Trade, Technology Adoption and Wage Inequalities

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September 7, 2007

Abstract

This paper studies the impact of trade liberalization on technology adoption and its effect on wage inequalities. We develop a trade model with heterogeneous firms introducing a fixed technology cost and different types of skilled labor. The contribution of this paper is to develop a possible explanation to the H-O-S puzzle. This traditional framework predicts a reduction of inequalities after trade reforms in developing countries, while there is widespread empirical evidence of an increase in the skill premium in these countries. In this model the key mechanism is based on the impact of trade on the decision of technology adoption and its effect on the relative wage of skilled labor. There are several channels through which trade liberalization affects firms’ decisions. There is a very well-known "selection effect" in the domestic and export markets presented in Melitz (2003). The new channel introduced in this paper is related to the effects of trade policy on the extensive margin of technology adoption and on the skill intensity in a general equilibrium framework. After trade reforms the increase in export revenues raises the probability that the most productive exporters will adopt high technology, which in turn will require higher skilled workers. The final effect of trade policy in this model is the skill premium effect. Exporters producing with high technology will increase their relative demand of skilled labor, thereby enhancing the inequalities.

*I am grateful to Robert Boyer, Thierry Mayer and Xavier Ragot for their helpful comments. I would also like to thank Ivan Ledezma and Gregory Corcos.

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1 Introduction

In order to analyze the impact of trade liberalization on both the relative demand of skilled workers and the skill premium, we develop a trade model with heterogeneous firms introducing a fixed technology cost and different types of skilled labor. The main mechanism through which trade policy affects the relative demand of skilled labor is based on technology adoption. In developing countries, which are highly dependent on foreign technology, a reduction of trade barriers encourages the most productive firms to adopt modern technology which is skilled biased, thereby increasing the skill premium.

This framework allows us to explore several facts described in empirical international trade literature, namely: (1) Trade liberalization took place in most developing countries during the eighties and the nineties, through a reduction of tariffs, non tariffs barriers and trade agreements; (2) Firms within the same industry are heterogeneous; exporters are more productive than firms selling only on their domestic markets; (3) Along with trade reforms, there has been an increase in wage inequalities between skilled and unskilled labor associated with a higher proportion of skilled workers within industries; (4) In most developing countries, the adoption of foreign technology is also related to the boom of imported capital equipment and intermediate goods.\(^1\)

There are several empirical studies which find consistent evidence of firm heterogeneity within the same industry. These studies confirm the existence of superior characteristics of exporters in comparison with non-exporters. There are two possible explanations. On the one hand, there is empirical evidence supporting the idea of a self selection mechanism through which the most productive firms are those that became exporters. These studies demonstrate that before entering foreign markets, exporters were more productive, had larger revenues and were more capital and skill intensive than non exporters.\(^2\) The other possible explanation is learning by exporting. The decrease in export costs has enabled new firms to sell their goods on foreign

\(^1\)Graph 1, Graph 2, Table 1 and Table 2 (Appendix A) show evidence from Chile of these stylized facts.

\(^2\)Bernard and Jensen (2001) for the US, Clerides et al. (1998) for Colombia, Mexico and Morocco, and Aw et al. (1999) for Taiwan, concerning the causality of productivity differences between exporter and (only) domestic sellers, suggest an ex-ante self-selection process based on productivity rather than an increase in productivity after selling overseas.
markets, thereby taking advantage of knowledge spillovers from those very markets.³

Both explanations might be complementary: The most productive firms are those that are able to face fixed export costs; besides these firms can also improve their productivity through positive externalities from foreign markets. Alvarez and Lopez (2005) tested these two explanations using Chilean’s plants databases from 1990 to 1996. They found robust evidence of the presence of both mechanisms: self-selection and learning by exporting. In our model we will focus on the self selection mechanism. However, contrary to Melitz (2003) we consider that firms can adopt foreign technology to reduce their marginal costs. When fixed technology costs are higher than export costs, trade liberalization enables the most productive exporting firms to switch from formerly low technology production to higher technological standards, hence allowing those firms to increase their profitability.

Another important empirical finding is the existence of growing wage inequalities across firms in the same industry after trade reforms. There are also two explanations for this phenomenon. On the one hand, a reduction of import tariffs reduces the relative price of imported capital and intermediary goods, leading to the adoption of foreign technology and raising the relative demand of skilled labor. Empirical studies of developing countries find evidence of a positive correlation between skilled premium and the incorporation of imported technologies within all sectors after trade liberalization.⁴ When analyzing specifically differences across sectors, Verhoogen (2006) for Mexico and Mundler (2005) for Brazil find an increased in the skilled premium mainly in unskilled intensive sectors. On the other hand, the second explanation focuses on the role of foreign competition as regards final goods. Indeed, trade liberalization increases foreign competition and encourages the adoption of technology or skilled biased technical change.⁵


⁵Behrman, Birdsall and Szekely (2000) use a panel of data for 18 Latin American countries, Thoenig and Verdier (2003) for France, Goldberg and Pavnick (2003) for Colombia,
The mechanisms through which trade policy affects the relative demand of skilled labor and skill premium have been studied by the traditional Helpcko-Olhin-Samuelson (H-O-S) theory or more recent studies in line with the "New new trade theory". These frameworks were analyzed in detailed in paper one. We can distinguish two types of arguments to explain the raise in wage inequalities after trade liberalization in developed as well as developing countries. The main difference between these two explanations is based on whether they focus mainly on the effects of international trade or on technological changes.

The traditional framework in international trade, the H-O-S theory, details the impact of integration on both international specialization and the factor demand using the Stolper-Samuelson theorem. After trade reforms, a developed country, which is significantly more endowed with skilled labor, will specialize in skilled intensive goods and import unskilled intensive ones. In developed countries trade reforms will therefore raise the relative demand of skilled labor and the skill premium. It is the exact opposite in developing countries as the pattern of specialization might lead to an increase in the relative demand of unskilled labor, which in turn will trigger a raise in relative unskilled wages thereby reducing income inequalities. The main problem of the H-O-S model is that these forecasts are not consistent with the evidence shown by empirical studies for developing countries. In this sense, we can think of a puzzle arising from the H-O-S theory applied to developing countries, mainly to Latin American countries. Our model offers a possible explanation to this paradox: how we can explain a raise in the skill premium in countries where unskilled labor is abundant.

Bernard, Redding and Schott (2004) have developed a two sector model using the H-O-S framework and introducing firm heterogeneity in each sector. The main difference with our framework is that we focus on the relationship between trade, technology adoption decision and wage inequalities where the main mechanism to explain the raise in wage inequalities after trade reforms is based on the existence of a fixed cost of technology skilled biased. In their model, the level of skill required in a given sector is exogenously determined. On the contrary, we have developed a framework in which the level of skill required in firms is determined by their endogenous decision to adopt foreign technology. Besides, the Bernard, Redding and Mundler (2005) for Brazil: find that the raise in the skill premium was driven by skilled biased technological change induced by increasing foreign competition due to trade integration.
Schott model (2004) can not be applied to developing countries as it does not solve the main problem of the H-O-S framework described previously.\(^6\) The second type of model is based on skill-biased technological change (SBTC) statements. These models have mainly been developed by Acemoglu (2003) and by Thoenig and Verdier (2003). International trade brings on innovation and SBTC, thereby raising the relative demand for skilled labor and consequently, the skill premium. In Acemoglu’s model the mechanism through which trade liberalization generates SBTC is an increase in the relative price of skilled intensive tradable goods in developed countries. This leads to a raise in the demand of technologies used to produce these goods and encourages SBTC.\(^7\) Unlike Acemoglu (2003), Thoenig and Verdier (2003) developed a dynamic quality leader model where the main mechanism is related to technological spillovers generated by trade liberalization. Open trade induces knowledge diffusion and increases the possibilities of imitation, thus encouraging firms to adopt defensive innovation strategies to reinforce non replication measures. This strategy requires an increase of skill intensiveness in the production process, raising the relative skill demand and the skill premium.\(^8\) The key mechanism of this model is based on endogenous technological changes and innovation, while the model presented in this paper focuses on a different and complementary channel based on technology adoption to explain the relation between the increase in wage inequalities and trade policy.

Our model is also closed related to Yeaple (2005) who develops a trade model of homogeneous firms and heterogeneous skills. In Yeaple’s model, firm heterogeneity arises endogenously from the distribution of skill workers

\(^6\)Within the framework of international trade, there are some theoretical works which focus on outsourcing as the main mechanism to explain the raise in skill premium in both industrialized and developing countries. Due to outsourcing of industrialized economies, developing countries begin to expand activities that are more skill intensive than those previously done in those countries increasing relative demand of skilled labor and the skill premium. See Feenstra and Hanson (1996, 1997, 2003) for a detail explanation.

\(^7\)Under the assumption that prior to trade liberalization developing countries only had access to local technologies, which are less skill biased than those used in developed countries, trade integration induces developing countries to import high technologies raising the skill premium.

\(^8\)Trade integration leads to an increase in wage inequality not only in industrialized countries, but also in developing countries. During the transition process there are different regimes of specialization across countries and at the end there would be a technical upgrading in developing countries that increases the wage gap between skilled and unskilled labor.
and the firm’s choice between two types of technologies. Different types of workers have a comparative advantage based on skills in each type of technology. Trade reduces the relative fixed costs of high technology and thus, increases the share of labor working with high technology, hence inducing a rise in the skill premium. However, the skill premium has no impact on the reallocation of workers and on technology adoption decisions.

Unlike Yeaple’s model (2005), in our model firms are heterogeneous even before they start producing and each firm employs both skilled and unskilled workers. Trade liberalization leads technology adoption in unskilled intensive sectors raising skilled labor demand in these sectors. Under the assumption that skilled labor is complementary with high technology whereas unskilled labor is more easily substituted by this technology, our model explains the reasons for skill upgrades in unskilled intensive industries in developing countries. Another important difference from Yeaple’s model is that in this model we take into account the effects of the skill premium on firm’s decisions to produce, export and adopt modern technologies.

Bustos (2005) develops a partial equilibrium model based on Melitz (2003) and Yeaple (2005) to explain the skill enhancements triggered by the adoption of technology after trade reforms in developing countries. Since her framework is based on partial equilibrium Bustos does not take into account neither the entry-exit firm’s process, the reallocation of resources among firms nor the impact of relative wages on price indexes and on other aggregated variables. Using a panel database of Argentinean firms, she finds evidence of skill upgrades within these very firms. The main difference with her model is that we develop a general equilibrium model with symmetric countries considering the impact of the skill premium on aggregated variables and on the selection process. Contrary to Bustos, we consider the entry and exit process of firms into domestic and foreign markets. Our model enables us to analyze the impact of trade on the relative demand of skilled labor in a general equilibrium framework.

In order to characterize the differences between firms in the same industry we have introduced firm’s heterogeneity following Melitz (2003). As we have analyzed in the first paper one of Melitz’s main assumptions is that firms differ in terms of productivity, which is randomly drawn from a distribution function. Within the framework of monopolistic competition, the most productive firms set lower prices, benefit from higher demand, produce larger quantities, hire more workers and have higher profits. Another
assumption is the existence of fixed entry costs on the domestic market, a fixed production cost along with a both variable and fixed cost to enter foreign markets. The interaction of these two assumptions generates a selection process whereby only the most productive firms will survive trade liberalization, while the least productive ones are eliminated in the process.

This "selection mechanism" leads to changes in market shares of firms as well as resource reallocation processes towards the most productive firms. In Melitz’s model there are two channels behind this selection process. The first mechanism is based on foreign competition. After trade liberalization, domestic firms have to face an increasing competition from the most productive foreign exporters, causing a substantial reduction in market shares and profits in the domestic market. The least productive firms cannot survive this evolution. The second channel is related to the increase in expected profits of exporters. Trade liberalization intensifies foreign demand. In order to satisfy this demand, exporting firms raise their labor demand thereby increasing real wages. The appreciation of wages forces the least productive firms to exit the domestic market. Therefore, labor will be reallocated towards the most productive firms which boosts market shares. In the end there will be an increase in aggregate productivity induced by the two channels.

This framework is based on the assumption that labor is homogeneous, when introducing different types of skilled labor and differences between firms as regards skill intensity (endogenously determined), this mechanism might have the opposite effect. In this model, we extend Melitz’s (2003) framework by introducing two different types of workers (skilled and unskilled) and a fixed technology adoption cost to explain the growth of the skill premium within firms of the same industry. The main assumption is that technology is skilled biased and allows firms to reduce marginal production cost. The most productive firms will have enough domestic profits to cover this fixed technology cost, which will in turn decrease their per unit cost and increase their market shares.

In an open economy equilibrium there are two different cases depending on the relationship between fixed technology costs, fixed and variable trade costs and relative skill per unit costs. In the first case, technology costs are more expensive than trade costs. Therefore only the most

\footnote{There is a specific condition of partitioning of firms by export and technology status (See Equilibrium Conditions: case 1 and 2).}
productive exporters will be able to adopt high technology. In this case there are three types of firms: (1) the least productive ones, which produce with low technology and sell only in their domestic markets; (2) exporters producing with low technology; (3) the most productive firms producing with high technology and exporting on foreign markets. In the second case adopting high technology is relatively cheaper than exporting and only the most productive domestic firms producing with high technology are able to export. In the second case all exporters produce with high technology and there are two different types of firms selling only in the domestic market. At the equilibrium there are also three types of firms: (1) the least productive ones that produce with low technology and sell only in the domestic market; (2) domestic firms producing with high technology; (3) the most productive firms producing with high technology and exporting their goods on foreign market.

There are several ways through which trade liberalization affects the extensive margin of trade (the number of firms exporting), the extensive margin of technology adoption (the number of firms upgrading technology), the relative demand of skilled labor and the inequalities. The first one is the "foreign competition effect" detailed in Melitz (2003) as aforementioned. By this mechanism trade integration increases the number of most productive foreign exporters selling in the domestic market and generates a reduction of domestic profits and market shares for all domestic firms. This channel induces the exit of least productive firms and a reallocation of resources towards the most productive ones.

In the meantime trade liberalization increases export revenues allowing new firms to acquire the export status. This will be a second channel introduced by trade reforms called the "export selection effect". Contrary to Melitz (2003), in this model the increase of the expected export profits has an impact on the skill premium. This effect depends on the open economy equilibrium that we have previously detailed. In the first case an increase in export revenues raises the probability that the most productive exporters will adopt high skill biased technology hence increasing the extensive margin of technology adoption. These firms increase their relative demand of skilled labor raising the skill premium. In the second case, trade liberalization through the increase of foreign competition will reduce domestic market shares of firms producing with high technology in their domestic market. Despite the reduction of the extensive margin of technology, the raise in export market shares will also increase the relative demand of skilled labor for ex-
porting firms producing with high technology. As a result, in both cases the inequalities will raise.

Finally, there is a general equilibrium effect of skill premium on firms’ decisions. However, this is a second order effect induced by the increase in the extensive margin of technology. The raise in the skill premium has a different effect than the real wage appreciation in Melitz’s model. Due to the different proportions of skilled labor between firms, the least productive ones, which have survived foreign competition might very well benefit from the rise in skill premium contrary to the most productive ones. A raise in the skill premium means a reduction of the relative wage of unskilled labor. Since the least productive firms use low skill intensive technology they can substitute skilled labor by unskilled one after an appreciation of the skill premium more easily. The skilled labor will thus be reallocated in the most productive firms producing with high technology and exporting on foreign markets. However, as a result of the general equilibrium effect, these firms will suffer from the raise of the skill premium. Since the increase in the skill premium is a second order effect, the improvement of profitability due the increase of the expected export profits is higher than the appreciation of the skill premium. Consequently, in the first case the global impact of trade liberalization on both the extensive margin of trade and the extensive margin of technology will be positive. In the second case the total effect of trade on the extensive margin of trade is positive but it is negative however, for the extensive margin of technology. In both cases the final effect of trade on the amount of domestic firms is negative since the effect of foreign competition is higher than the skill premium effect.

Introducing skilled and unskilled labor and fixed technology adoption costs in the framework of the "New new trade theory" within heterogeneous firms enables us to explain the effects of trade on wage inequalities in developing countries. The main contribution of this paper to the existing literature is to develop a possible explanation of the H-O-S traditional theory puzzle for developing countries. We can explain why there is a raise in the skill premium in unskilled intensive sectors with a relatively high endowment of unskilled labor.

The rest of the paper is organized as follows. In Section 2 the set-up of the model is presented. Section 3 presents the main theoretical results of this model. Section 4 shows the empirical estimations. Section 5 concludes.
2 Setup of the model: Closed economy

2.1 Households Consumption

The representative household allocates consumption between two types of domestic goods: the ones produced with low technology \( (C_l) \) and those produced using more advanced and skill biased technology \( (C_h) \). Each variety of goods is produced by different firms with different levels of productivity \( (\varphi) \). Hence, \( \varphi_l^* \) represents the productivity of the marginal firm producing with low technology and \( \varphi_h^* \) corresponds to the productivity of the marginal firm producing with high technology, \( N \) represents the total number of varieties available.

Consumer’s preferences are represented by standard C.E.S. utility function \( (C) \)

\[
C = \left( \int_{\varphi_l^*}^{\varphi_l^*} C_l^{\varphi_l^*} \frac{1}{\varphi_l^*} di \right) \left( \int_{\varphi_h^*}^{\varphi_h^*} C_h^{\varphi_h^*} \frac{1}{\varphi_h^*} di \right)^{\frac{\varphi_l^*}{\varphi_l^*-1}}
\]

The elasticity of substitution \( \varphi \) between home and foreign goods is the same in both countries and \( \varphi > 1 \). The optimal relative demand functions are as follows:

\[
C_l = \left( \frac{P}{P_l} \right)^\varphi C \quad \quad \quad \quad C_h = \left( \frac{P}{P_h} \right)^\varphi C
\]

The price index that corresponds to this CES consumption function is:

\[
P = \left[ \int_{\varphi_l^*}^{\varphi_l^*} P_l^{1-\varphi_l} di + \int_{\varphi_h^*}^{\varphi_h^*} P_h^{1-\varphi_h} di \right]^{\frac{1}{1-\varphi}}
\]
2.2 Production

There is a continuum of firms, each one of them producing a different variety of goods, in monopolistic competition. Production requires two different types of labor: unskilled \((l_i)\) and skilled labor \((h_i)\). Both types are inelastically supplied. We have introduced firm’s heterogeneity following Melitz (2003), thus all firms have different productivity levels \((\varphi_i)\).

The production function is represented by a CES function given by:

\[
Y_i = \varphi_i ((a_h h_i)^\alpha + (l_i)^\alpha)^{\frac{1}{\alpha}} \Rightarrow Y_i = Y_l, Y_h
\]

\[a_h = \{1, s\} \quad s > 1\]

The coefficient "\(a_h\)" represents the efficiency of high technology complementary with skilled labor. If the firm has acquired new technology paying the fixed technology adoption cost, it will have \(a_h > 1\). Therefore, firms which have decided to upgrade technology will increase their efficiency in skilled labor. In this sense, high technology is skill biased. If this is not the case, the firm will produce with low technology, having \(a_h = 1\).

The elasticity of substitution is \(\sigma = \frac{1}{1-\alpha}\). We assume that skilled and unskilled labor are imperfect substitutes, hence \(0 < \alpha < 1\) and \(1 \leq \sigma \leq \infty\).

In a closed economy equilibrium, we can distinguish two groups of domestic firms. In each group there is a range of firms with different productivity levels. In the first group there are firms with low productivity levels which do not have enough profits to face the fixed technology adoption costs \((N_l)\). The second group is formed by the most productive firms, which have acquired new technology \((N_h)\). Therefore, there are two different kinds of domestic per unit costs depending on whether the firm has acquired new technology or not \((c_l, c_h)\), thereby determining two different domestic prices \((p_l, p_h)\), different revenues \((r_l, r_h)\) and profits \((\pi_l, \pi_h)\).
Table 1: Characteristics of firms in closed economy equilibrium

<table>
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<tr>
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<th>Low technology firms ((N_l))</th>
<th>High technology firms ((N_h))</th>
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<tbody>
<tr>
<td><strong>Prices ((p_l)) and per unit cost ((c_l))</strong></td>
<td>(p_l = \frac{\phi}{\phi - 1} \frac{c_l}{\varphi} )</td>
<td>(p_h = \frac{\phi}{\phi - 1} \frac{c_h}{\varphi} )</td>
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<td></td>
<td>(c_l = \left( (w_l)^{\alpha - 1} + (w_h)^{\alpha - 1} \right)^{\frac{1}{\alpha - 1}} )</td>
<td>(c_h = \left( (w_l)^{\alpha - 1} + \left( \frac{w_h}{w_a} \right)^{\alpha - 1} \right)^{\frac{1}{\alpha - 1}} )</td>
</tr>
<tr>
<td><strong>Revenues ((r_l)) and profits ((\pi_l))</strong></td>
<td>(r_l = \left( \frac{p_l}{\varphi} \right)^{\phi - 1} R )</td>
<td>(r_h = \left( \frac{p_h}{\varphi} \right)^{\phi - 1} R )</td>
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<tr>
<td></td>
<td>(\pi_l = \frac{r_l}{\varphi} - f )</td>
<td>(\pi_h = \frac{r_h}{\varphi} - f - \delta f_l )</td>
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</table>

Firms using high technology have to pay a fixed technology adoption cost \((f_t)\) but they will have a lower marginal cost since the skill efficiency "\(a_h > 1\)" reduces the per unit cost \((c_h)\). Indeed, \(c_l > c_h\). The wage of unskilled labor is represented by "\(w_l\)" and the one of skilled labor is "\(w_h\)".

There are two types of fixed costs in a closed economy. Firstly, all firms must pay a fixed production cost \((f)\) during all periods. Secondly, there is a sunk fixed technology adoption cost \((f_t)\), firms pay the amortized cost per period: \(\delta f_t\). Main assumptions are that the amortized technology fixed cost per period is higher than the production fixed cost and that all fixed costs are measured in units of capital. The aforementioned assumption is done to render the model tractable. We could also assume that fixed costs are paid with both kinds of labor which complicates the calculation. However, we obtained broadly the same results. Thus, the price of capital used to cover fixed costs is normalized to one.
2.3 The decision to exit or stay and produce

Before entering a market and knowing its productivity level, entrepreneurs calculate the net value of the firm \( v^E \) and compare its discounted expected profits with the fixed sunk entry costs \( f_E \) to decide whether to enter in the domestic market or not. Entrants draw there productivity "\( \varphi_i \)" from an exogenous distribution function \( g(\varphi_i) \) and a continuous cumulative distribution function \( G(\varphi_i) \) with support \( 0 \leq \varphi_i \leq \infty \). The firm will obtain its productivity after paying the sunk entry cost and when it has entered the market. Once the firm knows its productivity draw, it decides to produce or to exit and never produce. If the firm decides to enter and produce, it will have to pay a fixed production cost.

Except by the marginal firm, all other firms earn positive profits. Hence, the average profit level \( \bar{\pi} \) is positive. Like in Melitz (2003) \( \bar{\pi} \) is the present value of the average profit flows: \( \bar{\pi} = \sum_{t=0}^{\infty} (1 - \delta)^t \frac{1}{\pi} \) and \( v^E \) is the net value of entry given by\(^{10}\):

\[
v^E = (1 - G(\varphi^*_i)) \bar{\pi} - f_E = \frac{1 - G(\varphi^*_i)}{\delta} \bar{\pi} - f_E
\]

From the value of the firm we obtain the Free Entry Condition (FE), when the value of entry is equal to zero.

\[
v^E = 0 \quad \implies \bar{\pi} = \frac{\delta f_E}{1 - G(\varphi^*_i)} \quad \text{(FE)}
\]

"\( 1 - G(\varphi^*_i) \)" represents the probability that the productivity of a firm "\( \varphi_i \)" takes a value higher than "\( \varphi^*_i \)". The value "\( \varphi^*_i \)" is the productivity cutoff to produce in the domestic market. This threshold represents the minimum productivity value of a firm whose domestic profits are equal to the fixed production cost:

\[
\pi_l(\varphi^*_i) = 0 \quad \Rightarrow \quad r_l(\varphi^*_i) = f \phi
\]

\(^{10}\)The factor of discount is modeled following Melitz with a Poisson death shock probability \( \delta \). This death shock ensures that in each period there is a fraction \( \delta \) of firms, which do not survive and this fraction corresponds to the same quantity of firms that enter. At the equilibrium, there will consequently always be the same number of firms. The Aggregate Stability Condition ensures that \( N_E [1 - G(\varphi^*_i)] = \frac{\delta N}{\delta} \).

The entry sunk cost is also paid with capital.
This threshold is determined by the zero cutoff profit condition to produce in the domestic market. This condition establishes that the only firms, which decide to stay and produce are those that have enough operating domestic profits to pay the fixed production cost.

2.4 The decision to adopt high technology

After having received its productivity draw, if a firm decides to stay in the market and produce it can also decide to adopt high technology or not, depending on its profitability. Firms that adopt high technology will reduce their per unit cost \((c_h < c_l)\). Only a subset of the most productive firms will switch to high technology. They will be those firms whose increase in domestic sales revenues from adopting high technology allows them to pay the fixed technology costs. The zero cutoff profit condition to acquire the technology \((ZCP^T)\) is given by:

\[
\pi_h(\varphi^*_h) = \pi_l(\varphi^*_h)
\]

\[
[r_h(\varphi^*_h) - r_l(\varphi^*_h)] = \delta f_T \phi
\]

The productivity cutoff to acquire high technology is represented by "\(\varphi^*_h\)", this value is the minimum level of productivity of the marginal firm, which is able to adopt high technology. Combining \(\varphi^*_h\) with \(\varphi^*_l\), we obtain:

\[
\varphi^*_h = \varphi^*_l \left( \frac{\delta f_T}{f_T} \right)^{\frac{\alpha-1}{\theta-1}} \left[ \left( \frac{c_h}{c_l} \right)^{\frac{1-\phi}{1-\theta}} - 1 \right]^{\frac{1}{\theta-\phi}} \quad ZCP^T
\]

The relative per unit cost of skilled labor \(\left( \frac{c_h}{c_l} \right)\) is an increasing function of the skilled premium \(\left( \omega = \frac{w_h}{w_l} \right)\) and it is determined by:

\[
\left( \frac{c_h}{c_l} \right) = \left( \frac{\omega^{\frac{\alpha}{1-\alpha}} + 1}{\omega^{\frac{\alpha}{1-\alpha}} + (a_h)^{\frac{1}{1-\alpha}}} \right)^{\frac{1-\alpha}{\alpha}}
\]

\[
\frac{\partial c_h}{\partial \omega} > 0 \quad \text{since} \quad a_h > 1
\]
To ensure that $\varphi^*_h > \varphi^*_l$, we have to assume that the amortized value of the fixed technology cost is much higher than the fixed production cost. More specifically in order to define two groups of firms, those producing with low technology and those adopting high technology, the partitioning condition which sustains the closed economy equilibrium is given by:

$$\frac{\delta f}{\left(\frac{c_h}{c_l}\right)^{1-\phi} - 1} > f$$

### 2.5 Labor demand and skill premium

The global demand for unskilled and skilled labor is determined by aggregated firm’s demand for unskilled and skilled, while taking into account firms producing in the domestic market with low and high technology (See appendix B.1).

\begin{align*}
(1) \quad L &= L_l + L_h = \int_{\varphi_l}^{\varphi_h^*} L(\varphi_i) d\varphi_i + \int_{\varphi_l}^{N_l} L(\varphi_i) d\varphi_i \\
(2) \quad H &= H_l + H_h = \int_{\varphi_l}^{\varphi_h^*} h(\varphi_i) d\varphi_i + \int_{\varphi_l}^{N_l} h(\varphi_i) d\varphi_i \\
&= \frac{H_l + H_h}{L_l + L_h} \Rightarrow \omega = g(a_h, f, f_t, H^aL^a)
\end{align*}

The skill premium ($\omega$) is determined by the equality between relative demand and supply for skilled workers. The skilled premium is a function of the relative supply of skilled labor ($\frac{H^a}{L^a}$), the skill efficiency parameter ($a_h$), the number of firms producing with low ($N_l$) and high technology ($N_h$) as well as the relative average productivity of each type of firms ($\frac{\overline{L^a}}{\overline{L}}$). In order to solve the model we assume a pareto distribution of productivity draws, which is widely used in the literature (See Appendix B.2). This assumption allows us to solve the average productivity levels and the number of firms. Under this assumption, the skill premium is a function of the production and technology fixed costs, the skill efficiency parameter and the relative skilled labor supply.

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\footnote{The cutoff productivity level will be cancelled out in the relative demand of skilled labor}
2.6 Determination of capital demand

Capital is required to pay fixed entry costs as well as production and technology adoption costs. Capital is supplied inelastically under the assumption that capital markets operate independently from labor markets. If we assume that fixed costs are paid with skilled and unskilled labor, this will complicate the calculation and the skilled premium will be a function of the production productivity cutoff. The Capital Market Clearing condition is:

\[ K = N_f f + N_h (f + \delta f_t) + N_E \delta f_E \]

2.7 Global Accounting Condition and number of firms

The global accounting condition establishes that the sum of unskilled and skilled revenues, the capital used to pay fixed costs (the price of capital is normalized to one) is equal to aggregated revenue of the economy \((R)\).

\[ w_h H + w_l L + K = R \]

By introducing the use of aggregated profits to obtain aggregated revenues in this condition, we obtain the total number of firms.

\[ N = \frac{w_h H + w_l L + K}{\overline{\frac{\xi}{\overline{\xi} + f + \delta f_t} \rho_h}} \]

The probability of having a productivity draw superior to the technology cutoff conditional on having entered the market is represented by: \( \rho_h = \frac{1 - G(\tilde{\varphi}_h)}{1 - G(\tilde{\varphi}_l)} \)

2.8 Closed Economy Equilibrium conditions

This subsection summarizes the main closed economy equilibrium conditions of the model. We get an analytical equilibrium solution for the production and the technological cutoff. We assume a pareto distribution of productivity draws to obtain closed and tractable solutions to the model (see Appendix B.2 and B.3).

Using this distribution we solve for the average productivity level of firms producing with low technology (\( \tilde{\varphi}_l \)) and with high technology (\( \tilde{\varphi}_h \)) (see Appendix B.2).
Free entry condition (FE), equation 1.A, implies a relation between average profit and the cutoff productivity level, while Zero Cutoff Profit (ZCP) condition, equation 2.A, also determines a relation between average profits and the productivity level of the marginal firm. The equality between these two conditions determines the equilibrium level of \( \varphi^*_l \). This cutoff then determines the level of the technological cutoff using the Zero Cutoff Profits Condition to adopt technology (ZCP\(^T\)), equation 3.A.

(1.A) FE: \[ \bar{\pi} = \frac{\delta f_E}{(1 - C(\varphi^*_l))} \]

(2.A) ZCP: \[ \bar{\pi} = \pi_l(\varphi^*_l) + \rho_h \pi_h(\varphi^*_h) \]

The equilibrium value of the production cutoff is a function of fixed entry, production and technology costs and the skill premium.

\[ \text{ZCP=FE} \quad \Rightarrow \quad \varphi^*_l = f(a_h, \omega, f_E, f, f_t) \]

This productivity cutoff is a decreasing function of the relative skill per unit costs and hence of the skill premium. In Appendix B.3 we demonstrate: \( \frac{\partial \varphi^*_l}{\partial \frac{c_h}{c_l}} < 0 \).

This implies that a raise in the relative skill per unit cost \( \left( \frac{c_h}{c_l} \right) \), due to an increase in the skill premium \( \left( \frac{\partial \omega}{\partial \varphi^*_l} > 0 \right) \), will reduce the production cutoff. Hence, an increase of the skill premium will benefit the least productive firms producing with low technology unskilled biased. Actually, a raise in the skill premium means a reduction of the wage of unskilled workers relative to skilled ones. Therefore, firms producing with unskilled intensive technology will replace skilled with unskilled labor if there is a raise of the skill premium.

Using the equilibrium value of the production cutoff and ZCP\(^T\) we obtain the equilibrium value of the technology productivity cutoff:

(3.A) ZCP\(^T\): \[ \varphi^*_h = \varphi^*_l \left( \frac{\delta f_h}{f} \right)^{\frac{1}{\sigma - 1}} \left[ \left( \frac{c_h}{c_l} \right)^{1-\phi} - 1 \right]^{\frac{1}{1-\sigma}} \]

As already discussed, the skill premium is determined by the labor market condition and is a function of the relative supply of skilled labor, the skill efficiency parameter and the fixed costs.
\[
(4.A) \text{LMC: } \left( \frac{H}{\ell} \right)^{S} = \left( \frac{H}{\ell} \right)^{D} = \frac{H_{l} + H_{h}}{I_{x} + L_{h}} \Rightarrow \omega = g(a_{h}, f, f_{t}, H^{s}L^{s})
\]

\[
(5.A): \quad N = \frac{w_{h}H + w_{l}L + K}{(\pi + [f + \delta f_{t}]\rho_{h})\phi}
\]

The number of firms producing with low technology \(N_{l} = (1 - \rho_{h})N\), those producing with high technology \(N_{h} = \rho_{h}N\) and the number of new entrants \(N_{E} = \frac{\delta N}{1 - G(f_{t})}\) are determined by the probabilities which depend on productivity cutoff levels and the total number of firms.

\[
(6) \text{KMC: } K = N_{l}f + N_{h}(f + \delta f_{t}) + N_{E}\delta f_{E}
\]

2.9 Setup of the model: Open economy

Following Melitz (2003) we assume that countries are symmetric in the open economy equilibrium. Therefore, imports of foreign country are equal to the exports of home country. Besides, aggregate variables (prices, consumption and revenues) are equivalent in both countries. This is the reason why there are no differences in the notation of variables of home and foreign countries.

In an open economy equilibrium there are two different cases depending on the relation between fixed technology cost \((f_{t})\), fixed \(f_{x}\) and variable trade costs \((\tau)\) and the relative skill per unit cost \((\frac{\rho_{h}}{G})\). The first case represents an economy where fixed technology costs are substantially higher than fixed and variable trade costs. In these conditions, only the most productive exporters will be able to adopt high technology. All firms, which adopt technology, sell on foreign markets, but not all exporters will be able to switch to high technology. It will depend on their productivity. In this case there are three groups of firms and in each group there is a range of heterogeneous firms. The first group of firms is composed by those selling only in their domestic market \((N_{dt})\). These firms are the least productive ones producing with low technology. The second group is composed by firms characterized by a level of productivity high enough to profitably enter the foreign market. Their productivity however is not sufficient to generate enough profits to pay the fixed technology cost \((N_{dx})\). These are exporting firms producing with low technology. Finally, there are the most productive
firms which are able to adopt high technology ($N_{xh}$). These firms produce and export to the foreign market using high, skill biased technology.

In the second case, fixed and variable trade costs are more expensive than the fixed technology cost. In this case adopting high technology is therefore relatively cheaper than exporting. Only the most productive domestic firms producing with high technology are able to export. Unlike in the first case, no firm will ever export without having adopted high technology. All exporters produce with high technology and there are two different types of firms selling only in the domestic market. At the equilibrium there are also three types of firms. As in the first case, the first group of firms is also formed by the least productive firms producing with low technology and selling only in their domestic market ($N_{dl}$). But in this case, the second group of firms will differ from the first case. This group is composed by firms producing with high technology and selling only in the domestic market ($N_{dh}$). These firms are more productive than those in the first group and therefore, they are able to adopt high technology but they can not face the fixed export costs. Similarly to case one, the third group is formed by the most productive firms producing with high technology and exporting on the foreign market ($N_{xh}$).
Table 2: The characteristics of firms in the two cases

Case 1: High Technological Costs

\[ \varphi_{xh} > \varphi_{xl} > \varphi_{dl} \]

1. Non exporters - Low Technology (\(N_{dl}\))

\[ \pi_{dl} = \frac{r_{dl}}{\phi} - f \]
\[ r_{dl} = \left( \frac{P_{dl}}{\tilde{P}_{dl}} \right)^{\phi-1} R \]
\[ p_{dl} = \frac{\phi}{\phi-1} \frac{Q}{\tilde{v}_{l}} \]

2. Exporters - Low Technology (\(N_{xl}\))

\[ \pi_{dl} + \pi_{xl} = \frac{r_{dl}}{\phi} \left[ 1 + \left( 1 + \tau \right)^{1-\phi} \right] - f - \delta f_{x} \]
\[ r_{xl} = \left( \frac{P_{xl}}{\tilde{P}_{xl}} \right)^{\phi-1} R \]
\[ r_{dl} + r_{xl} = r_{dl} \left[ 1 + (1 + \tau)^{1-\phi} \right] \]

3. Exporters - High Technology (\(N_{xh}\))

\[ \pi_{dh} + \pi_{xh} = \frac{r_{dh}}{\phi} \left[ 1 + \left( 1 + \tau \right)^{1-\phi} \right] - f - \delta f_{x} - \delta f_{t} \]
\[ r_{xh} = \left( \frac{P_{xh}}{\tilde{P}_{xh}} \right)^{\phi-1} R \]
\[ r_{dh} + r_{xh} = r_{dh} \left[ 1 + (1 + \tau)^{1-\phi} \right] \]

Case 2: High Trade Costs

\[ \varphi_{xh} > \varphi_{dh} > \varphi_{dl} \]

1. Non exporters - Low Technology (\(N_{dl}\))

\[ \pi_{dl} = \frac{r_{dl}}{\phi} - f \]
\[ r_{dl} = \left( \frac{P_{dl}}{\tilde{P}_{dl}} \right)^{\phi-1} R \]
\[ p_{dl} = \frac{\phi}{\phi-1} \frac{Q}{\tilde{v}_{l}} \]

2. Exporters - High Technology (\(N_{xh}\))

\[ \pi_{dh} + \pi_{xh} = \frac{r_{dh}}{\phi} \left[ 1 + \left( 1 + \tau \right)^{1-\phi} \right] - f - \delta f_{x} - \delta f_{t} \]
\[ r_{xh} = \left( \frac{P_{xh}}{\tilde{P}_{xh}} \right)^{\phi-1} R \]
\[ r_{dh} + r_{xh} = r_{dh} \left[ 1 + (1 + \tau)^{1-\phi} \right] \]
3 Open economy: Extremely High Technological Costs (case 1)

3.1 Case 1: Households Consumption

The representative household allocates consumption between domestic and foreign goods. Since countries are symmetric there is no specific notation for foreign goods.

Goods produced by domestic firms can be traded or not and produced with low or high technology depending on the firm’s profitability. The representative household allocates consumption between domestic goods produced with low technology \( (C_{dl}) \) and two different types of foreign imported goods produced with low \( (C_{xL}) \) and high technology \( (C_{xH}) \). Consumer’s preferences are represented by the standard C.E.S. utility function \( (C) \) between home and foreign goods.

Each variety of goods is produced by different firms with different levels of productivity \( (\varphi_i) \). Hence, \( \varphi_{dl} \), \( \varphi_{xL} \) and \( \varphi_{xH} \), represent the productivity levels of the marginal firms producing with low technology and selling only in domestic markets, producing with low technology but selling in foreign markets and producing with high technology to the foreign markets, respectively. \( N \) represents the total number of varieties available.

\[
C = \left( \int_{\varphi_{dl}}^{\varphi_{xL}} C_{dl}^{\phi-1} \, di + \int_{\varphi_{xL}}^{\varphi_{xH}} C_{xL}^{\phi-1} \, di + \int_{\varphi_{xH}}^{\phi R} C_{xH}^{\phi-1} \, di \right)^{\frac{1}{\phi-1}}
\]

3.2 Case 1: Production

Similarly to the closed economy equilibrium, the production function using skilled and unskilled labor is represented by a CES function given by :
\[ Y_i = \varphi_i((a_h h_i)^{\alpha} + (l_i)^{\alpha})^{\frac{1}{\alpha}} \Rightarrow Y_i = Y_{dl}, Y_{xl}, Y_{xh} \]

In this case, only the most productive exporters will be able to switch to high technology. Since high technology is skilled biased, firms which acquire this technology will have a higher efficiency in skilled labor \((a_h > 1)\) and a lower marginal cost \((c_h < c_l)\). As a consequence, the acquisition of high technology enables the most productive exporting firms to reduce even more their marginal cost.

The first column in Table 2 summarizes firms’ main characteristics: their revenues, profits and prices. More productive firms have lower per unit costs and are thereby able to set lower prices and have higher revenues as well as superior profits.

### 3.3 Case 1: Export decision

Similarly to Melitz (2003), the tradability condition implies that only firms with operating profits that counterweigh the amortized fixed export cost per period \((\delta f_{x})\) will be able to export. The zero cutoff profit condition to enter the export market (ZCP\(^X\)) is given by:

\[ \pi_{x}(\varphi_{x}^{*}) = 0 \Rightarrow r_{x} = \delta f_{x} \phi \quad \text{ZCP}\(^X\) \]

The export productivity cutoff is represented by "\(\varphi_{x}^{*}\)". This value corresponds to the productivity level of the marginal firm which is able to enter the foreign market.

The value of \(\varphi^{*}_{x}\) as a function of \(\varphi^{*}_{dl}\) (the same as Melitz (2003)) is given by:

\[ \frac{r_{x}(\varphi_{x})}{r_{x}(\varphi_{dl})} = \frac{\delta f_{x}\phi}{f_0} \Rightarrow \varphi^{*}_{x} = \varphi^{*}_{dl} \left( \frac{\delta f_{x}}{f_0} \right)^{\frac{1}{\sigma - 1}} (1 + \tau) \]
3.4 Case 1: The decision to adopt High Technology

After having entered the export market firms can also decide to adopt high technology or not depending on its profitability. Since in this case the fixed technology costs are higher than trade costs, a firm will never find it profitable to switch to high technology and decide not to export. Only a subset of exporters will switch to high technology. They will be those exporters whose increase in domestic and export sales revenues from adopting high technology allows them to pay the fixed technology costs. The zero cutoff profit condition to acquire the technology is given by:

$$\pi_{dh}(\varphi_{xh}) + \pi_{xh}(\varphi_{xh}) = \pi_{xl}(\varphi_{xh}) + \pi_{xh}(\varphi_{xh})$$

$$ZCP^{XH}$$

$$[r_{dh}(\varphi_{xh}) + r_{xh}(\varphi_{xh})] - [r_{xl}(\varphi_{xh}) + r_{xh}(\varphi_{xh})] = \delta f_x \phi$$

The productivity cutoff to acquire high technology is represented by \(\varphi_{xh}^*\). The value of \(\varphi_{xh}^*\) as a function of \(\varphi_{xl}^*\) is:

$$\varphi_{xh} = \varphi_{xl} \left( \frac{\delta f_x}{f} \right)^{\frac{1}{\phi - 1}} \left[ \left( \frac{c_h}{c_l} \right)^{-\phi} - 1 \right] \left[ 1 + (1 + \tau)^{1-\phi} \right]^{\frac{1}{1-\phi}}$$

In this case, the specific partitioning condition of firms by export and technology status depends on a specific relation between fixed production costs, technology acquisition costs, trade costs and relative per unit cost of skilled labor. The parameter condition which ensures that \(\varphi_{xh}^* > \varphi_{xl}^* > \varphi_{xl}^*\) is:

$$\frac{\delta f_x}{[1+(1+\tau)^{1-\phi}][\left( \frac{c_h}{c_l} \right)^{1-\phi} - 1]} > (1 + \tau)^{\phi - 1} \delta f_x > f$$

This condition establishes that adopting high technology is more expensive than exporting and thereby sustains that only the most productive exporters are able to upgrade technology.
3.5 Case 1: Open Economy Equilibrium conditions

This subsection summarizes the main open equilibrium conditions of the case 1. We have one more equation and one more variable than in closed economy since we introduce the export tradability condition. As in the closed economy equilibrium, we get an analytical equilibrium solution for the production, the technological and the export cutoffs using a pareto distribution of productivity draws (See Appendix C.2 and C.3).

The free entry condition (1.B.) remains unchanged. In the zero cutoff profit condition (2.B.) of the open economy equilibrium, we have to take into account the average profits of exporters producing with low and high technology. The equilibrium level of the productivity cutoff is determined by the free entry and the new zero cutoff profit condition, just as in closed economy equilibrium. (See Appendix C.3)

\[
\begin{align*}
(1.B) \text{FE:} & \quad \bar{\pi} = \frac{\delta_f}{(1-G(\varphi^*_d))} \\
(2.B) \text{ZCP:} & \quad \bar{\pi} = \pi_{dl}(\varphi_{dl})\rho_{dl} + \rho_{xl}[\pi_{xl}(\varphi_{xl}) + \pi_{xh}(\varphi_{xh})] + \rho_{xl} \pi_{dh}(\varphi_{xh}) + \rho_{xl} \pi_{xh}(\varphi_{xh}) \\
\rho_{dl} &= 1 - \frac{1-G(\varphi^*_d)}{1-G(\varphi^*_d)} \\
\rho_{xl} &= \frac{1-G(\varphi^*_d)}{1-G(\varphi^*_d)} - \frac{1-G(\varphi^*_h)}{1-G(\varphi^*_d)} \\
\rho_{xh} &= \frac{1-G(\varphi^*_h)}{1-G(\varphi^*_d)} \\
\end{align*}
\]

The variables \(\rho_{dl}, \rho_{xl}\) and \(\rho_{xh}\) represent the probabilities to enter the domestic market, to export and to adopt high technology conditional on the survival of firms.

\[
\text{ZCP=FE} \Rightarrow \quad \varphi^*_d = f(a_h, f_E, f, f_l, \omega) \\
(3.B) \text{ZCP}^{XL} : \quad \varphi^*_x = \varphi^*_d \left(\frac{\delta f}{T}\right)^{\frac{1}{\varphi - 1}} (1 + \tau) \\
(4.B) \text{ZPC}^{XH} : \quad \varphi^*_x = \varphi^*_d \left(\frac{\delta f}{T}\right)^{\frac{1}{\varphi - 1}} \left[\left(\frac{c_h}{c_l}\right)^{1-\phi} - 1\right] \left[1 + (1 + \tau)^{1-\phi}\right]^{\frac{1}{1-\phi}}
\]

The labor market (5.A.), the global accounting condition (6.A.) and the capital market as well as clearing conditions (7.A.) have to take into account
the demand of skilled and unskilled labor and of capital to pay export and technology fixed costs of firms exporting on the foreign market with low and high technology (See Appendix C.1).

The skill premium is determined by the relative skilled labor demand and supply as a function of fixed production, technology costs as well as fixed and variable trade costs. Under the specific partitioning condition of case 1, which ensures that \( \varphi_{dh}^* > \varphi_{dt}^* > \varphi_{dh}^* \); the skill premium is an decreasing function of tariffs (we show and explain this result in section 4).

\[
(5.B) \text{LMC: } \left( \frac{H}{L} \right)^S = \frac{H_{dl} + H_{xt} + H_{xh}}{L_{dl} + L_{xt} + L_{xh}} \quad \Rightarrow \quad \omega = g(a_h, f, f_t, f_x, \tau)
\]

\[
(6.B) \quad N = \frac{w_h H + w_l L + K}{\beta + f + (f + \delta f_x) \rho_x + (f + \delta f_x + \delta f_t) \rho_x h \phi}
\]

\[
(7.B) \quad K = N_{dl} f + N_{dt} (f + \delta f_x) + N_{xh} (f + \delta f_x + \delta f_t) + N_E f_E
\]

3.6 Open economy: Extremely High Trade Costs (Case 2)
3.7 Case 2: Households Consumption

In case 2, The representative household allocates consumption between two different types of domestic goods and one type of foreign imported goods \((C_{xh})\). There are domestic goods produced with low technology \((C_{dl})\) and those produced using more advanced technology \((C_{dh})\). The following C.E.S. utility function \((C)\) represents Consumer’s preferences:

\[
C = \begin{pmatrix}
\int_{\varphi_{dl}^*}^{\varphi_{dh}^*} \frac{a_{i0} - 1}{C_{dl}^\phi} \, di + \int_{\varphi_{dh}^*}^{\varphi_{dt}^*} \frac{a_{i0} - 1}{C_{dh}^\phi} \, di + \int_{\varphi_{dt}^*}^{\varphi_{xh}^*} \frac{a_{i0} - 1}{C_{xh}^\phi} \, di \\
\text{Low technology} & \text{High technology} & \text{High technology} \\
\text{Non traded goods} & \text{Traded goods} & \text{Traded goods}
\end{pmatrix}
\]
3.8 Case 2: Production

As in the previous case the production function is represented by \( Y_i = \varphi_i ((a_i h_i)^{\alpha} + (l_i)^{\alpha})^{1/\alpha} \), where there are firms producing for the domestic market with low (\( Y_i = Y_{dl} \)) and with high technology (\( Y_i = Y_{dh} \)) and all exporters producing with high technology (\( Y_i = Y_{xh} \)).

In this case, more firms will be able to adopt high technology since its cost is lower than the trade costs. The adoption of high technology allows the most productive non exporters as well as all exporting firms to reduce their marginal cost by an even greater margin. The second column in Table 2 (page 20) summarizes the revenues, profits and prices of firms producing in this specific case.

Since fixed technology costs are lower than trade costs, the technology adoption condition is exactly the same as in the case of a closed economy equilibrium (section 2.4). Indeed, in the next section, we will only analyze the decision to export.

3.9 Case 2: Export Decision

After more productive firms among producers have adopted high technology, the most productive firms among them will be able also to enter the foreign market. The tradability condition in this case is given by:

\[
\pi_{xh}(\varphi_{xh}) = 0 \quad \Rightarrow \quad r_{xh} = \delta f_x \phi \quad ZCP^{X}
\]

The export productivity cutoff is represented by "\( \varphi_{xh}^{*} \)." The value of the export cutoff "\( \varphi_{xh}^{*} \)" as a function of the productivity cutoff "\( \varphi_{dl}^{*} \)"

\[
\frac{r_{xh}(\varphi_{xh}^{*})}{r_{dl}(\varphi_{dl}^{*})} = \frac{\delta f_x \phi}{f_x} \quad \Rightarrow \quad \varphi_{xh} = \varphi_{dl}^{*} \left( \frac{\delta f_x}{f_x} \right)^{\frac{1}{\phi-1}} \left( \frac{c_h}{c_l} \right) (1 + \tau)
\]

In this case, in order to ensure \( \varphi_{xh}^{*} > \varphi_{dl}^{*} > \varphi_{dl}^{*} \), we assume that fixed and variable trade costs are high enough to generate this partitioning condition:

\[
f_x (1 + \tau)^{\phi - 1} \left( \frac{c_h}{c_l} \right)^{\phi - 1} > \frac{f}{\left( \frac{c_h}{c_l} \right)^{1-\phi} - 1} > f
\]
3.10 Case 2: Open Economy Equilibrium conditions

(1.C) FE: \[ \bar{\pi} = \frac{\delta f_E}{1 - G(\varphi_{dt}^*)} \]

(2.C) ZCP: \[ \bar{\pi} = \rho_{dt} \pi_{dt}(\varphi_{dt}) + \rho_{dh} \pi_{dh}(\varphi_{dh}) + \rho_{xh} [\pi_{dh}(\varphi_{xh}) + \pi_{xh}(\varphi_{xh})] \]

\[ \rho_{dt} = 1 - \frac{1 - G(\varphi_{dt}^*)}{1 - G(\varphi_{dl}^*)} \quad \rho_{dh} = \frac{1 - G(\varphi_{dh}^*)}{1 - G(\varphi_{dl}^*)} - \frac{1 - G(\varphi_{xh}^*)}{1 - G(\varphi_{dl}^*)} \quad \rho_{xt} = \frac{1 - G(\varphi_{xh}^*)}{1 - G(\varphi_{dl}^*)} \]

FE=ZCP \Rightarrow \varphi_{dt}^* = f(a_h, f_E, f, f_t, \omega)

(3.C) ZCP\textsuperscript{T}: \[ \varphi_{dh}^* = \varphi_{dt}^* \left( \frac{\delta f}{f} \right)^{\frac{1}{\phi - 1}} \left[ \frac{c_h}{c_{\ell}} \right]^{-\phi} - 1 \]

(4.C) ZCP\textsuperscript{XH}: \[ \varphi_{xh} = \varphi_{dt}^* \left( \frac{\delta f}{f} \right)^{\frac{1}{\phi - 1}} \left( \frac{c_h}{c_{\ell}} \right) (1 + \tau) \]

(5.C) LMC \[ \left( \frac{H}{F} \right)^S = \left( \frac{H}{F} \right)^D = \frac{H_{dt} + H_{dh} + H_{xh}}{L_{dt} + L_{dh} + L_{xh}} \Rightarrow \omega = g(a_h, f, f_t, f_x, \tau) \]

(6.C) \[ N = \frac{w_h H + w_{\ell} L + K}{[\bar{\pi} + f + (f + \delta f_t)\rho_{xh} + (f + \delta f_{\ell} + \delta f_E)\rho_{xh}] \phi} \]

(7.C) KMC: \[ K = N_{dt} f + N_{dh} (f + \delta f_t) + N_{xh} (f + \delta f_x + \delta f_t) + N_E f_E \]

Appendix C.4 details the labor market condition for case 2, Appendix C.5 shows the parametrization of the productivity draws assuming a pareto distribution and C.6 the equilibrium cutoff.
4 Results of the model

4.1 The impact of Trade Liberalization: Extremely High Technological Costs (Case 1)

In this section, we will focus on the impact of trade liberalization via tariffs reductions on firms’ decisions in the case 1 (higher fixed technology costs than trade costs). The reduction of tariffs affects both the extensive margin of trade (the number of exporters) and the extensive margin of technology adoption (the number of firms producing with high technology).

There are several ways through which changes in tariffs affect firms’ decisions to produce, export and adopt modern technology. The first channel is the "foreign competition effect" detailed in Melitz (2003). The entry of most productive foreign exporters in the domestic market after trade liberalization reduces the market shares of all firms selling in the domestic market. The reduction of domestic profits induces the exit of the least productive domestic firms that can no longer afford to pay the fixed production cost.

At the same time, there is a second channel based on the export selection effect. Trade reforms increase the expected export profits and have a positive impact on the extensive margin of trade. In this sense, a reduction of tariffs allows new firms to enter the foreign market and increases export revenues of new and incumbent exporters. This increase in export profitability creates incentives to adopt new and high technology.

These two first mechanisms are precisely the selection effect in the domestic and in the foreign markets developed by Melitz (2003). The contribution of this model aims at introducing yet another channel based on the effects of trade on the extensive margin of technology adoption and its impact on the skill premium. The increase in revenues of all exporting firms allows the most productive exporters, using low technology before trade reform, to switch to the high technology. Since there is an increase in the number of firms using high technology, the latter being skill biased, there will be a raise in the relative demand of skilled labor.

The last channel of trade liberalization is "the skill premium effect". The raise in the relative demand of skilled labor increases inequalities even if the country has a high endowment of unskilled labor. In the general equilibrium the raise of the skill premium has a differentiated impact on
firms' decisions depending on the intensity of skilled and unskilled labor of each firm. However this is a second order effect stemming from the raise of the extensive margin of technology. In this model, the appreciation of the skill premium does not have the same impact as the raise of real wages in Melitz's model which reinforces the exit process of the least productive domestic firms. Since these firms produce with low, unskilled intensive technology, they will benefit from a reduction of the relative wage of unskilled labor (the raise of the skill premium) by replacing skilled with unskilled labor. Therefore, within the least productive firms those which were able to survive from foreign competition will benefit from the skill premium appreciation in comparison with the most productive, skilled intensive firms.

Table 3 summarizes the main results of the effects of a tariff reduction on firms' decisions for the first case. The equilibrium production cutoff depends on the skill premium and this variable is determined in the labor market equilibrium (equation 4.B.) by the relative skilled labor demand and supply. The skill premium is a function of variable trade costs. Therefore, to study the impact of a tariff reduction on the productivity cutoff we run simulations of the cutoff function under the partitioning condition of case 1. Graph 1 and 2 (Appendix D) detail these simulation results. Graph 3 shows (Appendix D) the simulation results of the impact of a tariff reduction on the aggregated relative demand of skilled labor and on the skill premium. These results show that the skill premium is an increasing function of tariffs.

Two opposite forces affect both the production and the technology cutoff: on the one hand, "foreign competition" and "export selection effect" and on the other hand, the skill premium effect. Under the specific partitioning condition of firms by export and technology status, the effects of trade reforms are rather unambiguous. Since the increase of the skill premium is a second order effect derived from the other two effects, the global effect of trade reforms on the production cutoff is negative (Graph 1). The effect of foreign competition predominates over the skill premium. Therefore, there will be a raise in the average productivity of the country after trade reforms. The impact of tariffs is unambiguous and positive for the extensive margin of trade. New unskilled intensive firms find it profitable to start exporting. Finally, the last effect of trade liberalization on the extensive margin of technology is also positive. Under the partitioning condition of firms of case 1, the raise in export profitability compensates the appreciation of the skill premium (Graph 2). The most productive exporters using low technology before trade reforms will find it profitable to upgrade technology while
taking into account the raise of the skill premium.

Table 3: The impact of variable trade cost (τ) in case 1

<table>
<thead>
<tr>
<th>Domestic cutoff φ^*_{dl}</th>
<th>Export cutoff φ^*_{xl}</th>
<th>Technology cutoff φ^*_{xh}</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \frac{\partial \phi^*_{dl}}{\partial \tau} = F.C + \omega \text{ effect} )</td>
<td>( \frac{\partial \phi^*_{xl}}{\partial \tau} = X.S + \omega \text{ effect} &gt; 0 )</td>
<td>( \frac{\partial \phi^*_{xh}}{\partial \tau} = X.S + \omega \text{ effect} )</td>
</tr>
<tr>
<td>(A) Foreign Competition (FC) (-)</td>
<td>(C) Export selection effect (X.S) (+)</td>
<td>(D) Extensive margin Tech (X.S) (+)</td>
</tr>
<tr>
<td>( \frac{\partial \phi^*_{dl}}{\partial \left( \frac{\tau}{\tau} \right)} &lt; 0 \Rightarrow \uparrow \left( \frac{\tau}{\tau} \right) \uparrow \omega )</td>
<td>( \downarrow \frac{1}{\omega} ) Benefits unskilled intensive firms</td>
<td>( \uparrow \omega ) hurts most productive firms skilled intensive</td>
</tr>
<tr>
<td>Final effect on φ^*_{dl}</td>
<td>Final effect on φ^*_{xl}</td>
<td>Final effect on φ^*_{xh}</td>
</tr>
<tr>
<td>( \frac{\partial \phi^*_{dl}}{\partial \left( \frac{\tau}{\tau} \right)} &lt; 0 )</td>
<td>( \frac{\partial \phi^*_{xl}}{\partial \left( \frac{\tau}{\tau} \right)} &lt; 0 )</td>
<td>( \frac{\partial \phi^*_{xh}}{\partial \left( \frac{\tau}{\tau} \right)} &gt; 0 )</td>
</tr>
</tbody>
</table>

4.2 The impact of Trade Liberalization: Extremely High Trade Costs (Case 2)

If trade costs are extremely high in relation to fixed technology adoption costs, a reduction of tariffs also increases the extensive margin of trade. However, it might actually reduce the extensive margin of technology.

As in the previous case the foreign competition effect induces the exit of the least productive firms producing with low technology for their domestic market, while the export selection effect increases the extensive margin of trade. The raise in export revenues allows the most productive domestic
firms, producing with high technology, to enter the foreign market and acquire the export status. Since in this case new and formerly-exporting firms produce using high, skill biased technology, the increase in both market shares and revenues of all exporters generates a raise in the relative demand of skilled labor, thereby increasing the skill premium.

The impact of trade reforms on the extensive margin of technology is different from the previous case. Since there are firms producing with high technology on the domestic market, the reduction of domestic revenues of all firms induced by foreign competition will have a negative impact on the extensive margin of technology. The least productive firms, producing with high technology, will be penalized by trade reforms, whereas the most productive ones will take advantage of trade reforms by obtaining the export status. Despite the reduction of the number of firms producing with high technology, there is an increase in the skill premium since the impact of trade reforms on the extensive margin of trade is higher than its effect on the extensive margin of technology (see graph 6 Appendix D). Under the specific partitioning condition of case 2, the raise of the relative skilled labor demand induced by new and incumbent skill biased exporters prevails over the negative effect on the relative skilled labor demand triggered by the reduction of the extensive margin of technology.

Finally, just as in the previous case, the raise of the skill premium will have a general equilibrium effect of second order on firms’ decisions. The reduction of unskilled labor wages in comparison to skilled labor will benefit to the least productive and unskilled intensive firms using low technology. However, the foreign competition effect overcomes this skill premium effect. The global effect of trade on the production cutoff is unambiguously negative. Besides, the global impact of tariff reductions on the extensive margin of trade is positive. In this case, the raise in the expected export profits induced by the export selection effect outweighs the negative effect of the increase in the skill premium on export decisions.

Table 4 shows the main results of the effects of tariff reductions on firm’s decisions in the second case. Graph 4, 5 and 6 (Appendix D) show the simulation results\(^\text{12}\) of the impact of tariff reductions on the relative demand

\(^\text{12}\)Just as in the previous case, we run simulations of cutoff function and of the labor market equilibrium (equation 4.B) to analyze the effect of a tariffs reduction under the partitioning condition: 

\[ f_x (1 + \tau)^{\phi - 1} \left( \frac{c_{cl}}{c_{lh}} \right)^{\phi - 1} > \frac{f_x}{\left( \frac{c_{cl}}{c_{lh}} \right)^{1 - \phi - 1}} \]
of skilled labor and on the skill premium, on the production cutoff and on
the extensive margin of technology.

Table 4: The impact of variable trade cost ($\tau$) in case 2

<table>
<thead>
<tr>
<th>Domestic cutoff $\varphi_{dl}^*$</th>
<th>Technology cutoff $\varphi_{dh}^*$</th>
<th>Export cutoff $\varphi_{xh}^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{\partial \varphi_{dl}^*}{\partial \tau} = F.C + \omega \text{ effect}$</td>
<td>$\frac{\partial \varphi_{dh}^*}{\partial \tau} = F.C + \omega \text{ effect} &lt; 0$</td>
<td>$\frac{\partial \varphi_{xh}^*}{\partial \tau} = X.S. + \omega \text{ effect}$</td>
</tr>
<tr>
<td>(A) Foreign Competition (FC) (-)</td>
<td>(C) Foreign Competition (FC) (-)</td>
<td>(D) Export selection effect (X.S) (+)</td>
</tr>
<tr>
<td>(B) Skill premium effect (+)</td>
<td>(B) Skill premium effect (-)</td>
<td>(B) Skill premium effect (-)</td>
</tr>
<tr>
<td>↓ $\frac{1}{\tau}$ Benefits least productive firms unskilled intensive</td>
<td>↑ $\omega$ hurts skilled intensive firms</td>
<td></td>
</tr>
<tr>
<td>$\frac{\partial \varphi_{dl}^*}{\partial \left( \frac{1}{\tau} \right)} &lt; 0$</td>
<td>$\frac{\partial \varphi_{dh}^*}{\partial \left( \frac{1}{\tau} \right)} &gt; 0$</td>
<td>$\frac{\partial \varphi_{xh}^*}{\partial \left( \frac{1}{\tau} \right)} &gt; 0$</td>
</tr>
<tr>
<td><strong>Final effect on $\varphi_{dl}^*$</strong></td>
<td><strong>Final effect on $\varphi_{dh}^*$</strong></td>
<td><strong>Final effect on $\varphi_{xh}^*$</strong></td>
</tr>
<tr>
<td>$\frac{\partial \varphi_{dl}^*}{\partial \tau} &lt; 0$ F.C. effect dominates</td>
<td>$\frac{\partial \varphi_{dh}^*}{\partial \tau} &lt; 0$</td>
<td>$\frac{\partial \varphi_{xh}^*}{\partial \tau} &gt; 0$</td>
</tr>
</tbody>
</table>

5 Empirical evidence

5.1 Data and descriptive analysis

In this section we provide some evidence supporting the key assumption of
the theoretical model, namely high technology is skill-biased. Since the theo-
retical mechanisms through which trade affects the skill premium depend
crucially on this assumption, we directly measure the impact of technology
on the relative skilled labor demand and wage at firm level.

In order to test this assumption, we use plant level data from ENIA
Survey of INE (Instituto Nacional de Estadísticas de Chile). This survey
is a manufacturing census of Chilean plants with more than 10 employees covering the period 1979-1999. We use data of value added, investment in capital equipment, imported inputs, foreign technology assistance and wage bill share of skilled and unskilled labor. We used several specific defectors at sectoral level (Isic-3dig Rev2 1992) for added value, technology measures, materials and investment.  

Since Chile is a developing country highly dependant on imported capital equipment and intermediate inputs, we consider that the more adequate proxies for high technology are foreign technology measures. One of these measures is an indicator of the total amount of expenditure in foreign technological assistance (FTA). This variable is a good proxy of technology adoption since those plants which produce with foreign technology are the only ones that will pay for an overseas technological assistance. The second proxy of high technology is an indicator equals to one if the plant reports using imported inputs. We can consider that foreign technology is embodied in imported inputs and that this type of technology is more advanced than domestic one.  

We only have data available of the amount of export sales since 1990. Table 1 (Appendix A) summarizes the main characteristics of exporting firms and those of firms selling only to the domestic market. The data base contains data for an average of 3,805 plants per year. Firms selling only to the domestic market represents on average 79% and thus, exporters are on average 21%. Within exporters 40% of plants are large and 36% are medium size, while only 20% are small firms.  

Regarding the ownership structure of the plant, there are on average 11% of exporters that are classified as foreign firms and 89% of exporters are domestic firms. Unlike exporters, the most part of firms that only sell to the domestic market are small ones 74%, while 20% are medium and only 6% are large. Concerning the ownership structure, only 1% of these firms are foreigners, while most of then (99%)

---

13 The capital series were constructed following the methodology developed by Bergoeing, Hernando and Repetto (2006)  
14 Unfortunately, we can not distinguish domestic from imported capital equipment goods. However, we can assume that there is a large amount of these goods which are imported. See Gallego (2006) for a detail explanation of the dependence of Chile on imported capital goods from developed countries  
15 Size classification: large firms are those with more than 150 workers, medium are those with more than 50 and less than 149 workers and finally, small firms have more than 10 and less than 49  
16 We follow the standard classification of the ownership structure: a foreign plant is one which reports that more than 50% of the total assets are foreigners
are domestic firms. Exporters are also more productive (higher TFP) than non exporters. The percentage of exporters reporting having used foreign technological assistance is 14%, while only 3% of domestic firms used this type of technological assistance.

In order to analyze the evolution of the relative skilled labor demand and the skill premium we use the decomposition approach developed by Machin (1998). Table 3 (Appendix A) shows the between and within industry decompositions of the aggregate variation in the relative skilled labor demand and in the relative skilled wage. In the period 1979-1999, there was an increase of 20% in the skill intensity at 3 digit industry level and this increase is entirely explained by within industries. The between indicator is negative and extremely small. For the period 1979-1986, during the debt crisis, the skill intensity raises up to 37% at 2 digit industry level. Part of this increase is explained by the within estimator 26% while only 11% is explained by the between indicator. In the nineties, there is also a raise in the relative demand of skilled labor which is entirely explained by the within estimator. Similar results hold for the case of the relative skilled wage in all periods. This descriptive evidence indicates that the raise in relative wages of skilled labor can be explained by technology transfers after trade reform.

The descriptive evidence confirms two stylized facts for Chile. Firstly, firms within the same industry are heterogeneous: exporters are more productive and use more foreign technology than firms selling only to the domestic market. Secondly, we find that the increase in the skill intensity is entirely explained by within industries estimator indicating that skilled biased technology might be one important determinant of the evolution of skilled intensity.

5.2 Estimations: The impact of technology adoption on wage inequalities

In order to test whether foreign technology is skill-biased we apply a minimization cost function approach used by Pavnick (2002a) and Machin (1998). Pavnick (2002a) also uses the ENIA data base of Chilean’s plants but for a smaller sample from 1979 to 1986. There two main problems with this period. Firstly, the data base only reports data on export sales since 1990, 

\footnote{\textsuperscript{17}Similar results hold at 2 digit industry level and at firm level.}
thereby Pavnick is not able to distinguish differences between firms by export status. Secondly, there was a raise of import tariffs to 26% from 1982 to 1985 in Chile due to the debt crises (Graph 1 Appendix A). Therefore, during this period there could be a negative incentive to adopt imported technology.

Contrary to Pavnick, we test the relationship between foreign technology and skill upgrading taking into account the export status of firms. First, we use the whole period from 1979 to 1999 and we test this relationship in three different sub-samples distinguishing between firms belonging to export oriented, import competing and non traded sector.\footnote{We classified sectors by trade orientation using 4 digit industry classification. Plants belonging to 4 digit industry which have more than 15% of exports over total production are classified as exported oriented plants; while plants belonging to 4 digit industry which have more than 15% of import penetration indicator are classified as import competing plants. The rest are considered as non traded plants. See Pavcnik (2002) for further details concerning this classification.} Second, we use data of export sales for the nineties classifying firms by export status in continuing exporters, firms that stop exporting, new exporters that continue to export during the whole period once they entered the foreign market, new exporters that stop exporting before the end of the period and never exporting firms.

In order to test the key assumption of the model we use a translog cost function where firms minimized the cost of both skilled and unskilled labor assuming that capital stock is quasi-fixed. We do not consider the skill premium, the relative wage of skilled over unskilled labor, due to endogeneity issues. Actually, the variation of relative wages across plants is endogenous in this specification. For this reason, we introduce 3 digit industry and year dummies instead of relative wages. We also control for possible agglomeration effects using area indicators. We estimate the following equation:

\begin{equation}
(2) S_{it} = \beta_1 + \beta_y \ln(Y_{it}) + \beta_k \ln(K_{it}/Y_{it}) + \beta_T TECH + \beta_I IND + \beta_A AREA + \beta_T YEAR + \epsilon_{it}
\end{equation}

The dependant variable ($S_{it}$) is the share of skilled workers in wage bill. "lnK/lnY" is the logarithm of capital stock over value added and lnY is the logarithm of value added. "Tech" is a vector of different technology measures indicators (expenditure in foreign technological assistance, FTA, and imported inputs).
Table 1 (Appendix E) reports the results of OLS regressions for the whole period (1979-1999) in the three sub-samples (export oriented, import competing and non traded sector) and in the full sample. After controlling for 3 digit ISIC industry, area and year indicators, the coefficient of capital stock over value added is positive indicating that capital is complementary to skill workers in all cases. We can notice that capital is more complementary to skilled labor in firms belonging to export oriented sector than those in import competing and non traded sectors. As the coefficient of value added is significantly different from zero, we have to reject the constant returns scale hypothesis. Finally, both technology measures are skilled biased since their coefficients are positive and significant in the full sample (1.8% and 6%) as well as in all sub-samples. Not only the adoption of foreign technology assistance but also the uses of imported inputs have a more significant impact on skill upgrading in firms belonging to export oriented sectors (3% and 9% respectively) relative to the other sectors.

Nevertheless, these results could be a direct consequence of firms’ unobserved characteristics. To check robustness of our results we run the same regression with individual plant fixed effects controlling for the unobserved plant characteristics (Table 2). After controlling for plant heterogeneity, the coefficients of foreign technical assistance and imported intermediate goods are positive and highly significant for firms selling in the foreign market (1.5% and 2%). On the contrary, for firms belonging to import competing and non traded sectors only the estimated coefficients of imported inputs are positive and significant, while the coefficients of FTA are no longer significant.

Then we run similar regressions using data of export sales for 1990-1999. We add four dummy variables to equation 1 indicating the export status of the firm. The omitted variable in this regression is firms selling only in the domestic market in the whole period (never exporting firms). The first two columns of table 3 report the results of OLS regressions without and with the export status indicator variables, while the last two columns report the fixed effects results. The results of the second column show that both measures of technology are complementary with skilled labor during

\footnote{We also run the same regressions using the skill premium as a dependent variable instead of the wage bill share of skilled labor. Since we find similar results, we only comment those using the wage bill share of skilled labor. The other results are reported in table 4 and 5 in Appendix E}
the nineties. The wage bill share of skilled labor is higher for all exporting firms relative to non-exporting ones. Moreover, continuing exporters (7%) and new exporters that sell in the foreign market during the whole period (new.cont, 6%) have higher skill intensity than those firms stop exporting (3%) and those that entered the foreign market after 1990 and afterwards they stop exporting (New.stop, 4%). When we focus on the results of fixed effect estimations we note that only the coefficient of continuing exporters and new and stop exporters is positive and significant. Individual fixed effects might be correlated with the export status.

To sum up, the results of these estimations confirm for the case of Chile that foreign technology is complementary with skilled labor. Assuming that foreign technology is more advance than domestic technology in a developing country like Chile, we are able to find evidence that support our theoretical key assumption of high technology being skill-biased.

6 Conclusions

This paper has explored how firm’s decision of technology adoption is influenced by firm’s productivity level. Indeed, we have developed a trade model with heterogeneous firms to explain the changes of the extensive margin of technology adoption (the number of firms switching to high technology) after trade reforms and its effect on wage inequalities. The mechanism is based on the impact of the decision to adopt technology on the relative demand of skilled labor and thereby on the skill premium. The main assumption is that high technology is skill biased.

Concerning policy implications, trade liberalization through tariff reductions increases the number of firms selling abroad. The effect on the decision to adopt technology depends on the relation between fixed technology costs and fixed and variable trade costs. If technology costs are extremely high compared to trade costs, a tariff reduction will encourage adopting high technology. In this case, the increase in export revenues allows the most productive exporters to adopt high technology, increasing the extensive margin of technology. However, if trade costs are extremely higher than fixed technology costs, trade liberalization will diminish the domestic revenues of all firms and reduce the extensive margin of technology. In this case, only
the most productive firms producing with high technology in the domestic market will be able to acquire the export status.

In both cases, tariff reductions increase inequalities between skilled and unskilled labor. In the first case, the increase in the number of firms producing with high technology enhances the relative demand of skilled labor and boosts up the skill premium. In the second case, although there is a reduction of the extensive margin of technology, there is also a raise in the skill premium. Trade reforms increase export market shares of new and formerly exporting firms using high, skill biased technology. These firms raise their demand of skilled labor, thereby further deepening the inequalities.

This framework enables to explain widespread empirical evidence concerning superior characteristics of exporters in comparison with non exporters: firms selling in foreign markets are not only more productive but they also resort to modern technologies and are more skill intensive than firms selling only on their domestic markets. Contrary to previous works, the skill intensity of firms is endogenously determined by the decision to adopt technology.

Finally, the main contribution of this model to the existing literature is to propose a possible explanation to H-O-S paradox. Using a framework of heterogeneous firms and fixed technology costs, we are able to explain why there is also a rise in inequalities in unskilled intensive developing countries. The empirical estimations confirm the key theoretical assumption (concerning the skilled biased technology) as well as the predictions of the model.
6.1 Appendix A

Graph 1:
Evolution of Nominal Tariffs in Chile: 1979-2000

Source: Central Bank of Chile

Graph 2:
Evolution of wage bill share of skilled labor by sector

1979=1
Full Sample Export Oriented Import competing Non Traded Year
Table 1: Characteristics of Firms by Export Status

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Exporters</th>
<th>Domestic firms Non exporters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Firms</td>
<td>7940 (21%)</td>
<td>30688 (79%)</td>
</tr>
<tr>
<td>Continuing exporters</td>
<td>4980 (13%)</td>
<td></td>
</tr>
<tr>
<td>New exporters</td>
<td>1540 (4%)</td>
<td></td>
</tr>
<tr>
<td>Stops exporting</td>
<td>1420 (4%)</td>
<td></td>
</tr>
<tr>
<td>Size %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large (more than 150)</td>
<td>40</td>
<td>6</td>
</tr>
<tr>
<td>Medium (50-149)</td>
<td>36</td>
<td>20</td>
</tr>
<tr>
<td>Small (10-49)</td>
<td>24</td>
<td>74</td>
</tr>
<tr>
<td>TFP (average)</td>
<td>10.21</td>
<td>7.77</td>
</tr>
<tr>
<td>Type of Ownership</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Foreign</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>% Domestic</td>
<td>89</td>
<td>99</td>
</tr>
<tr>
<td>Foreign Technology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% FTA</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td>Continuing exporters</td>
<td>87</td>
<td></td>
</tr>
<tr>
<td>New exporters</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Stops exporting</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: % of Plants that use different kinds of technology measures

<table>
<thead>
<tr>
<th>Year</th>
<th>FTA</th>
<th>Patent</th>
<th>Imports</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979</td>
<td>4</td>
<td>64</td>
<td>22</td>
</tr>
<tr>
<td>1980</td>
<td>4</td>
<td>63</td>
<td>21</td>
</tr>
<tr>
<td>1981</td>
<td>4</td>
<td>67</td>
<td>23</td>
</tr>
<tr>
<td>1982</td>
<td>4</td>
<td>70</td>
<td>22</td>
</tr>
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<td>1983</td>
<td>4</td>
<td>76</td>
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<td>1986</td>
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<td>80</td>
<td>25</td>
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<tr>
<td>1987</td>
<td>6</td>
<td>83</td>
<td>26</td>
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<tr>
<td>1988</td>
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<td>86</td>
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</tr>
<tr>
<td>1999</td>
<td>6</td>
<td>89</td>
<td>28</td>
</tr>
</tbody>
</table>

Table 3: Decomposition of Relative Demand and Wages of Skilled labor

Relative Demand of Skilled Labor

\[
\text{Relative Demand of Skilled Labor} = \frac{\text{Within/Total}}{\text{Between/Total}}
\]

Relative Skilled Wage

\[
\text{Relative Skilled Wage} = \frac{\text{Within/Total}}{\text{Between/Total}}
\]
6.2 Appendix B: closed economy equilibrium

6.2.1 B.1.0. Relative skill per unit cost

The relative skill per unit cost is an increasing function of the skill premium:

\[
\frac{c_h}{c_l} = \left( \frac{\omega}{(\omega + (a_h)^{1-\sigma})} \right)^{\frac{1-\alpha}{\alpha}} \]

\[
\frac{\partial(c_h/c_l)}{\partial \omega} = \left( \frac{1-\alpha}{\alpha} \right) \left( \frac{c_h}{c_l} \right)^{-1} \left[ \frac{\left( \frac{\omega}{(\omega + (a_h)^{1-\sigma})} \right)^{\frac{1-\alpha}{\sigma}} - \left[ \frac{\omega}{(\omega + (a_h)^{1-\sigma})} \right]^{\frac{1-\alpha}{\sigma}}}{\left[ \frac{\omega}{(\omega + (a_h)^{1-\sigma})} \right]^{\frac{1-\alpha}{\sigma}}} \right] \]

\[
\frac{\partial(c_h/c_l)}{\partial \omega} > 0 \quad \text{since} \quad (a_h)^{1-\sigma} > 1 \quad \text{and} \quad \frac{1}{\omega} < \frac{1}{(a_h)^{1-\sigma}} < 1
\]

6.2.2 B.1. Labor Market condition

The aggregated relative demand of skilled labor is determined by ratio between the sum of the aggregated demand of skilled and unskilled labor of firms producing with low and high technology.

1. \( L = L_l + L_h = \int_{\varphi_l}^{\varphi_h} L (\varphi_i) d\varphi_i + \int_{\varphi_l}^{N} L (\varphi_i) d\varphi_i \)

2. \( H = H_l + H_h = \int_{\varphi_l}^{\varphi_h} H (\varphi_i) d\varphi_i + \int_{\varphi_l}^{N} H (\varphi_i) d\varphi_i \)

\[
\frac{H^s}{L^s} = \frac{H_l + H_h}{L_l + L_h} \quad \Rightarrow \omega = g(a_h, f, f_t, H^s L^s) \]

The skill premium is determined by the labor market clearing condition:

\[
\frac{H^s}{L^s} = \left( \frac{\omega}{(\omega + (a_h)^{1-\sigma})} \right)^{\frac{1}{\sigma}} \left( 1 + \frac{N_h}{N_l} \frac{\varphi_h}{\varphi_l} \frac{(c_h/c_l)}{\varphi_l} \right)^{-\frac{1}{\sigma}} \left( \frac{\omega}{(\omega + (a_h)^{1-\sigma})} \right)^{\frac{1}{\sigma}} \left( 1 + \frac{N_h}{N_l} \frac{\varphi_h}{\varphi_l} \frac{(c_h/c_l)}{\varphi_l} \right)^{-\frac{1}{\sigma}}
\]

The relative demand of skilled labor is a decreasing function of the skill premium.
6.2.3 B.2. Averages productivities assuming Pareto distribution

Following Melitz and Ghironi (2005) and Melitz and Ottaviano (2005), we parametrize the productivity draws to get closed solutions of the model. We assume that productivity draws are distributed according to a Pareto distribution, with a lower bound $\varphi_{\text{min}}$ and a shape parameter $k$ indexing the dispersion of productivity levels among firms. When this parameter increases there is a reduction of the dispersion of productivity levels which will be concentrated towards the lower bound $\varphi_{\text{min}}$. We assume that $\varphi_{\text{min}} = 1$ and the condition that ensures a finite variance of firm size is $k > 1$.

The cumulative distribution function is $G(\varphi_i) = 1 - \left(\frac{\varphi_{\text{min}}}{\varphi_i}\right)^k$.

Using this specific distribution of productivity draws and equation (3.A) we solve for the average productivities $(\bar{\varphi}_l, \bar{\varphi}_h)$ and also the probabilities $(\rho_l, \rho_h)$.

**Average productivity of firms producing with low technology**

\[
\bar{\varphi}_l^{\phi-1} \equiv \frac{1}{\varphi_l^{\phi-1} - \varphi_l} \int_{\varphi_l}^{\varphi_h^*} (\varphi_i)^{\phi-1} g(\varphi_i) d\varphi_i \quad \text{if} \quad \varphi_i^* < \varphi_i < \varphi_h^*
\]

\[
\bar{\varphi}_l \equiv v \varphi_l^{\phi-1} \left[ \frac{1 - (\xi)^{\phi-1}}{1 - \xi^{\phi}} \right]^{1/\phi-1}
\]

Where \( v = \left[ \frac{k}{1 - (\xi^{\phi-1})} \right]^{1/\phi} \quad \xi = \left( \frac{\varphi_h^*}{\varphi_l} \right)^{\phi-1} \left[ \left( \frac{\varphi_h^*}{\varphi_l} \right)^{1-\phi} - 1 \right]^{1/\phi} \)

**Average productivity of firms producing with high technology**

\[
\bar{\varphi}_h^{\phi-1} \equiv \frac{1}{1 - G(\varphi_h^*)} \int_{\varphi_l}^{\varphi_h} (\varphi_i)^{\phi-1} g(\varphi_i) d\varphi_i \quad \text{if} \quad \varphi_i > \varphi_h^*
\]

\[
\bar{\varphi}_h \equiv v \varphi_h^{\phi-1}
\]

**Determination of probabilities:**

\[
0 \quad \varphi_l^* \quad \varphi_h^* \quad \rho_l \quad \rho_h \quad \infty
\]

42
\[ \rho_l = 1 - \frac{1 - G(\varphi^*_l)}{1 - G(\varphi^*_t)} = 1 - \frac{\varphi^*_l^{\frac{1}{k}}}{\varphi^{\frac{1}{k}}} = 1 - \left( \frac{\varphi^*_l}{\varphi^*_t} \right)^k \]
\[ \rho_h = \frac{1 - G(\varphi^*_t)}{1 - G(\varphi^*_h)} = \left( \frac{\varphi^*_h}{\varphi^*_t} \right)^k \]

### 6.2.4 B.3 Determination of closed economy equilibrium

Equations 1.A. (FE) and 2.A. (ZCP) jointly determine the equilibrium cutoff level \((\varphi^*)\). Plugging in the ZCP condition the averages productivities (using the pareto distribution), the technology cutoff implicitly defined in equation 3.A as a function of production cutoff and the probabilities of being each type of firm (also solved by the pareto distribution) and inserting also in the FE condition the probability of having a productivity draw higher than the cutoff, we obtain the equilibrium cutoff level.

\[
\begin{align*}
\delta f_E \frac{\delta f_E}{(1 - G(\varphi^*_t))} &= \rho_l^t \pi_l(\tilde{\varphi}_l^t) + \rho_h^t \pi_h(\tilde{\varphi}_h^t) \\
\text{Z.C.P} = \text{F.E.} &
\end{align*}
\]

\[ \varphi^*_t \delta f_E = \left[ \rho_l \left( \frac{\bar{\varphi}_l}{\varphi^*_t} \right)^{\phi - 1} + \rho_h \left( \frac{\bar{\varphi}_h}{\varphi^*_t} \right)^{\phi - 1} \left( \frac{\bar{\varphi}_h}{\varphi^*_t} \right)^{\phi - 1} - 1 \right] f - \rho_h f_t \]

\[ \varphi^*_t = \left[ A + \left( \frac{e_1}{c_1} \right)^{1-\phi} - 1 \right]^{\frac{k}{k - 1}} B - \frac{f}{\delta f_E} \]

Where:

\[ A = \frac{1}{\delta f_E} (\nu)^{\phi - 1} \]
\[ B = \left( \frac{\bar{\varphi}_h}{\varphi^*_t} \right)^{\phi - 1} \left( \nu \right)^{\phi - 1} - 1 \]

Determination of \( \frac{\partial \varphi^*_t}{\partial \left( \frac{c_1}{c_i} \right)} \)

\[ \frac{\partial \varphi^*_t}{\partial \left( \frac{c_1}{c_i} \right)} = \frac{1}{k} \left( \varphi^*_t^{-k} \right)^{\frac{1}{k - 1}} \left( \frac{k}{\varphi^{\frac{1}{k}}} \right) (1 - \phi) \left( \frac{e_1}{c_1} \right)^{-\phi} \left[ \left( \frac{e_1}{c_1} \right)^{1-\phi} - 1 \right]^{\frac{k}{k - 1}} B \]

\[ \frac{\partial \varphi^*_t}{\partial \left( \frac{c_1}{c_i} \right)} < 0 \]
6.3 Appendix C: open economy equilibrium

6.3.1 C.1 Labor Market condition case 1

\[ H = \int_{\varphi_{tH}}^{\varphi_{tH}^*} h(\varphi) d\varphi + \int_{\varphi_{tL}}^{\varphi_{tL}^*} h(\varphi) d\varphi + \int_{\varphi_{tL}}^{\varphi_{tL}^*} h(\varphi) d\varphi \]

\[ L = \int_{\varphi_{tL}}^{\varphi_{tL}^*} L(\varphi) d\varphi + \int_{\varphi_{tL}}^{\varphi_{tL}^*} L(\varphi) d\varphi + \int_{\varphi_{tL}}^{\varphi_{tL}^*} L(\varphi) d\varphi \]

\[ (H/L)^{1/\tau} = \frac{f_{tL} + f_{tH} + f_{tL}}{L_{tL} + L_{tL} + L_{tL}} \Rightarrow \omega = g(a_h, f_t, f_{tx}, \tau) \]

\[ (H/L)^{1/\tau} = \omega^{1/\tau} \left[ \frac{1 + (\phi_{hl})^{\phi_{hl} - 1} \left[ 1 + (1 + \phi_{hl})^{\phi_{hl}} \right] \left( \frac{c_{hl}}{c_{hl}} \right)^{\phi_{hl}} \left( \frac{c_{hl}}{c_{hl}} \right)^{\phi_{hl}} + 1}{1 + \left( \frac{c_{hl}}{c_{hl}} \right)^{\phi_{hl}} \left( \frac{c_{hl}}{c_{hl}} \right)^{\phi_{hl}} + 1} \right] \]

6.3.2 C.2 Averages productivities assuming Pareto distribution: case 1

Average productivity of non exporters firms producing with low technology:

\[ \tilde{\varphi}_{dl}^{\phi_{dl} - 1} \equiv \frac{1}{\mu(\varphi_{dl}) - \mu(\varphi_{dl})} \int_{\varphi_{dl}}^{\varphi_{dl}^*} (\varphi) d\varphi \]

if \( \varphi_{dl} < \varphi < \varphi_{dl}^* \)

\[ \tilde{\varphi}_{dl} = v^{\phi_{dl}} \left[ \frac{1 - (\phi)^{1 + \phi - 1}}{1 - (\phi)^{1 + \phi - 1}} \right]^{1/\tau} \]

Where \( \varphi = \left( \frac{L'}{L} \right)^{1/\tau} (1 + \tau) \)

Average productivity of exporters producing with low technology:
\[(\varphi_{xt})^{\phi - 1} = \frac{1}{\varphi(\varphi_{xt}) - \varphi(\varphi_{t})} \int_{\varphi_{xt}}^{\varphi_{t}} (\varphi_{i})^{\phi - 1} g(\varphi_{i}) d\varphi_{i}\]

if \(\varphi_{xt} < \varphi_{i} < \varphi_{t}\)

\[\varphi_{xt} \equiv \psi_{xt}^{*} \left[ \frac{1}{1 - (\Omega)^{-1} (\phi^{1} - 1)} \right]^{\frac{1}{\phi - 1}}\]

Where \(\Omega = (1 + \tau)^{-1} \left( \beta_{t} \right)^{\frac{1}{\phi - 1}} \left[ \left( \frac{C_{t}}{C_{i}} \right)^{1 - \phi} - 1 \right] \left[ 1 + (1 + \tau)^{1 - \phi} \right] \right]^{\frac{1}{\phi - 1}}\)

Average productivity of exporters producing with high technology:

\[(\varphi_{xh})^{\phi - 1} \equiv \frac{1}{1 - \varphi(\varphi_{xh})} \int_{\varphi_{xh}}^{\infty} (\varphi_{i})^{\phi - 1} g(\varphi_{i}) d\varphi_{i}\]

if \(\varphi_{i} > \varphi_{xh}\)

\[\varphi_{xh} \equiv \psi_{xh}^{*}\]

Determination of probabilities:

\[\varphi_{dt}^{*} = 1 - \frac{1 - \varphi(\varphi_{dt}^{*})}{1 - \varphi(\varphi_{xh}^{*})}\]

\[\varphi_{xt}^{*} = \frac{1 - \varphi(\varphi_{xt}^{*})}{1 - \varphi(\varphi_{xh}^{*})} - \frac{1 - \varphi(\varphi_{xh}^{*})}{1 - \varphi(\varphi_{xh}^{*})}\]

\[\varphi_{xh}^{*} = \frac{1 - \varphi(\varphi_{xh}^{*})}{1 - \varphi(\varphi_{xh}^{*})}\]

Probability of having a productivity draw higher than the production cutoff

\[\rho_{dt} = \left[ 1 - \left( \frac{\varphi_{dt}^{*}}{\varphi_{xh}^{*}} \right)^{k} \right]\]

Probability of exporting conditional on surviving

\[\rho_{xt} = \left( \frac{\varphi_{dt}^{*}}{\varphi_{xh}^{*}} \right)^{k} - \left( \frac{\varphi_{dt}^{*}}{\varphi_{xh}^{*}} \right)^{k}\]

Probability of adopting high technology conditional on surviving

\[\rho_{xh} = \left( \frac{\varphi_{dt}^{*}}{\varphi_{xh}^{*}} \right)^{k}\]

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6.3.3 C.3 Determination of the equilibrium: case 1

Like in the closed economy equilibrium FE (equation 1.B) and ZCP (2.B) conditions jointly determine the equilibrium cutoff level. Plugging in the ZCP condition the following variables: \( \bar{\phi}_{d}, \bar{\phi}_{x}, \bar{\phi}_{xt}, \rho_{d}, \rho_{x}, \rho_{xt} \), we obtain the equilibrium cutoff level.

\[
\frac{\delta f_{E}}{(1 - G(\phi^{*}))} = \pi_{dl}(\bar{\phi}_{dl}) + \pi_{xl}(\bar{\phi}_{xl}) + \rho_{xh} \left[ \pi_{dh}(\bar{\phi}_{dh}) + \pi_{xh}(\bar{\phi}_{xh}) \right]
\]

Following similar steps as we did in the closed economy equilibrium, we get in this case:

\[
\phi^{k} \delta f_{E} = f (v)^{\phi-1} \left[ 1 - (e)^{-k+\phi-1} \right] + f_{x} \bar{\theta}^{-k} \left[ \left[ 1 - \left( \frac{\phi}{e} \right)^{k} \right] (v)^{\phi-1} \left[ 1 - (\Omega)^{-2+\phi-1} \right] - 1 \right] + \\
\varepsilon^{-k} f_{t} \left[ \left[ 1 - \left( \frac{\phi}{e} \right)^{\phi-1} \right] - 1 \right] - f
\]

Where

\[
\varepsilon = \left( \frac{f}{\bar{f}} \right)^{\frac{1}{\phi-1}} \left[ \left( \frac{\phi}{e} \right)^{1-\phi} - 1 \right] \left[ 1 + (1 + \tau)^{1-\phi} \right] \left[ 1 - \left( \frac{\phi}{e} \right)^{\phi-1} \right]^{-1}
\]

\[
\bar{\theta} = \left( \frac{f}{\bar{f}} \right)^{\frac{1}{\phi-1}} (1 + \tau)
\]

\[
\Omega = (1 + \tau)^{-1} \left( \frac{f}{\bar{f}} \right)^{\frac{1}{\phi-1}} \left[ \left( \frac{\phi}{e} \right)^{1-\phi} - 1 \right] \left[ 1 + (1 + \tau)^{1-\phi} \right] \left[ 1 - \left( \frac{\phi}{e} \right)^{\phi-1} \right]^{-1}
\]
6.3.4 C.4 Labor Market condition case 2

\[ H = \int_{\varphi_{dl}}^{\varphi_{dh}} h(\varphi_i) \, d\varphi_i + \int_{\varphi_{dh}}^{\varphi_{sl}} h(\varphi_i) \, d\varphi_i + \int_{\varphi_{sl}}^{\varphi_{sh}} h(\varphi_i) \, d\varphi_i \]

\[ L = \int_{\varphi_{dl}}^{\varphi_{dh}} l(\varphi_i) \, d\varphi_i + \int_{\varphi_{dh}}^{\varphi_{sl}} l(\varphi_i) \, d\varphi_i + \int_{\varphi_{sl}}^{\varphi_{sh}} l(\varphi_i) \, d\varphi_i \]

\[ \left( \frac{H}{L} \right)^d = \frac{H_{dl} + H_{dh} + H_{sh}}{L_{dl} + L_{dh} + L_{sh}} \]

\[ \frac{H^*}{L^*} = \frac{H_{dl} + H_{dh} + H_{sh}}{L_{dl} + L_{dh} + L_{sh}} \Rightarrow \omega = g(a_h, f, f_t, f_x, \tau) \]

\[ \frac{H^*}{L^*} = \left( \omega \right)^{\frac{1}{1-\tau}} \left[ 1 + (a_h)^{\frac{1}{1-\tau}} \left[ N_{dh} \left( \varphi_{dh} \right)^{\phi - 1} + N_{sl} \left( \varphi_{sl} \right)^{\phi - 1} \right] \left( \frac{c_h}{c_{dh}} \right)^{-\phi} \left( \frac{\omega}{\varphi_h} \right)^{\frac{1}{1-\tau} - 1} \right] \]

\[ \left[ 1 + \left[ N_{dh} \left( \varphi_{dh} \right)^{\phi - 1} + N_{sl} \left( \varphi_{sl} \right)^{\phi - 1} \right] \left( \frac{c_h}{c_{dh}} \right)^{-\phi} \left( \frac{\omega}{\varphi_h} \right)^{\frac{1}{1-\tau} - 1} \right] \]

6.3.5 C.5 Averages productivities assuming Pareto distribution: case 2

Average productivity of non exporters firms producing with low technology:

\[ \tilde{\varphi}_{dl}^{\phi - 1} \equiv \frac{1}{G(\varphi_{dl}) - G(\varphi_{dh})} \int_{\varphi_{dl}}^{\varphi_{dh}} (\varphi_i)^{\phi - 1} g(\varphi_i) \, d\varphi_i \]

if \( \varphi_{dl} < \varphi_i < \varphi_{dh} \)

\[ \tilde{\varphi}_{dl} \equiv \varphi_{sl}^{\phi - 1} \left[ \frac{1 - (\xi)^{-1 - \phi - 1}}{1 - \xi^{-1}} \right]^{\frac{1}{1-\tau}} \]

Where

\[ \xi = \left( \frac{\tilde{\varphi}_{dl}}{\tilde{\varphi}_{sl}} \right)^{\frac{1}{1-\phi}} - 1 \]

Average productivity of non exporters firms producing with high technology:

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\[
\overline{\varphi}^{\phi-1}_{dh} = \frac{1}{\alpha(\varphi_{dh})} \int_{\varphi_{dh}}^{\varphi_{xh}} (\varphi_i)^{\phi-1} g(\varphi_i) d\varphi_i \\
\text{if } \varphi_{xh} < \varphi_i < \varphi_{dh} \\
\overline{\varphi}_{dh} \equiv v \varphi_{dh} \left[ \frac{1-(\chi)^{-k+\phi-1}}{1-\chi^{\phi-1}} \right]^{\frac{1}{\phi-1}}
\]

Where

\[
\chi = \left[ \left( \frac{c_{il}}{\bar{c}_i} \right)^{1-\phi} - 1 \right] \sigma^{-1} \left( \frac{c_{il}}{\bar{c}_i} \right) \left( \frac{f_i}{f} \right) \sigma^{-1} (1 + \tau)
\]

Average productivity of exporters producing with high technology:

\[
\overline{\varphi}^{\phi-1}_{xh} = \frac{1}{1-C(\varphi_{xh})} \int_{\varphi_{xh}}^{\infty} (\varphi_i)^{\phi-1} g(\varphi_i) d\varphi_i \quad \text{if } \varphi_i > \varphi_{xh} \\
\overline{\varphi}_{xh} \equiv v \varphi_{xh}
\]

Determination of the probabilities:

\[
\rho_{dl} = 1 - \left( \frac{\varphi_{xh}}{\varphi_{dl}} \right)^k \\
\rho_{dh} = \left[ \frac{1-C(\varphi_{xh})}{1-C(\varphi_{dl})} \right] - \left[ \frac{1-C(\varphi_{xh})}{1-C(\varphi_{dl})} \right] \\
\rho_{xh} = \left[ \frac{1-C(\varphi_{xh})}{1-C(\varphi_{dl})} \right]
\]

Probability of having a productivity draw higher than the production cutoff

\[
\rho_{dl} = 1 - \left( \frac{\varphi_{xh}}{\varphi_{dl}} \right)^k
\]

Probability of adopting high technology conditional on surviving

\[
\rho_{dh} = \left( \frac{\varphi_{xh}}{\varphi_{dl}} \right)^k - \left( \frac{\varphi_{xh}}{\varphi_{dl}} \right)^k
\]

Probability of exporting conditional on surviving

\[
\rho_{xh} = \left( \frac{\varphi_{xh}}{\varphi_{dl}} \right)^k
\]
6.3.6 C.6 Determination of the equilibrium: case 2

To obtain the equilibrium cutoff level, we follow similar steps as we did in the previous cases.

\[
\frac{\delta f_E}{(1 - G(\varphi^*))} = \sum_{F.E.} \tau = \pi_{dl}(\varphi_{dl}) + \pi_{dh}(\varphi_{dh}) + \pi_{xh}(\varphi_{xh})
\]

\[
\delta f_E = f \left[ \rho_{dl} \left( \frac{\varphi_{dl}}{\varphi_{dl}} \right)^{\phi-1} + \rho_{ht} \left( \frac{\varphi_{ht}}{\varphi_{ht}} \right)^{\phi-1} - 1 \right] - \rho_h \hat{f}_t + f_x \rho_{xh} \left[ \left( \frac{\varphi_{xh}}{\varphi_{xh}} \right)^{\phi-1} - 1 \right]
\]

\[
\varphi_t^k = \left[ \frac{1}{f_E} \left( A + \left( \left( \frac{c_h}{c_i} \right)^{\phi-1} - 1 \right) \frac{\phi-1}{\phi-1} \right) + E \left( \frac{c_h}{c_i} \right)^{-k} - f \right]^{\frac{1}{k}}
\]

Where

\[A = \frac{f}{\delta f_E} (v)^{\phi-1}\]

\[B = \frac{f^{\phi-1}}{\delta f_E} f_t^{\phi-1} \left[(v)^{\phi-1} - 1\right]\]

\[E = f_x \left( \frac{f_t}{T} \right)^{\phi^{-1}} (1 + \tau)^{-k} \frac{\phi-1}{k(\phi-1)} \]

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6.3.7 D. Simulations results

Case 1: The impact of trade liberalization

**Graph 1:**
The final effect of a reduction of tariffs on the production cutoff

```
φ*
```

"Foreign competition effect" dominates over the "skill premium effect": the least productive firms exit the market.

**Graph 2:**
The impact of a reduction of tariffs on the extensive margin of technology

```
φ_{xh}
```

"Extensive margin of technology": a reduction of tariffs increases market shares and profits of all exporters allowing new firms to adopt high technology. The increase in export profitability compensates the negative impact of the raise in the skill premium on the technology adoption decision.

**Partitioning condition:**

\[
\frac{\delta f_x}{[1+(1+\tau)^{1-\phi}] \left( \frac{a_h}{c_l} \right)^{1-\phi} - 1} > (1 + \tau)^{\phi - 1} \delta f_x > f
\]

**Parameters values:** \( \phi=3; \ k=4; \ \alpha=0.6; \ a_h=2; \ f_l=500, \ f_c=80, f=4, \ \delta=0.06, \ f_y=100 \)
Graph 3:
The impact of a reduction of variable trade cost ($\tau$) on the skill premium (Case 1)

$(H/L)^8$

Parameters values:
$\phi=3; \ k=4; \ \alpha=0.6; \ ah=2; \ f_t=500, \ f_z=80, \ f=4, \ \delta=0.06$

Partitioning condition case 1:

$$\frac{\delta f_t}{\delta f_z} < (1 + \tau)^{\phi-1} \delta f_z > f$$
Case 2: The impact of trade liberalization

Graph 4:
The final effect of a reduction of tariffs on the production cutoff \( \phi^* \)

\[
\phi^* = \frac{1}{\tau} \left( 1 + \tau \right)^{\frac{1}{\phi} - 1} \left( \frac{\xi}{\phi} \right)^{\frac{1}{\phi} - 1} > f
\]

"Foreign competition effect" dominates over the "skill premium effect": the least productive firms exit the market.

Graph 5:
The impact of a reduction of variable trade cost on the extensive margin of trade \( \phi_{xh}^* \)

"Extensive margin of trade": a reduction of tariffs increases market shares and profits of all exporters allowing new firms to export. The increase in export profitability compensates the negative impact of the raise in the skill premium on the technology adoption decision.

Partitioning condition:

\[
f_x \left( 1 + \tau \right)^{\frac{1}{\phi} - 1} \left( \frac{\xi}{\phi} \right)^{\frac{1}{\phi} - 1} > f
\]

Parameters values:  \( \phi = 3; k = 4; \alpha = 0.6; a_h = 2; f_x = 200, f_e = 500, f = 4, \delta = 0.06, \xi = 100 \)
Graph 6:
The impact of a reduction of variable trade cost ($\tau$) on the skill premium (Case 2)

$$(H/L)^{\theta}$$

Parameters values:

$\phi=3; k=4; \alpha=0.6; a_h=2; f_t=200, f_x=500, f=4, \delta=0.06, \ell_s=100$

Partitioning condition:

$$f_x (1 + \tau)^{\phi-1} \left( \frac{f_t}{f_x} \right)^{\theta-1} > \frac{f_t}{\left( \frac{f_t}{f} \right)^{1-\phi} - 1} > f$$

---

$\tau = 0.9$  
$\tau = 0.5$
### 6.4 Empirical results

Table 1: Dependent variable: Wage bill share of skilled labor (1979-1999)

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Note: Huber White Standard errors in parentheses
*p < 0.10, **p < 0.05, ***p < 0.01
Table 2: Dependant variable: Wage bill share of skilled labor (1979-1999)

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Note: Huber White Standard errors in parentheses
*p < 0.10, **p < 0.05, ***p < 0.01
Table 3: Dependant variable: Wage bill share of skilled labor (1990-1999)

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<td></td>
<td>(0.006)</td>
<td></td>
</tr>
<tr>
<td>Plant_Ind</td>
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<td>NO</td>
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<td>YES</td>
</tr>
<tr>
<td>ISIC_3_Ind</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Area_Ind</td>
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<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>YEAR_Ind</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Number Obs</td>
<td>27120</td>
<td>27120</td>
<td>27120</td>
<td>27120</td>
</tr>
<tr>
<td>R2</td>
<td>0.207</td>
<td>0.213</td>
<td>0.145</td>
<td>0.150</td>
</tr>
</tbody>
</table>

Note: Huber White Standard errors in parentheses
*p < 0.10, **p < 0.05, ***p < 0.01
Table 4: Dependant variable: Skill premium (1979-1999)

<table>
<thead>
<tr>
<th></th>
<th>OLS</th>
<th>Export Oriented</th>
<th>Import Competing</th>
<th>Non Traded</th>
<th>Full Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln(K/VA)</td>
<td>0.222***</td>
<td>0.069***</td>
<td>0.103***</td>
<td>0.144***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.023)</td>
<td>(0.019)</td>
<td>(0.025)</td>
<td>(0.013)</td>
<td></td>
</tr>
<tr>
<td>ln(VA)</td>
<td>0.941***</td>
<td>0.936***</td>
<td>0.977***</td>
<td>0.994***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.027)</td>
<td>(0.029)</td>
<td>(0.055)</td>
<td>(0.020)</td>
<td></td>
</tr>
<tr>
<td>FTA</td>
<td>0.290***</td>
<td>0.535***</td>
<td>0.024</td>
<td>0.297***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.089)</td>
<td>(0.207)</td>
<td>(0.169)</td>
<td>(0.088)</td>
<td></td>
</tr>
<tr>
<td>Imported</td>
<td>0.607***</td>
<td>0.432***</td>
<td>0.422***</td>
<td>0.480***</td>
<td></td>
</tr>
<tr>
<td>Input</td>
<td>(0.154)</td>
<td>(0.084)</td>
<td>(0.100)</td>
<td>(0.061)</td>
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</tr>
<tr>
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<td>NO</td>
<td>NO</td>
<td>NO</td>
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<td>YES</td>
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<td>YES</td>
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<tr>
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<td>YES</td>
<td>YES</td>
<td>YES</td>
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<tr>
<td>Number Obs</td>
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<td>19572</td>
<td>14292</td>
<td>55633</td>
<td></td>
</tr>
<tr>
<td>R2</td>
<td>0.260</td>
<td>0.230</td>
<td>0.247</td>
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</table>

Note: Huber White Standard errors in parentheses
*p < 0.10, **p < 0.05, ***p < 0.01
Table 5: Dependant variable: Skill premium (1979-1999)

<table>
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<th>F.E.</th>
<th>[Export Oriented]</th>
<th>[Import Competing]</th>
<th>[Non Traded]</th>
<th>[Full Sample]</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln(K/VA)</td>
<td>0.030</td>
<td>0.205***</td>
<td>0.054</td>
<td>0.110***</td>
</tr>
<tr>
<td></td>
<td>(0.044)</td>
<td>(0.040)</td>
<td>(0.051)</td>
<td>(0.026)</td>
</tr>
<tr>
<td>ln(VA)</td>
<td>0.441***</td>
<td>0.597***</td>
<td>0.564***</td>
<td>0.533***</td>
</tr>
<tr>
<td></td>
<td>(0.063)</td>
<td>(0.053)</td>
<td>(0.061)</td>
<td>(0.034)</td>
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<tr>
<td>FTA</td>
<td>0.722***</td>
<td>0.073</td>
<td>0.154</td>
<td>0.145</td>
</tr>
<tr>
<td></td>
<td>(0.052)</td>
<td>(0.211)</td>
<td>(0.112)</td>
<td>(0.149)</td>
</tr>
<tr>
<td>Imported</td>
<td>0.341*</td>
<td>0.245***</td>
<td>0.132</td>
<td>0.246***</td>
</tr>
<tr>
<td>Input</td>
<td>(0.178)</td>
<td>(0.089)</td>
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</tr>
<tr>
<td>Plant_IND</td>
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<td>YES</td>
<td>YES</td>
<td>YES</td>
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<tr>
<td>YEAR_IND</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Number Obs</td>
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<td>19572</td>
<td>14292</td>
<td>55633</td>
</tr>
<tr>
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<td>0.154</td>
<td>0.159</td>
<td>0.148</td>
</tr>
</tbody>
</table>

Note: Huber White Standard errors in parentheses
*p < 0.10, **p < 0.05, ***p < 0.01
References


[9] Bernard, Jensen and Schott (2003), ”Falling trade costs, heterogeneous firms and industry dynamics”, NBER


