skill premia in less-developed countries. For instance, Milanovic and Squire (2005) claim that the decline in the power of unions has been such a force. If unionization is higher in sectors that had higher tariff protection or is more prevalent among unskilled workers, and if labor market reforms are coupled with trade liberalization[3], then the net effect could be the opposite of what the HOS model alone suggests. Milanovic and Squire conclude that since skill premia

[3]Milanovic and Squire claim that trade liberalization usually comes within a package of other reforms, one of which is labor market reform, which diminishes union power. However, Olson (1982, chapter 5) describes how trade liberalization alone could diminish the power of unions, without an explicit labor market reform. The case of the car-industry workers union IG Metal in Germany after enlargement of the EU in May 2004 provides a recent compelling exmaple.

have indeed increased in less-developed countries, it must be the case that unionization has fallen there by enough to overturn what is suggested by the HOS model.

Krugman (2000) suggests that if education is only a signal for innate ability, which is private information, then small changes in relative prices might induce a regime-switch from a pooling equilibrium to a separating one. In the separating equilibrium more high-ability types have an incentive to reveal their type, thus seeking more formal education (a proxy for "skill") and thus increasing the skill premium.

This paper revives and extends the work of Minhas (1962), who considered capital-labor intensity reversals in the HOS model. Here I apply his analysis to *skill*-intensity reversals. By relaxing the stringent assumption of "no factor intensity reversals" the model's predictions become consistent with the stylized facts of skill premia, both in less-developed, relatively skill-scarce countries and developed, skill-abundant countries. In particular, the model captures differences in levels of skill premia and—more importantly—magnitudes of changes following trade liberalization. Thus, as far as "North-South" trade is concerned, the factor endowments theory of comparative advantage cannot be rejected on the grounds of changes in skill premia or their levels.

The analysis also provides a potential explanation for why less-developed countries protected their skill-*un*intensive sectors, which have a comparative advantage under standard assumptions. With skill-intensity reversals, this sector might be in direct international competition with the skill-intensive sector in developed countries.

The modified model succeeds where the standard one fails due to the fact that it allows two cones of diversification with only *two* goods. The North produces in one and the South in the other. Each country produces *both goods* with different input mixes and exhibits different skill premia, although technology is the same in both countries.

Most related to this point is the conclusion of Schott (2003). After constructing "Heckscher-Ohlin aggregates" that correspond to the conceptual goods in the model, Schott finds that all countries in his sample can be separated into two cones of diversification. In this sense he provides empirical support to the model's cone structure. However, Schott's cone structure requires *three* goods, so each country does not produce one of the goods and must import all of its consumption of that good. Moreover, Schott considers

capital and labor as factors of production[4]. In this sense his work is orthogonal to this paper: here both goods are produced by both countries, and I consider skilled and unskilled labor as factors of production.

Factor intensity reversals are technically possible whenever elasticities of substitution between factors are not equal in all sectors. In other words, the strong version of the "no FIRs" assumption relies on elasticities of substitution being equal across sectors. A weaker version of this assumption would be that the variation in skill premia across countries is empirically too small to allow FIR in practice[5]. It is argued here that this is the exception, rather than the rule, i.e. that elasticities of substitution are not equal across sectors and that the variation of skill premia across countries is indeed large enough to make possibility a practice. The next section provides evidence to support this last claim. Section 3 outlines the model, which calibration I discuss in Section 4. In Section 5 I simulate comparative statics and Section 6 concludes.

2 The rise in skill premia: some facts

The increases of skill premia across the globe are widely documented and their magnitudes are strikingly large[6]. For example, in the United States, the relative wage of college graduates to high school graduates increased by roughly 24% from 1979 to 1996[7]. A similar magnitude of change has been observed in the United Kingdom. In other OECD countries such changes have not been observed[8]. In European countries this is probably due to the

[4]The Heckscher-Ohlin aggregates are identified by capital-labor intensity in production.

[5]In light of Minhas' work, Leontief (1964) examined empirically the variation in wages relative to returns to capital (w/r) across countries and sectors and concluded that they are seldom large enough to be consistent with capital-labor intensity reversals in practice, although he did find. that they are large enough in some sectors across countries.

[6]It common practice in this line of research that education and certain occupations are associated with skill—whether inherent ability or acquired knowledge—which lead to blurring the distinction between the two. I will follow suit here, but one should take note of the caveats of seeing them as one and the same.

[7]This has been widely documented and analyzed, e.g. by Katz and Murphy (1992), Berman, Bound and Griliches (1994) and Katz and Autor (1999). Most of the increase in the skill premia in the U.S. has been caused by plummeting high school graduates' real wages in the face of a modest increase in college graduates' real wages.

[8]Katz and Autor (1999) document small increases in Australia, Canada and Japan; and moderate increases in Italy and New Zealand. They do not find significant increases

rigid wage structure; since wages could not adjust, the flipside was a dramatic increase in unemployment[9].

The empirical literature on the rise in skill premia has curiously focused on the developed countries, but similar patterns have been observed elsewhere. Table 1 gives a taste of how widespread the phenomenon is[10]. The years are selected according to the studies mentioned in the sources for the table; they correspond to periods of increased openness to trade[11].

Table 1: Levels of skill premia and percent-changes

Country	S.P. (year)	S.P. (year)	%-change
Colombia	2.56 (1986)	3.03 (1998)	17%
Chile	3 (1975)	5.2 (1991)	73%
China	1.17 (1995)	1.64 (2000)	40%
Ghana	1.36 (1991)	3.43 (1997)	152%
Mexico	1.93 (1984)	2.545 (1990)	32%
U.S.	1.48 (1979)	1.84 (1996)	24%

Sources: Columbia – Attansio et al. (2004), Chile (urban households) – Robbins (1994), China (urban) – Li and Xu (2003), Ghana (manufacturing sector) – Gorg and Strobl (2002), Mexico – Hanson and Harrison (1999) (manufacturing sector) US – Acemoglu (2003). Samples are periods of increased openness to trade (tariff reductions).

More qualitative evidence on the increase in wage premia in some South American countries and cities[12] due to changes in trade regimes is summa-

for other OECD countries.

[9] See Freeman (1995).

[10] In the appendix I reproduce Table 10 from Katz and Autor (1999). The numbers in that table are logs of 90:10 wage ratios, and therefore the levels are not comparable to my Table 1 (e.g., a log ratio of 1 means that the ratio is equal to $e \approx 2.7183$). However, the last column in Katz and Autor's Table 10 is comparable, because it represents percent changes.

[11] In Ghana there was an increase in public-sector real wages in 1992 (following the 1992 elections and increased international aid) which might have contributed to the increase in the skill premium there. However, the data in Gorg and Strobl (2002) are from the manufacturing sector. Moreover, most of the increase ocurred in 1993-4 and 1995-6.

[12] Argentina (Buenos Aires), Chile (Santiago), Colombia (seven cities), Costa Rica and Uruguay (Montevideo).

rized by Wood (1997), who cites various studies carried out by Donald Robbins and coauthors (see references therein). Richardson (1995) cites other studies that corroborate Wood and document similar trends in the same and other developing countries[13] (see references therein). So one can safely conclude that during periods of increased openness skill premia have indeed risen around the globe.

Table 1 also shows that in this small sample the increases in skill premia were much larger in less developed countries (Colombia is atypical in the percent change, although the sample is half the length of the U.S. data). This fact has mostly gone unnoticed in the literature. An exception to this are Milanovic and Squire (2005); they find in a panel regression of 118 countries in 1983-1999 that the effect of tariff reductions on occupational Gini coefficients (indicators of skill premia) was much stronger in poorer countries (and in the same direction as in Table 1).

Another important feature in the data—documented by Robbins (1996, Figure 4)—is that the levels of skill premia in developing countries are typically much higher than what is observed in developed countries. Average skill premia over various years (samples do not coincide) are for Chile: 6, Columbia: 4.5, Costa Rica: 3.5, Malaysia: 7, Taiwan: 1.7 and Uruguay: 2.3. This can also be seen in Table 1 (China and Taiwan are atypical in the level). Indeed, Milanovic and Squire (2005) find that occupational Gini coefficients are negatively correlated with income per capita. More directly, Repetto and Ventura (1997) find a negative correlation between skill premia and skill abundance across countries. Thus, it seems plausible that the variation of skill premia across countries is indeed large enough to make skill-intensity possible.

We can summarize the stylized facts on skill premia as follows:

(1) skill premia are higher in the skill-scarce, less-developed countries, relative to skill-abundant, developed countries;

(2) skill premia rose both country types; and

(3) skill premia rose more in the less-developed countries.

The model presented below captures all of these three stylized facts.

[13] Brazil, Korea, Singapore and Morocco.

3 Skill premia and skill-intensity reversals

The Heckscher-Ohlin model is well known and studied[14]. Therefore I focus only on features which are different from the standard version, and on the main theoretical predictions for trade liberalization. The analysis builds on Minhas (1962).

3.1 A 2x2x2 model

The model consists of two countries, "North" and "South", each of which is populated with a fixed number of workers that are not mobile across countries. All workers have identical homothetic preferences. The workers are either skilled (S) or unskilled (L) and cannot leave their country, but are mobile between sectors.

Each country has access to two constant returns to scale technologies that produce two tradable goods (sectors). These technologies are the same across countries up to a neutral productivity shifter, and both use skilled and unskilled labor as factors of production. For a particular sector, output is given by $Q_{ic} = A_{ic}F_i(S_{ic}, L_{ic})$, where $i \in \{1, 2\}$ denotes sectors, $c \in \{n, s\}$ denotes countries and A_{ic} denotes the neutral productivity shifter. I assume that these technologies are of the constant elasticity of substitution (CES) class

$$Q_{ic} = A_{ic}\left[\alpha_i S_{ic}^{\theta_i} + (1-\alpha_i)L_{ic}^{\theta_i}\right]^{1/\theta_i},$$

where α_i is a distribution parameter and $\theta_i \in (-\infty, 1]$ is a substitution parameter[15]. The elasticity of substitution (EOS) between skilled and unskilled labor is $\epsilon_i = 1/(1-\theta_i)$. Notice that the latter three parameters are sector-specific, but are identical across countries.

All markets are competitive (i.e. firms and workers are price takers). Since workers are mobile across sectors, the returns to each worker type must be equal in both sectors in equilibrium. Firms maximize profits; by the

[14] For an exposition, see Feenstra (2004).

[15] One can think of the productivity shifter as capturing capital as well as TFP. If $Q = (T \cdot K^{\gamma})\left[\alpha S^{\theta} + (1-\alpha)L^{\theta}\right]^{\frac{1-\gamma}{\theta}}$, where T and K denote TFP and capital, respectively, then $A = (T \cdot K^{\gamma})$ and all the results derived below hold exactly. However, this relies on the assumption that the elasticity of capital with skilled and unskilled labor is the same, which is at odds with a body of literature starting with Griliches (1969), which finds that capital and skill are more complementary than capital and unskilled labor.

zero profit condition for CRS technology in a competitive economy, payments to factors exhaust revenues and factor returns are given by the value of their respective marginal products. Let z and w denote the returns to skilled and unskilled labor, respectively. By manipulating the first order conditions for the firms one can express the optimal skill intensity as a function of the skill premium as follows

$$x_{ic} = \left(\frac{\alpha_i}{1-\alpha_i}\right)^{\epsilon_i} \pi_c^{-\epsilon_i},$$

where $x_{ic} = S_{ic}/L_{ic}$ is the skill intensity in sector i in country c, and $\pi_c = z_c/w_c$ is the skill premium in country c. The relative skill intensity across sectors is given by

$$\frac{x_{1c}}{x_{2c}} = \left(\frac{\alpha_1}{1-\alpha_1}\right)^{\epsilon_1} \left(\frac{\alpha_2}{1-\alpha_2}\right)^{-\epsilon_2} \pi_c^{\epsilon_2-\epsilon_1}.$$

It can be seen from this expression that unless $\epsilon_1 = \epsilon_2$, then relative skill intensity in a country cannot be determined separately from the skill premium. Moreover, the relationship between the two is not monotone. Without loss of generality, let

$$\epsilon_1 > \epsilon_2.$$

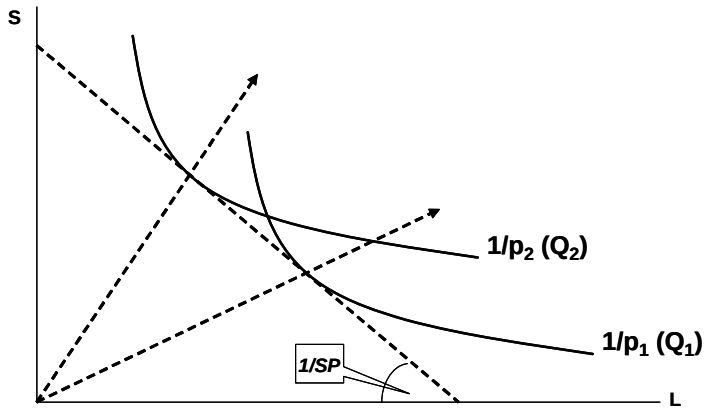
Under this assumption sector 1 is skill intensive relative to sector 2 for low skill premia and the opposite for high values of skill premia.

The standard assumption that allows us to neatly separate the solution for prices from quantities (and then calculate quantities as residuals) is known as "no factor intensity reversals". Under this assumption, for every pair of factor returns (or skill premium) one good will be produced with higher skill intensity relative to the other. As long as both goods are produced[16], the "no FIRs" assumption gives rise to "factor price insensitivity": factor prices are uniquely given only by goods prices—not by factor endowments. In terms of this model, this amounts to assuming $\epsilon_1 = \epsilon_2$.

The difference between "no FIRs" to "yes FIRs" can be seen using a Lerner diagram. Figure 1 illustrates unit-revenue curves for two sectors in a particular country when $\epsilon_1 = \epsilon_2$ and the equilibrium unit-cost line. Notice that good 2 will always be produced with greater skill-intensity relative to

[16] I.e., factor endowment vectors are within cones of diversification.

Figure 1: No skill intensity reversals



good 1. The skill premium is the reciprocal of the slope of the unit-cost line. As long as both goods are produced, their prices uniquely determine the skill premium in equilibrium.

However, if $\epsilon_1 > \epsilon_2$, this unique relationship does not hold, as can be seen in Figure 2, where $\epsilon_2 = 0$ for expositional purposes (Leontief production function). Now there are two possible equilibria, which are characterized by two skill premia. The selection between equilibria for a particular country will be determined by its skill abundance. I assume that North is sufficiently skill abundant to be in the top equilibrium and South is sufficiently skill scarce to be in the lower one.

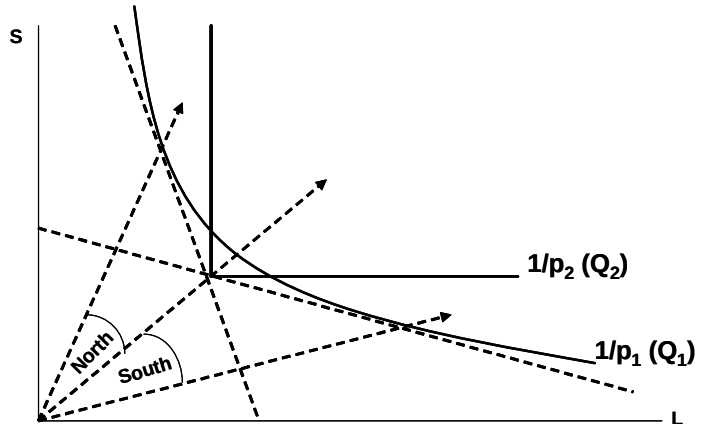
Notice that in the North good 1 is produced with greater skill-intensity relative to good 2, whereas the opposite is true in the South. Thus, the general notion of a skill-intensive good becomes a local concept and I adopt the term "locally skill-intensive" to describe exactly that. Notice also that the North produces all goods with higher skill intensity than the South (except when $\epsilon_2 = 0$, in which case good 2 is produced with the same skill-intensity).

The relationship between skill premia and relative prices in a particular country can be written as follows

$$p = \frac{1}{A} \cdot \frac{\left[\alpha_1^{\epsilon_1} \pi^{1-\epsilon_1} + (1-\alpha_1)^{\epsilon_1}\right]^{\frac{1}{1-\epsilon_1}}}{\left[\alpha_2^{\epsilon_2} \pi^{1-\epsilon_2} + (1-\alpha_2)^{\epsilon_2}\right]^{\frac{1}{1-\epsilon_2}}},$$

where $p = p_1/p_2$ and $A = A_1/A_2$. This relationship is not monotone. For the

Figure 2: Skill intensity reversals



following parameter values, $A = 1$, $\alpha_1 = .55$, $\alpha_2 = .45$, $\epsilon_1 = 1.6$, $\epsilon_2 = .9$, the function is drawn in Figure 3 in levels (top panel) and in logs. The derivative of log price with respect to log skill premium is

$$\frac{d\log p}{d\log \pi} = \frac{a_1\pi^{1-\epsilon_1} - a_2\pi^{1-\epsilon_2}}{(1+a_1\pi^{1-\epsilon_1})(1+a_2\pi^{1-\epsilon_2})} \tag{1}$$

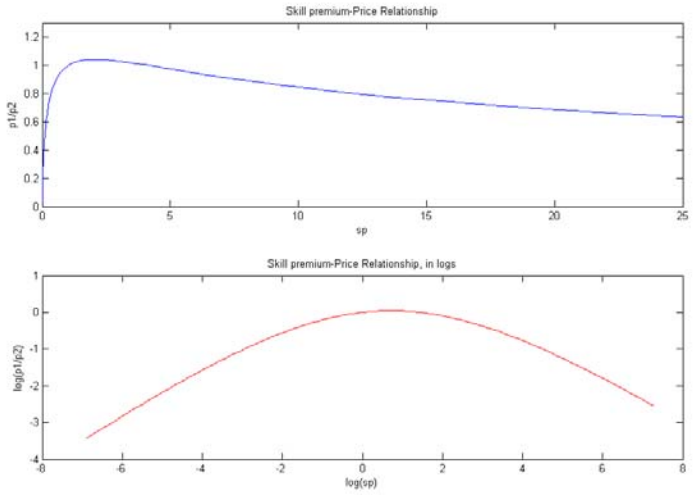
$$\begin{cases} > 0 \text{ when } \pi < \pi^* \\ < 0 \text{ when } \pi > \pi^*, \end{cases} \tag{2}$$

where $\pi^* = (a_1/a_2)^{\frac{1}{\epsilon_1-\epsilon_2}}$ and $a_i = [\alpha_i/(1-\alpha_i)]^{\epsilon_i}$. Since the price-skill premium relationship is monotone outside of π^*'s neighborhood, one can piecewise-invert the function without including the unique $p(\pi^*)$ (and all values above it) in the domain and without the critical point π^* in the range. In this case the derivative of the log skill premium with respect to log price is the reciprocal of (1). What is important for the analysis here is that it does not change sign, so one can write

$$\frac{d\log \pi}{d\log p} \begin{cases} > 0 \text{ when } \pi < \pi^* \\ < 0 \text{ when } \pi > \pi^* \end{cases} . \tag{3}$$

Anticipating what will follow, the non-monotone price-skill premium relationship will be key in explaining rising skill premia both in the North and in the South.

Figure 3: Price-skill premium relationship



The factor market clearing condition for a particular country is

$$\lambda x_1 + (1-\lambda)x_2 = \overline{x}, \quad \lambda \in (0,1),$$

where $\overline{x} = \overline{S}/\overline{L}$ is the skill abundance in that country and $\lambda = L_1/\overline{L}$. Restricting $\lambda \in (0,1)$ means that both goods are produced; this is equivalent to requiring $x_1 < \overline{x} < x_2$ or $x_2 < \overline{x} < x_1$. Using the market clearing condition one can write the relative labor allocation in equilibrium as a function of the skill premium as follows

$$l(\pi) = \frac{L_1}{L_2} = \frac{\overline{x} - a_2\pi^{1-\epsilon_2}}{a_1\pi^{1-\epsilon_1} - \overline{x}}.$$

The relative supply of good 1 in a particular country, $q = Q_1/Q_2$, can also be written as a function of the skill premium as follows

$$q = k \cdot l(\pi)\frac{\left[a_1\pi^{1-\epsilon_1}+1\right]^{1/\theta_1}}{\left[a_2\pi^{1-\epsilon_2}+1\right]^{1/\theta_2}},$$

where $k = A(1-\alpha_1)^{1/\theta_1}/(1-\alpha_2)^{1/\theta_2}$ is a constant. As with the price-skill premium relationship, this one is also not monotone

$$\frac{d\log q}{d\log \pi} = (1+\overline{x}\pi)\left[\frac{\epsilon_1 x_1}{(x_1-\overline{x})(1+x_1\pi)}+\frac{\epsilon_2 x_2}{(\overline{x}-x_2)(1+x_2\pi)}\right] \quad (4)$$

$$\begin{cases} >0 & \text{when } x_2<\overline{x}<x_1 \\ <0 & \text{when } x_1<\overline{x}<x_2 \end{cases}. \quad (5)$$

Noting that x_i are functions of the skill premium, it is not surprising that the sign of (4) given by (5) is equivalent to condition (2), i.e.

$$\begin{aligned} x_2 < \overline{x} < x_1 &\iff \pi < \pi^* \\ x_1 < \overline{x} < x_2 &\iff \pi > \pi^*. \end{aligned}$$

However, condition (5) is more informative for understanding comparative statics in the light of Figure 2; it tells us, ceteris paribus, how the skill premium and quantities produced respond to price changes conditional on which equilibrium we are in (North or South). For example, if we are in the North, then the skill premium increases as the relative price of good 1 increases and so does the relative supply of good 1 (q); in the South the skill premium falls as the relative price of good 1 increases and the relative supply of good 1 decreases[17].

3.2 Trade liberalization

Suppose that both countries are initially in autarky. In general, the equilibrium price and allocation values will be determined by every parameter of the model, but since preferences are restricted to be identical and homothetic, I consider only technology parameters and endowments. The South is characterized by much lower skill abundance than in the North. It is assumed that it is low enough to ensure that the South will be in an equilibrium in which $x_{1s} < \overline{x}_s < x_{2s}$, or $\pi_s > \pi^*$. Likewise, the North is assumed to be skill abundant enough to be in an equilibrium in which $x_{2n} < \overline{x}_n < x_{1n}$, or $\pi_n < \pi^*$.

Let the relative price of good 1 in the North and South be p_n^{aut} and p_s^{aut}, respectively. Suppose that $p_n^{aut} < p_s^{aut}$; this will be determined by relative

[17] The model does not have a closed form solution, since the equilibrium is characterized by a system of non-linear equations. Therefore, numerical methods are called upon.

skill abundance in both countries, and by the relative productivity of sectors in each country. It can be shown that p_n^{aut} decreases in the skill abundance of the North, and p_s^{aut} increases in the skill abundance of the South. Given the assumptions on the relative skill abundance of each country, $p_n^{aut} < p_s^{aut}$ will be a natural outcome[18].

Now suppose that these countries engage in free trade. In this case $p_n^{trade} = p_s^{trade} = p^*$, where the "world" equilibrium price, p^*, will fall between the autarky prices, i.e. $p_n^{aut} < p^* < p_s^{aut}$. This implies that the relative price in the North increases, whereas in the South it falls. Noting the pattern of endowments and the footwork summarized in (3) and (4)-(5), we have the skill premium increasing in both countries. The relative supply of good 1 expands in the North, and it will export the excess supply to the South and import good 2. The opposite will hold in the South. The change of regime from autarky to free trade is purely heuristic and I consider tariff reduction as well; the results remain qualitatively the same.

This analysis also provides a potential explanation to why less-developed countries protect their skill-*un*intensive sectors in the first place. In the standard HOS model, the South has a comparative advantage in skill-*un*intensive production and, therefore, would not have to protect that sector from international competition. But with skill-intensity reversals, sector 1 in the South is in direct competition with sector 1 in the North and might like to be protected.

Thus, so far, it has been shown that the model captures two of the stylized facts: that the skill premium is larger in the South; and that following trade liberalization skill premia increase both in the North and in the South. It remains to be shown that the model also captures the third stylized fact, that skill premia increase more in the South. This is addressed in the next section.

4 Calibration and comparative statics

When choosing parameter values for calibration, one must keep in mind that this model is extremely stylized and simplified. For instance, there are only two countries engaging in trade whereas in reality there are many "Norths"

[18]However, this is not guaranteed. It would be determined jointly by skill abundance and relative sector productivities. Given that we are interested in North-South trade, it is reasonable to assume that the endowments are such that $p_n^{aut} < p_s^{aut}$.

and "Souths". More importantly, there are no two sectors and factors that naturally correspond to the ones in the model. I deal with this issue first.

4.1 Identifying workers and sectors

I restrict attention to sectors for which unaggregated data are available and which the literature has previously examined: the manufacturing sector. I use data from the NBER-CES Manufacturing Industry Database[19], and following many empirical studies, I identify S as non-production workers and L as production workers. Clearly, these are crude proxies for skill and unskilled labor, but better ones are not readily available at the industry level[20]. By postulating country endowments $\overline{S}_n = 45$, $\overline{L}_n = 55$, $\overline{S}_s = 10$, $\overline{L}_s = 100$, I complete the demographic characterization of the model. In doing this I make sure that both countries are of the same size, so that neither dominates the equilibrium international prices under a free trade regime[21]. The relative magnitudes of $\overline{S}_c/\overline{L}_c$ ensure that the North is skill-abundant enough to be in the "North" equilibrium depicted in Figure 2 and the South in the "South" equilibrium. This means that in the North good 1 is locally skill-intensive, whereas in the South good 2 is locally skill-intensive.

I assume that all workers spend equal amounts of their income on both goods. These preferences are represented here by Cobb-Douglas utility function $u(c_1, c_2) = c_1^{\beta} c_2^{1-\beta}$, where $\beta = 1/2$. This it an innocuous assumption that does not affect the results.

Recall that under the free trade regime the North exported good 1 and imported good 2, and that sector 1 was skill intensive relative to sector 2 in the North. Moreover, the relative price of the skill intensive good in the North increased. Eaton and Kortum (2001) show that developed countries are predominant exporters of capital goods to the South. Under their definition, manufactured capital goods are all industries that fall under SICs 35 (Industrial Machinery and Equipment), 36 (Electronic and Other Electric

[19] Bartlesman, Becker and Gray (2000). Available at http://www.nber.org/nberces/

[20] In particular, both clerks and engineers are classified as non-production workers, while it is obvious that their skill levels are very different. Moreover, many production workers are highly skilled technichians. See Leamer (1994) for a critique of the use of this classification to proxy for skilled and unskilled workers. However, Berman, Bound and Griliches (1994) do find that this classification is a good proxy for skilled and unskilled workers in the U.S.

[21] It prevents the price change from being much larger for the smaller of the two countries due to its size alone.

Equipment) and 38 (Instruments and Related Products). In what follows, I identify sector 1 as SICs 35-38, adding SIC 37 (Transportation Equipment) to what is used by Eaton and Kortum, and call it the "capital goods" sector.

Sachs and Shatz (1994) find a pronounced increase in the importation of low skill-intensity manufactured goods to the U.S. from 1978 to 1990. They also find a 9% increase in the relative price of skill-intensive manufactured goods in the U.S. from 1978 to 1989. This last result is corroborated by Krueger (1997), who finds a 5% increase in this relative price from 1989 to 1995[22]. Therefore, I identify sector 2 as SICs 22 (Textile Mill Products) and 23 (Apparel and Other Textile Mill Products), which are much less skill intensive than SICs 35-38. I call this sector "light manufactures". Table 2 provides S/L ratios, simply averaged over the 1959-1996 period and over the 4-digit industries that fall within the corresponding sectors.

Table 2: Non-production to Production Workers Ratios

	Sector 1				Sector 2	
SIC	35	36	37	38	22	23
$S:L$	1:2	1:2.25	1:2.2	1:2.7	1:7	1:6.5

Notes: S:L are non-production to production workers ratios.
Numbers are averages over 1959-96 and 4-digit industries.
Source: NBER-CES Manufacturing Industry Database.

Sector 1 is locally skill-intensive in the U.S.: the proportion of non-production to production workers is relatively high within the manufacturing sector. These two sectors by any means do not exhaust the entire manufacturing sector. However, they are characteristic of trade patterns between the U.S. and other less developed countries.

This characterization of sectors assumes that sector 1 (capital goods) is *not* the locally skill-intensive in the South. Capital goods may be produced by very different input mixes, although the service they provide (in an hedonic sense) is very similar. On the other hand, light manufactures are produced with relatively similar input mixes in both countries (with $\epsilon_2 = 0$, it is the same), which makes sense, since their production methods are more standardized and "simple".

[22]Incidentally, when extrapolating 5% over 6 years to 11 years (Sachs and Shatz's sample length) one gets roughly the same magnitude of increase as Sachs and Shatz find.

4.2 Technology parameters

4.2.1 Elasticities of substitution (ϵ_i)

In order to test the model's predictions for the magnitude of changes in skill premiums, one must come up with plausible estimates for technology parameters. To my best knowledge, industry- or sector-level estimates of EOSs between skilled- and unskilled-labor are depressingly scarce. One reason may be that variation in skill premia (and in wages over time) is not very large and exhibits strong inertia, which would make estimation inherently imprecise, due to short time series available[23].

The only sector-level exercise I know of was carried out by Fallon and Layard (1975). They estimate the parameters of the sectoral production functions that take the following nested-CES form:

$$Q = A\left[\alpha\left(\left(\beta K^{\theta} + (1-\beta)S^{\theta}\right)^{\frac{1}{\theta}}\right)^{\rho} + (1-\alpha)L^{\rho}\right]^{\frac{1}{\rho}}.$$

This specification is consistent with skilled labor having different (smaller) EOS with capital than unskilled labor with capital[24]. They identify the parameters from international, cross section variation, making the explicit assumption that these production functions are identical across countries.

Fallon and Layard obtain parameter estimates for four sectors, using different definitions for skill and labor. Despite the small sample size (14-16 countries), their estimates are surprisingly precise. But since they do not estimate the EOS between skilled- and unskilled labor directly, only ranges for this parameter can be examined[25]. For one set of estimates in the following 4 sectors, the ranges are: mining: 0.76-1.45; manufacturing: 0.74-1.66; construction: 0.25-0.9; electricity, gas and water: 1.03-1.06. These ranges are quite broad and no clear ranking can be obtained. However, the main point to take away from Fallon and Layard's results is that the elasticity might be very different for various industries.

At the aggregate level Fallon and Layard estimate the EOS between skilled- and unskilled labor between 0.3 and 1.5[26]. Card and Lemieux (2001)

[23] Nevertheless, this seems to be possible, at least for the U.S. using the NBER-CES Manufacturing Industry Database. This estimation project is work in progress.

[24] That is, capital is more complementary to skilled labor than to unskilled labor (Griliches (1969)).

[25] In this production function the EOS between S and L depends on the level of K.

[26] Surprisingly, their estimates for a subsample of rich countries are 0.55-1.85 and for a

estimate the EOS between skilled- and unskilled male workers between 2 and 2.5, and between 1.1 and 1.6 for both genders. Krusell et al. (2000) estimate it between 0.67 and 1.67; Heckman, Lochner and Taber (1998) find that it is 1.441; Katz and Murphy (1992) find 1.41; Johnson (1970) finds 1.5. Johnson and Stafford (1999) note that recent studies at the aggregate level obtain a higher range for the elasticity of substitution between skilled- and unskilled labor between 1.5 and 2.

Thus in what comes next, I postulate $\epsilon_1 = 1.6$ and $\epsilon_2 = 0.9$, which is consistent with Fallon and Layard's range for manufacturing, and also consider $\epsilon_2 = 0$. In practice, the results hold for a wide range of elasticities that maintain the condition $\epsilon_1 > \epsilon_2$.

4.2.2 Distribution parameters (α_i)

I now turn to the distribution parameters. Given a range for the elasticity of substitution, one can gauge the value of the distribution parameter for various industries, using the following equation

$$\frac{\alpha_i}{1-\alpha_i} = \left(\frac{z_i}{w_i}\right)\left(\frac{S_i}{L_i}\right)^{1/\epsilon_i}$$

As noted above, I identify skilled workers and unskilled workers in the NBER-CES Manufacturing Industry Database as non-production and production workers, respectively. I calculate z_i and w_i as the average wages of non-production and production workers, respectively. S_i and L_i are the number of non-production and production workers, respectively, in the sectors described above. Using my postulated values for ϵ_i I obtain the following ranges: $\alpha_1 \in [0.41,\ 0.6]$ and $\alpha_2 \in [0.25\ ,\ 0.45]$ [27]. In what follows, I take $\alpha_1 = 0.55$ and $\alpha_2 = 0.45$. This implies that skilled labor is relatively more productive than unskilled labor in both sectors[28].

subsample of poor countries 0.67-2.13.

[27] These are ranges within the relevant 4-digit SICs that lie within the sectors Identified above.

[28] When $\epsilon > 1$ ($\theta \in (0, 1]$), then $\alpha > 0.5$ implies that skilled labor is relatively more productive. When $\epsilon < 1$ ($\theta \in (-\infty, 0)$), then $\alpha < 0.5$ implies that skilled labor is relatively more productive.

4.2.3 Relative productivity (A_i)

Acemoglu and Zilibotti (2001) and Golub and Yeaple (2002) provide sectoral TFP measures that are internationally comparable[29]. Acemoglu and Zilibotti find that relative industry-level TFP is higher in skill-intensive industries. By examining Golub and Yeaple's estimates, I come to a similar conclusion. These estimates are fixed in time, so a major concern is technical change. Since I examine comparative statics that are meaningful only over periods of time that allow labor to reallocate between sectors, this is a real issue. However, what is important for this exercise are the industry TFP rankings within each country, which are likely to remain similar over long periods of time.

Thus, for practical purposes, I postulate the following values for industries and countries: in the North, $A_{1n} = 1.1$, $A_{2n} = 1$; in the South, $A_{1s} = 0.9$, $A_{2s} = 1$. Since prices are not identified separately from sector TFP in this model, the actual magnitudes are not important. What is significant is that these values ensure $\frac{A_{1s}}{A_{2s}} < \frac{A_{1n}}{A_{2n}}$, which is consistent with the patterns observed. The choice of $A_{2n} = A_{2s}$ reflects that there seems to be no reason why light manufactures would be more productive in the North relative to the South after controlling for capital, especially since this sector employs relatively much more unskilled labor.

Table 3 summarizes the parameters for calibration.

Table 3: Calibrated parameters

Demographics		Preferences		Technology		Productivity	
$\overline{S}_n$	45	β	1/2	α_1	0.55	A_{1n}	1.1
$\overline{L}_n$	55			α_2	0.45	A_{2n}	1
$\overline{S}_s$	10			ϵ_1	1.6	A_{1s}	0.9
$\overline{L}_s$	100			ϵ_2	0.9	A_{2s}	1

Given the discussion above, one should consider these parameters for heuristic purposes alone. Nevertheless, the results hold for reasonable per-

[29] The NBER-CES Manufacturing Industry Database's TFP estimates are indices that are normalized to a base year and are not comparable across industries. The ICOP Industrial Database (1987 Benchmark) (Groningen Growth & Development Center, University of Groningen, available online at http://www.ggdc.net/icop.html) provides year-by-year comparable estimates of value added per worker, but not by industries. Moreover, they do not control for capital intensity.

mutations of these parameters. We are now ready to turn to the impact of lowering trade barriers and free trade on both countries.

5 Comparative statics

Given the parametric setup above, I perform two comparative statics experiments: "globalization" and "tariff reduction"[30]. The first experiment considers the changes in both economies when they move from autarky to a free trade regime with no barriers or transportation costs. In the second experiment I treat each country separately as a small open economy and consider the changes in each economy when it reduces tariffs while keeping international goods prices fixed. Both experiments test the ability of the model to match qualitatively and quantitatively the stylized facts on skill premia. The first one is a more strict test because prices are endogenous; the second aims to be more realistic in the sense that tariffs are not eliminated altogether.

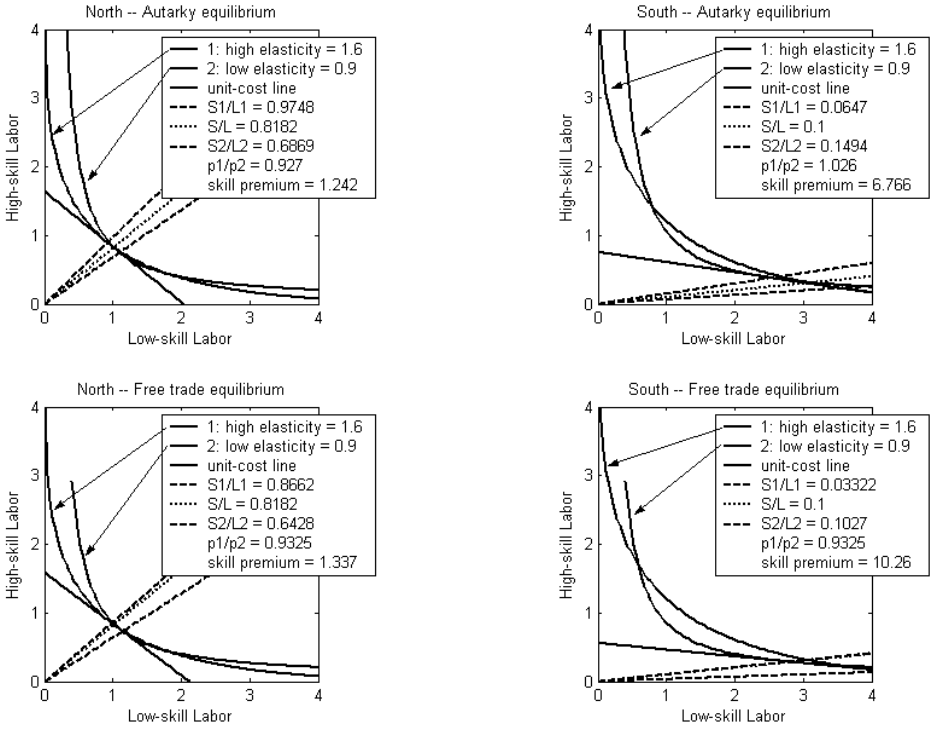
5.1 Globalization

The main experiment here is "globalization", which aims to show that the calibrated model captures stylized fact 3, namely that the skill premium increases more in the South as trade barriers are reduced. The economies start in autarky. This is illustrated in the top panels of Figure 4. The rays from the origin mark the country skill-abundance and skill-intensity in both sectors. Since both goods are demanded, then in autarky both goods are produced, which ensures $x_2 < \overline{x} < x_1$ in the North and $x_1 < \overline{x} < x_2$ in the South (recall: $x_i = S_i/L_i$ and $\overline{x} = S/L$ for each country).

The South exhibits a higher skill premium as expected, which is consistent with the first stylized fact. Given (3), the fact that $p_n^{aut} < p_s^{aut}$ and the analysis above, we can predict that the skill premium will rise in both countries when they engage in free trade (stylized fact 2). The bottom panels of Figure 4 illustrates this, but also the fact that the skill premium increases

[30] These experiments require numerical solution of the model, since the equilibrium is characterized by a system of non-linear equations with no closed-form solution. Matlab codes for computing the equilibrium and producing the graphical exposition are available upon request.

Figure 4: "Globalization"



more in the South, which is stylized fact 3. The skill premium increases by 7.6% in the North, and by 51% in the South.

Notice that the relative price increased by only 0.5% in the North, but caused a skill premium increase fifteen-fold bigger. Similarly in the South, the relative price decreased by only 9% and caused a skill premium increase five-fold bigger. This is a manifestation of the Stolper-Samuelson theorem. In fact, their proof holds locally in this model as well, in the same sense of local skill-intensity. Hence, their theorem can be understood as a general magnification theorem, without imposing the direction of the effect[31]. Due to

[31]The proof relies on small deviations from equilibrium and on the relative size of cost shares of each factor in both sectors. The magnification result in the proof generalized costlessly to this setting. Global determination of the direction of the effect relies on the

trade liberalization both countries become very specialized in production—but not completely, so that the same conditions for equilibrium hold[32].

This last magnification result is germane to the debate on whether price changes have been large enough to induce the wage changes needed to justify the observed increases in skill premia. For instance, Lawrence and Slaughter (1993) and Sachs and Shatz (1994) have argued that the price changes of skill-intensive goods in the U.S. could not have been large enough to explain the rise in the U.S. economy-wide skill premium[33]. This experiment shows how strong the magnification effect can be. If this effect is present in reality, its potential impact might be underestimated. Moreover, these claims disregard the fact that in general equilibrium wages are set at the margin. In theory, these effects will spread to other sectors, including non-tradables. Unless labor markets are segmented enough to isolate workers from the effects of the tradeables sector, the effect will be felt in all sectors of the economy. Thus, the "tail" (price) might yet "wag the dog" (economy-wide wages).

The same experiment is reported in the appendix for fixed-proportions production in sector 2.

5.2 Tariff reductions

One possible critique of the theoretical globalization experiment is that countries do not, in fact, move from complete autarky to completely free trade; they lower their tariffs, usually only gradually, but do not eliminate them altogether. This is particularly true for "North-South" trade. Moreover, there are many countries engaged in trade, so that the international equilibrium price of traded goods is not drastically affected by the policy of one country. Therefore, it is useful to examine countries as "small open economies", where

"no FIRs" assumption.

[32]That is, the experiment does not move the cone of diversification away from the endowment vector.

[33]Lawrence and Slaughter (1993) find a slight decline in the relative price of skill-intensive goods in the U.S. However, Sachs and Shatz (1994) show that most of Lawrence and Slaughter's price series do not cover their entire sample and that their result is driven by computers' prices. When using consistent price series and controlling for computers, Sachs and Shatz find that skill-intensive goods' prices have increased by 9% from 1978 to 1989—but maintain the view that this can not explain the increase in the skill premium. Feenstra and Hanson (1996b) emphasize the fact that the relative price of imports to domestic goods has fallen over time, reflecting an improvement in the terms of trade for the North, thus contributing to wage inequality.

they do not have an impact on the international equilibrium price of traded goods.

I report the results of the "tariff reductions" experiment when sector 2 has fixed-proportions production structure. As will be soon apparent, all three stylized facts are still captured by this experiment. For heuristic purposes I modify the parametrization of the model. I impose $\epsilon_2 = 0$, and change the endowments to $\overline{S}_n = 70$, $\overline{L}_n = 70$, $\overline{S}_s = 40$, $\overline{L}_s = 100$; this way we gain a wider range for policy, without moving the cone of diversification away from the endowment vector. The endowment vectors keep the same considerations as before. Another modification is changing slightly the values of the substitution parameters to $\alpha_1 = 0.6$ and $\alpha_2 = 0.4$; this reduces the sensitivity of the skill premium to tariff-price changes[34] and also increases the range of policy experiments. Preferences and productivity parameters remain the same.

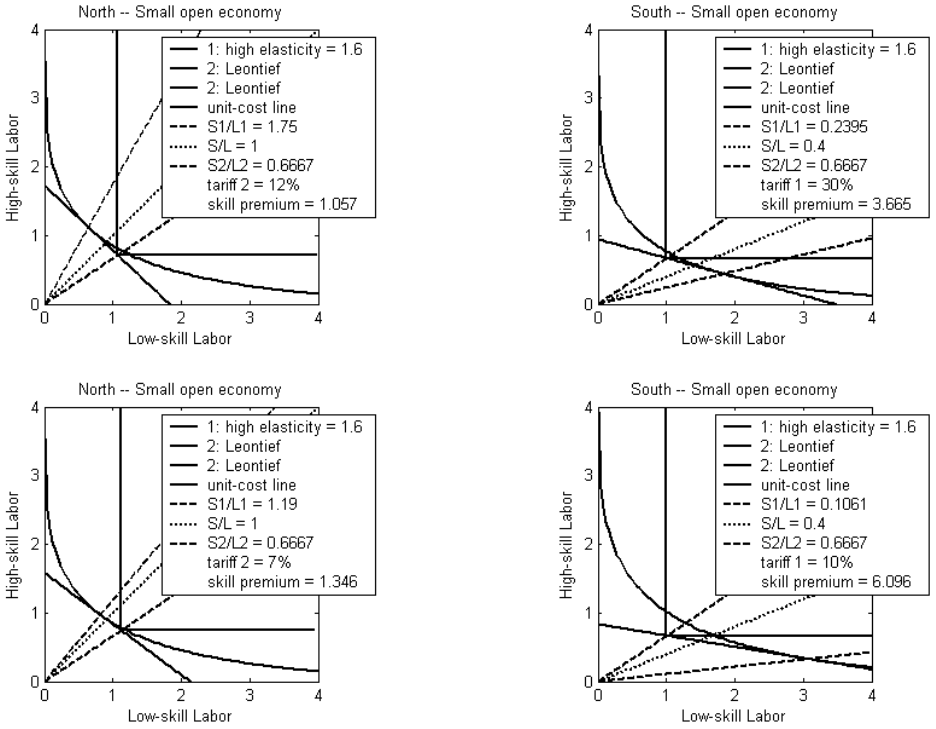
Figure 5 illustrates the experiment. Both countries protect their locally skill-*un*intensive sector; in the North it is sector 2, whereas in the South it is sector 1. To match casual observation, tariffs in the North are an order of magnitude smaller than in the South. However, the results are not sensitive to this at all. What is important is that the North reduces its tariffs less than the South. In the experiment here the North reduces tariffs by 5% and the South by 20%; this causes the skill premium to increase by 27% in North and by 66% in the South. Once again, all stylized facts are captured in this experiment. Moreover, the price (tariff) changes are much smaller than the increases in skill premia that they induce.

6 Conclusions

The global rise in skill premia has been one of the most important economic phenomena in labor markets during the 1980s and 1990s. I have presented evidence that it has indeed been a global phenomenon; and as such, economists have attempted to find explanations for it that are global in scope: trade in goods, technology, outsourcing and institutional changes

[34]The sensitivity is governed by the cost shares of the factors of production: the more similar they are—the more sensitive is the skill premium to price changes. These cost shares are govenred by the substitution parameters: the more similar α_1 and α_2 are, the closer the cost shares will be for all ranges of prices. However, the magnification effect of the Stolper-Samuelson (1941) theorem holds for arbitrary values of α_i.

Figure 5: "Tariff Reductions"



that are induced by increased openness. The trade liberalization explanation offered by the standard Heckscher-Ohlin-Samuelson model has been rejected by most economists due to its counter-factual predictions for skill premia in less-developed countries after tariff reductions. This paper makes the claim that trade liberalization has been a strong force behind the increase in skill premia nonetheless.

The simple general equilibrium model of international trade which is presented here captures the stylized facts of global increases in skill premia. In particular, by releasing the assumption of "no factor intensity reversals" the Heckscher-Ohlin-Samuelson framework becomes consistent with observation on skill premia, both in developed and less-developed countries. The calibrated model serves to show that the magnitudes of changes of skill pre-

mia are in line with the stylized facts. Thus, the paper reconciles factor-endowment theory of comparative advantage with evidence on skill premia.

The analysis also provides a potential explanation to why less-developed countries protect their skill-*un*intensive sectors. With skill-intensity reversals, this sector might be in direct international competition with the skill-intensive sector in developed countries.

By showing that this theory can encompass the global rise in skill premia, the conclusion that other forces have been driving this phenomenon is weakened. Evidence on skill-biased technical change and other institutional changes like the decline in unionization is indirect at best. As noted by Krugman (2000), these explanations are too much of a "deus ex machina", and make many economists feel uneasy. On the other hand, there is much hard evidence on prices and trade flows. Therefore, this paper serves as a guide: *it might have been trade after all.*

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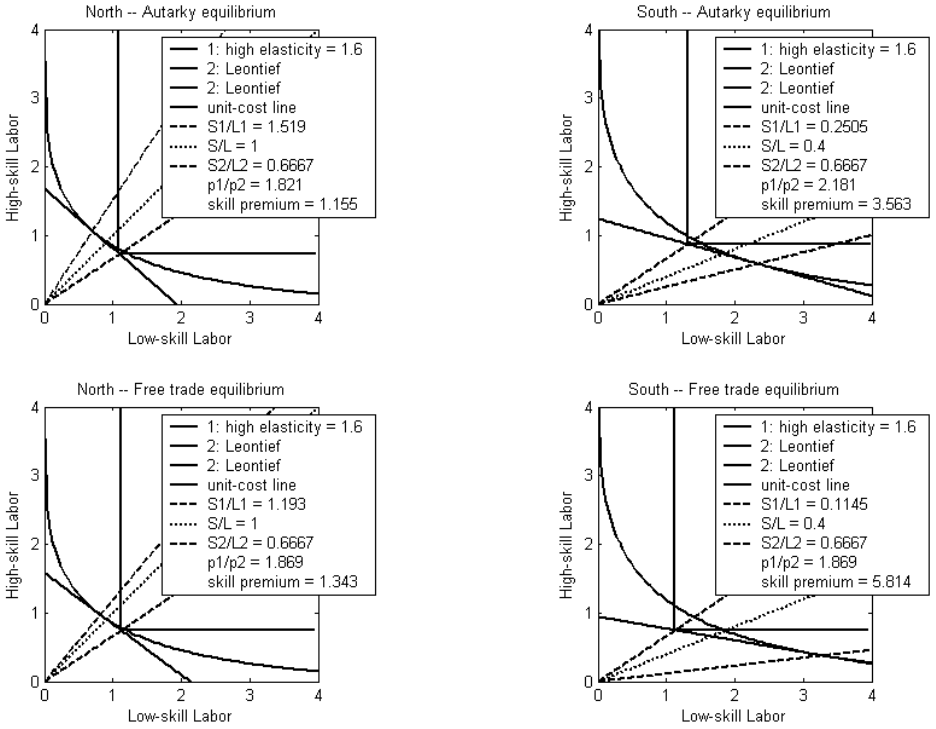
7 Appendix

I report here the results of the "globalization" experiment when sector 2 has fixed-proportions production structure. The point of this exercise is to provide a robustness check for the results above. As will be soon apparent, all three stylized facts are still captured in this experiment. The parametrization of the model is modified. Technology parameters are now $\epsilon_2 = 0$, $\alpha_1 = 0.6$ and $\alpha_2 = 0.4$; the endowments are $\overline{S}_n = 70$, $\overline{L}_n = 70$, $\overline{S}_s = 40$, $\overline{L}_s = 100$. See discussion above in the "tariff reductions" section. Preferences and productivity parameters remain the same.

The results are presented in Figure 6. The skill premium in autarky is higher in the South. "Globalization" yields a rise of 16% in the skill premium in the North, whereas it increases by 63% in the South, which is consistent

Figure 6: "Globalization"



with stylized facts 2 and 3. The relative price in the North increases by 2.6%; it decreases by 14% in the South.

The "tariff reductions" experiment when sector 2 has an EOS of 0.9 and with the regular parametrization is reported here. Figure 7 illustrates the experiment. Both countries protect their locally skill-*un*intensive sector; in the North it is sector 2, whereas in the South it is sector 1. In the experiment here the North reduces tariffs by 1% and the South by 5%; this causes the skill premium to increase by 12% in North and by 24% in the South. Once again, all stylized facts are captured in this experiment.

Figure 7: "Tariff Reductions"

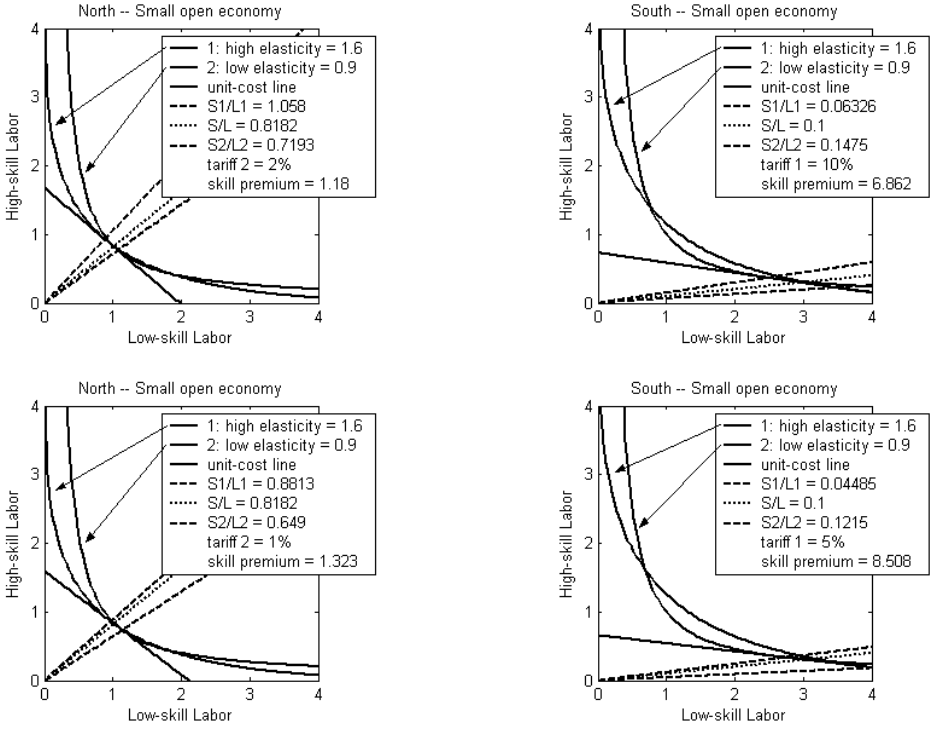


TABLE 10

Trends in Wage inequality for Males, Selected OECD countries, 1979 to 1994[a]

Log of ratio of wage of 90th percentile earner to 10th percentile earner

Country	1979	1984	1989	1994	Change from earliest to latest year
Australia	1.01	1.01	1.03	1.08	0.07
Austria[b]	0.97		1.00		0.03
Canada[c]	1.24	1.39	1.38	1.33	0.09
Finland[d]	0.89	0.92	0.96	0.93	0.04
France	1.22	1.20	1.25	1.23	0.01
Germany[e]		0.87	0.83	0.81	-0.06
Italy	0.83	0.83	0.77	0.97	0.14
Japan	0.95	1.02	1.05	1.02	0.07
Netherlands[f]		0.92	0.96	0.95	0.03
New Zealand[g]		1.00	1.12	1.15	0.15
Norway[h]	0.72	0.72	0.77	0.68	-0.04
Sweden[i]	0.75	0.71	0.77	0.79	0.04
United Kingdom	0.90	1.02	1.12	1.17	0.27
United States	1.16	1.30	1.38	1.45	0.29

SOURCE: OECD (1996), Table 3.1, pp. 61-62.

NOTES:

[a] The samples generally consist of full-time workers, with the exceptions of Austria, Italy, and Japan. See OECD (1996, pp. 100-103) for details on the samples and earnings measures.

[b] Data for Austria in the 1979 column are for 1980.
[c] Data for Canada are for 1980, 1986, 1990, and 1994
[d] Data for Finland are for 1980, 1983, 1989, and 1994.
[e] Data for Germany are for 1983, 1989, and 1993.
[f] Data for the Netherlands are for 1985, 1989, and 1994.
[g] Data for New Zealand are for 1984, 1990, and 1994.
[h] Data for Norway are for 1980, 1983, 1987, and 1991.
[i] Data for Sweden are for 1980, 1984, 1989, and 1993.