Trade, Technology Adoption and Wage Inequalities

Maria BAS *†

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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 increase in the skill premium in developping countries. The traditional framework, H-O-S, 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 our 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.

Keywords: Firm heterogeneity, trade reforms, technology adoption, skill premium.

JEL Classification: F10, F12 and F41

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†PSE joint research unit Cnrs-Ehess-Enpc-Ens, Paris. Email: bas@pse.ens.fr. Postal Address: Pse-Ens, 48 bd Jourdan, 75014 Paris, France. Phone: +33(0)14313 6254.

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 dependant 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 integration between countries using similar technologies and factor endowments took place in most developing countries during the eighties and the nineties, not only through a reduction of bilateral tariffs but also 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 evidence of growing wage inequalities across firms in the same industry after trade reforms. There are 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.[2] 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 [3].

The mechanisms through which trade policy affects the relative demand of skilled labor and skill premium have been studied by the traditional Herckser-Olhin-Samuelson (H-O-S) theory or more recent studies in line with the "'New new trade theory". We can distinguish two types of arguments to explain the raise in wage inequalities after trade liberalization. The main difference between these two explanations is based on whether they focus mainly on the effects of international trade or on technological changes.

[1]Graph 1, Graph 2, Table 1 and Table 2 (Appendix A) show evidence form Chile of these stylized facts.

[2]For an exhaustive survey on developing countries see Pavcnik and Goldberg (2005). Gasparini and Acosta (2002) and Bustos (2005)for Argentina, Sanchez-Paramo and Schady (2003) for Argentina, Chile, Colombia and Mexico, Verhoogen (2006) for Mexico and Mundler (2005) for Brazil: find evidence of a positive correlation between adoption of imported technologies after trade reform and a raise in the skill premium.

[3]Behrman, 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, 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.

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 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[4].

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. 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. The key mechanism of this model is based on endogenous technological changes and innovation, while our model focuses on a different and complementary channel based on technology adoption to explain the relation between the increase in wage inequalities and trade policy.

[4]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.

This 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 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 aggregate 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 aggregate 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). 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 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 productive exporters will be able to adopt high technology. In the second case adopting high technology is relatively cheaper than exporting, hence there will be domestic firms producing with high technology and within these firms only the most productive are able to export.

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 exporting firms producing with high technology. As a result, in both cases the inequalities will raise.

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 beneficiate 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.

Finally, we provide some evidence supporting the key assumption of the theoretical model. High technology is assumed to increase the efficiency skilled labor and thereby to reduce the per unit cost of production. In this sense, high technology is skill-biased. Since the theoretical mechanism through which trade affects the skill premium depends on this assumption, we directly measure the effects of technology on the wage bill share of skilled labor at firm level using the case of Chile.

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 between symmetric countries 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

2.1 Closed economy equilibrium

2.1.1 Households Consumption

The representative household allocates consumption between the set of available domestic varieties (j) produced with low technology (Ω_l) and those produced using more advanced and skill biased technology (Ω_h). The standard C.E.S. utility function (C) resumes consumer's preferences

:

$$C = \left(\underbrace{\int_{j\in\Omega_l} C_{lj}^{\frac{\phi-1}{\phi}} dj}_{\text{Low technology goods}} + \underbrace{\int_{j\in\Omega_h} C_{hj}^{\frac{\phi-1}{\phi}} dj}_{\text{High technology goods}} \right)^{\frac{\phi}{\phi-1}}$$

The elasticity of substitution ϕ between low and high technology goods is $\phi > 1$. The optimal relative demand functions are as follows:

$$C_l = \left(\frac{P}{p_l}\right)^{\phi} C \qquad\qquad C_h = \left(\frac{P}{p_h}\right)^{\phi} C \qquad (1.A)$$

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

$$P = \left[\int_{j\in\Omega_l} p_l^{1-\phi} dj + \int_{j\in\Omega_h} p_h^{1-\phi} dj\right]^{\frac{1}{1-\phi}}$$

2.1.2 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 (φ). The production function is represented by a CES function given by:

$$Y_i = \varphi\left((a_h h_i)^{\alpha} + (l_i)^{\alpha}\right)^{\frac{1}{\alpha}} \qquad i = \{l, h\} \qquad (2.A)$$

$$a_h = \{1, s\} \qquad s > 1$$

The subscript "l"is used for firms producing with low technology and "h " for firms producing with high technology. 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 (f_t), it will have a "$a_h > 1$". 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).

First order condition of monopolistic firms means that prices remain a mark-up over the marginal cost. In this model marginal costs can be divided into an intrinsic productivity term (φ) and the per unit cost of production (c_l or c_h) which reflects the relationship between skilled (w_h) and unskilled (w_l) wages paid by the firm. 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 (π_l, π_h) [5]. Table 2.1.1 summarizes these variables.

[5]In section 2.3 we show that $\pi_l = p_l Y_l - w_l l_l - w_h h_l - f = \frac{r_l}{\phi} - f$

Table 2.1.1: Characteristics of firms in closed economy equilibrium

Low technology firms (N_l)	**High technology firms (N_h)**
Prices (p_l) and per unit cost (c_l)	**Prices (p_h) and per unit cost (c_h)**
(3.A) $p_l = \frac{\phi}{\phi-1}\frac{c_l}{\varphi_i}$	$p_h = \frac{\phi}{\phi-1}\frac{c_h}{\varphi_i}$
(4.A) $c_l = \left((w_l)^{\frac{\alpha}{\alpha-1}} + (w_h)^{\frac{\alpha}{\alpha-1}}\right)^{\frac{\alpha-1}{\alpha}}$	$c_h = \left((w_l)^{\frac{\alpha}{\alpha-1}} + \left(\frac{w_h}{a_h}\right)^{\frac{\alpha}{\alpha-1}}\right)^{\frac{\alpha-1}{\alpha}}$
Revenues (r_l) and profits (π_l)	**Revenues (r_h) and profits (π_h)**
(5.A) $r_l = \left(\frac{P}{p_l}\right)^{\phi-1} R$	$r_h = \left(\frac{P}{p_h}\right)^{\phi-1} R$
$r_l = r_h \left(\frac{c_h}{c_l}\right)^{\phi-1}$	$r_h = r_l \left(\frac{c_h}{c_l}\right)^{1-\phi}$
(6.A) $\pi_l = p_l Y_l - w_l l_l - w_h h_l - f$	$\pi_h = p_h Y_h - w_l l_h - w_h h_h - f - \delta f_t$
$\pi_l = \frac{r_l}{\phi} - f$	
Goods Market Equilibrium	
(7.A) $Y_i = C_i$	for $i = \{l, h\}$

There are three types of fixed costs in a closed economy. Firstly, there is a sunk fixed entry cost (f_E) that firms have to pay to enter the market. This cost is mainly associated with initial investment costs like those costs of developing a blueprint. Secondly, all firms must pay a fixed production cost (f) during all periods. This is a per-period fixed cost that all firms must incur which can be associated with investments in local distribution for example. Finally, there is a fixed technology adoption cost (f_t) and firms can pay the amortized cost per-period: δf_t . This cost represents the investment in a new and more advanced technology which we assume to be skilled biased. Other 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. The price of capital used to cover fixed costs is normalized to one.

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). Note that "a_h" is not heterogeneous, all firms that adopt the high technology will reduce their per unit cost in the same proportion. Even if two firms have the same productivity level, revenues of a firm producing with the more advanced technology are higher than those of a firm producing with low technology ($c_l > c_h \Rightarrow r_l < r_h$). Hence, firms that decide to upgrade technology will increase their revenues by $\left(\frac{c_h}{c_l}\right)^{1-\phi}$ (where $\phi > 1$).The introduction of firm's heterogeneity in terms of productivity levels determines the endogenous "technological" status of firms. Only most productive firms will be able to switch to high technology and this technology will allow them to become even more efficient.

The term $\left(\frac{c_h}{c_l}\right)$ represents the relative per unit cost of skilled labor and it is determined by the skill premium $\omega = \frac{w_h}{w_l}$ and the skill efficiency "$a_h > 1$" :

$$\left(\frac{c_h}{c_l}\right) = \left(\frac{(\omega)^{\frac{\alpha}{1-\alpha}}+1}{(\omega)^{\frac{\alpha}{1-\alpha}}+(a_h)^{\frac{\alpha}{1-\alpha}}}\right)^{\frac{1-\alpha}{\alpha}} \qquad (8.A)$$

This relative per unit cost of skilled labor is an increasing function of the skilled premium $\frac{\partial \frac{c_h}{c_l}}{\partial \omega} > 0$ since $0 < \alpha < 1$.

2.1.3 The decision to exit or stay and produce

To enter the market, firms have to pay a sunk entry cost before knowing their productivity level. Entrants will then draw their productivity "φ" from common distribution density $g(\varphi)$, with support $[0, \infty]$ and cumulative distribution $G(\alpha)$. These functions will be defined in next section. Once the firm knows its productivity draw, it decides to produce or to exit and never produce. Since there is a fixed production cost (f), only those firms that have enough profits to pay this cost will produce. The marginal firm that decides to stay and produce is the one whose profits are equal to zero: $\pi_l(\varphi_l^*) = 0$. Hence , the value "φ_l^* " is the productivity cutoff to produce.

$$\pi_l(\varphi_l^*) = 0$$

$$\frac{r_l(\varphi_l^*)}{\phi} = f \qquad \Rightarrow \qquad \varphi_l^{*\phi-1} = f \;\; c_l^{\phi-1}\frac{\phi}{\Psi} \qquad (9.A)$$

Where $\Psi = P^{\phi-1}R\left(\frac{\phi}{\phi-1}\right)^{1-\phi}$

2.1.4 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 since the fixed technology cost is higher than the fixed production cost. They will be those firms whose increase in domestic sales revenues from adopting high technology allows them to pay the fixed technology costs.

Indeed, the condition to acquire the new and more advanced technology is given by:

$$\pi_h(\varphi_h^*) = \pi_l(\varphi_h^*)$$

$$\frac{\left[r_h(\varphi_h^*)-r_l(\varphi_h^*)\right]}{\phi} = \delta f_t \qquad \Rightarrow \varphi_h^{*\phi-1} = \frac{\delta f_t}{\left[c_h^{1-\phi}-c_l^{1-\phi}\right]}\frac{\phi}{\Psi} \qquad (10.A)$$

The productivity cutoff to acquire high technology is represented by "φ_h^*", this value is the minimum level of productivity of the marginal firm, which is able to adopt high technology. Combining equation (9.A) with (10.A) we obtain φ_h^* as an implicit function of φ_l^*.

$$\left(\frac{\varphi_h^*}{\varphi_l^*}\right)^{\phi-1} \Rightarrow \qquad \varphi_h^* = \varphi_l^*\left(\frac{\delta f_t}{f}\right)^{\frac{1}{\phi-1}}\left[\left(\frac{c_h}{c_l}\right)^{1-\phi}-1\right]^{\frac{1}{1-\phi}} \qquad (11.A)$$

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:

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

2.2 Aggregation

The distribution of productivity levels of low and high technology firms are represented by $\mu_l(\varphi)$ and $\mu_h(\varphi)$. Therefore, $\mu_l(\varphi)$ is the conditional distribution of $g(\varphi)$ on $[\varphi_l^*, \varphi_h^*]$ while $\mu_h(\varphi)$ is the conditional distribution of $g(\varphi)$ on $[\varphi_h^*, \infty)$.

$$\mu_l(\varphi) = \frac{g(\varphi)}{G(\varphi_h^*)-G(\varphi_l^*)} \quad \text{if} \quad \varphi_l^* < \varphi_i < \varphi_h^* \qquad (12.A)$$
$$0 \quad \text{Otherwise}$$

$$\mu_h(\varphi) = \frac{g(\varphi)}{1-G(\varphi_h^*)} \quad \text{if} \quad \varphi_i > \varphi_h^* \qquad (13.A)$$
$$0 \quad \text{Otherwise}$$

Where $[1 - G(\varphi_l^*)]$ and $[1 - G(\varphi_h^*)]$ represent the "ex-ante" probability of successful entry and the "ex-ante" probability of having a productivity draw higher than φ_h^*.

These distributions define the weighted averages of firm's productivity levels as functions of the cutoffs.

$$\widetilde{\varphi_l}^{\phi-1} \equiv \frac{1}{G(\varphi_h^*)-G(\varphi_l^*)}\int_{\varphi_l^*}^{\varphi_h^*}(\varphi)^{\phi-1}g(\varphi)d\varphi \qquad (14.A)$$

$$\widetilde{\varphi_h}^{\phi-1} \equiv \frac{1}{1-G(\varphi_h^*)}\int_{\varphi_h^*}^{\infty}(\varphi)^{\phi-1}g(\varphi)d\varphi \qquad (15.A)$$

$\widetilde{\varphi_h}$ represents the "ex-ante" weighted average productivity level of high technology firms before they decide to adopt this technology. The "ex-post" productivity average of high technology firms have to take into account the increase in the efficiency of these firms due to the acquisition of the more advanced technology which allows them to decrease their per unit costs and increase their market shares by this term $\left(\frac{c_h}{c_l}\right)^{1-\phi}$ since $r_h(\widetilde{\varphi_h}) = r_l(\widetilde{\varphi_h})\left(\frac{c_h}{c_l}\right)^{1-\phi}$.

Hence, the weighted productivity average index of the economy ($\widetilde{\varphi_T}$) which represents the market shares of all firms producing with low and high technology is given by:

$$\widetilde{\varphi_T}^{\phi-1} = \frac{1}{N}\left[N_l\left(\widetilde{\varphi_l}\right)^{\phi-1} + N_h\left(\frac{c_h}{c_l}\right)^{1-\phi}\left(\widetilde{\varphi_h}\right)^{\phi-1}\right] \qquad (16.A)$$

The low and high technology average productivity levels and the aggregate productivity index define all aggregate variables (See Appendix B for the determination of $\widetilde{\varphi_T}$ and aggregate variables):

$$P = N^{\frac{1}{1-\phi}} p\left(\widetilde{\varphi_T}\right) \qquad R = Nr\left(\widetilde{\varphi_T}\right) \qquad \Pi = N\pi\left(\widetilde{\varphi_T}\right)$$

$$\widetilde{r} = \rho_l r_l(\widetilde{\varphi_l}) + \rho_h r_h(\widetilde{\varphi_h}) \qquad \widetilde{\pi} = \rho_l \pi_l(\widetilde{\varphi_l}) + \rho_h \pi_h(\widetilde{\varphi_h})$$

Where the probability of producing with low technology conditional on having entered the market is: $\rho_l = 1 - \frac{1-G(\varphi_h^*)}{1-G(\varphi_l^*)}$. Indeed, the probability of having a productivity draw superior to the technology cutoff conditional on having entered the market is represented by :$\rho_h = \frac{1-G(\varphi_h^*)}{1-G(\varphi_l^*)}$.

2.3 Labor Market Equilibrium and skill premium

Both skilled and unskilled labor are assumed to be perfectly mobile across firms in a country. Although firms have different labor demands depending on its productivity level, all firms pay the same skilled wage and unskilled wage. This means that there is a unique skill premium in a country which is determined by the aggregate skilled and unskilled labor demands.

Firm's skilled and unskilled labor demands are determined by profit maximization. Plugging equation (2.A) into (6.A), profit maximization process yields the following relationship between skilled, unskilled labor and the skill premium:

$$\frac{h_i}{l_i} = \omega^{\frac{1}{\alpha-1}}\left(a_h\right)^{\frac{1}{1-\alpha}} \qquad \text{for } i = \{l, h\} \qquad (17.A)$$

$$a_h > 1 \quad \text{if } i = h$$

A firm that produces with a more advanced technology skilled biased will have a higher relative skilled labor demand than firms producing with low technology.

In monopolistic competition firms anticipate their final demand. Indeed, plugging (17.A) into (2.A) and then into the equation that ensures the goods market equilibrium (7.A) yields to firm's skilled and unskilled labor demands [6]:

[6] Using the price rule given by equation 3.A, putting 7.A (goods market equilibrium) into 6.A. (profits) and plugging 18.A (labor demands) into 17.A and then into 6.A, we find that :
$\pi_l = \frac{r_l}{\phi} - f = p_l Y_l - w_l l_l - w_h h_l - f =$

$$l_i = \frac{C_i}{\varphi} c_i^{\frac{1}{1-\alpha}} (w_l)^{\frac{1}{\alpha-1}} \qquad (18.A)$$

$$h_i = \frac{C_i}{\varphi} c_i^{\frac{1}{1-\alpha}} (w_h)^{\frac{1}{\alpha-1}} (a_h)^{\frac{\alpha}{1-\alpha}} \qquad (19.A)$$

Where C_i is the demand for good "i" produced with low or high technology, φ is the productivity level of the firm, (w_l, w_h) are unskilled and skilled labor wages and c_i is per unit cost. If the firm produces with low technology $c_i = c_l$ and $a_h = 1$,while $c_i = c_h$ and $a_h > 1$ if the firm produces with the more advanced technology.

The global demand for unskilled and skilled labor at country level is determined by aggregating firm's demand taking into account firms producing in the domestic market with low and high technology (See Appendix B).

$$L^d = \int_{\varphi_l^*}^{\varphi_h^*} N_l l_l(\varphi) \mu_l(\varphi) d\varphi + \int_{\varphi_h^*}^{\infty} N_h l_h(\varphi) \mu_h(\varphi) d\varphi \qquad (20.A)$$

$$H^d = \int_{\varphi_l^*}^{\varphi_h^*} N_l h_l(\varphi) \mu_l(\varphi) d\varphi + \int_{\varphi_h^*}^{\infty} N_h h_h(\varphi) \mu_h(\varphi) d\varphi \qquad (21.A)$$

The skill premium (ω) is determined by the equality between aggregate relative demand and supply for skilled workers. Hence, the skill premium is a function of the relative supply of skilled labor $(\frac{H^s}{L^s})$, 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 $(\frac{\widetilde{\varphi_h}}{\widetilde{\varphi_l}})$.

$$\frac{H^s}{L^s} = \frac{H^d}{L^d} \qquad \Rightarrow \omega = g\left(\frac{H^s}{L^s}, a_h, N_l, N_h, \frac{\widetilde{\varphi_h}}{\widetilde{\varphi_l}}\right)$$

$$\frac{H^s}{L^s} = \omega^{\frac{1}{\alpha-1}} \left(\frac{1+(a_h)^{\frac{\alpha}{1-\alpha}} \left(\frac{N_h}{N_l}\right) \left(\frac{\widetilde{\varphi_h}}{\widetilde{\varphi_l}}\right)^{\phi-1} A}{1+\left(\frac{N_h}{N_l}\right) \left(\frac{\widetilde{\varphi_h}}{\widetilde{\varphi_l}}\right)^{\phi-1} A} \right) \qquad (22.A)$$

where $A = \left(\frac{c_h}{c_l}\right)^{-\phi} \left(\frac{(\omega)^{\frac{\alpha}{\alpha-1}}+1}{\left(\frac{\omega}{a_h}\right)^{\frac{\alpha}{\alpha-1}}+1} \right)^{\frac{1}{\alpha}}$

We assume that unskilled labor supply is higher than skilled one $(L^s > H^s)$.

2.4 Closed Economy Equilibrium conditions

The equilibrium production cutoff level (φ_l^*) depends on the skill premium which is determined by equation 22.A. Therefore, in this model the equilibrium value of φ_l^* is determined by three conditions: Free Entry (FE), Zero Cutoff Profits condition (ZCP) and the Labor Market Equilibrium. The value of φ_l^* at the equilibrium will then pin down the rest of the variables of the model.

Free Entry Condition (FE)

Before entering the market and knowing its productivity level, entrepreneurs calculate the present value of the average profit flows, to decide whether to enter in the domestic market or not. Except by the marginal firm, all other firms earn positive profits. Hence, the average profit level $\widetilde{\pi}$ is positive. Like in Melitz (2003) $\widetilde{v}$ is the present value of the average profit flows: $\widetilde{v} = \left[\sum_{t=0}^{\infty} (1-\delta)^t \, \widetilde{\pi} \right]$ and v^E is the net value of entry given by[7]:

$$v^E = (1 - G(\varphi_l^*))\,\widetilde{v} - f_E = \frac{1-G(\varphi_l^*)}{\delta}\widetilde{\pi} - f_E$$

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

FE: $$v^E = 0 \qquad \Rightarrow \widetilde{\pi} = \frac{\delta f_E}{\left(1-G(\varphi_l^*)\right)} \qquad (23.A)$$

From this condition the average profit is an increasing function of the cutoff: $\frac{\partial \widetilde{\pi}}{\partial \varphi_l^*} > 0$. A higher productivity cutoff reduces the probability of having a productivity draw higher than the cutoff level. Hence, a higher profit is needed to keep a firm indifferent between entering and exiting the market.

Zero Cutoff Profit Condition (ZCP)

The Zero Cutoff Profit Condition also determines a relation between average profits and the productivity level of the marginal firm.

ZCP: $$\widetilde{\pi} = \rho_l \pi_l(\widetilde{\varphi_l}) + \rho_h \pi_h(\widetilde{\varphi_h}) \qquad (24.A)$$

$$\widetilde{\pi} = \frac{1}{N}\left[\frac{1}{\phi}\left[N_l \int_{\varphi_l^*}^{\varphi_h^*} r_l(\varphi)\mu_l(\varphi)d\varphi + N_h \int_{\varphi_h^*}^{\infty} r_h(\varphi)\mu_h(\varphi)d\varphi\right] - Nf - N_h \delta f_t\right]$$

Plugging in average profits the revenues of low and high technology firms (eq. 5.A) and then using equation 9.A in order to express average profits as a function of the production cutoff, we obtain (See Appendix B):

$$\widetilde{\pi} = \left[\left[\rho_l \left(\frac{\widetilde{\varphi_l}}{\varphi_l^*}\right)^{\phi-1} + \rho_h \left(\frac{c_l}{c_h}\right)^{\phi-1} \left(\frac{\widetilde{\varphi_h}}{\varphi_l^*}\right)^{\phi-1} - 1\right] f - \rho_h \delta f_t\right]$$

The equality between Free entry (FE) and Zero Cutoff Profit (ZCP) conditions determines a level of "φ_l^* " which depends on the relative skill per unit cost, and thereby on the skill premium. Indeed, the equilibrium cutoff productivity level is also determined by the Labor Market Equilibrium Condition (equation 22.A).

ZCP=FE $$\varphi_l^* = f(a_h, \omega, \delta f_E, f, \delta f_t)$$

[7].The factor of discount is modeled following Melitz with a Poisson death shock probability 3b4. This variable ensures that in each period there is a fraction δ 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 $\underbrace{N_E\left[1-G(\varphi_l^*)\right]}_{\text{New entrants}} = \underbrace{\delta N}_{\text{Exiting firms}}$.

The entry sunk cost is also paid with capital.

LMC $\frac{H^s}{L^s} = \frac{H^d}{L^d}$ $\Rightarrow \omega = g(\frac{H^s}{L^s}, a_h, f, f_t, \delta)$

We get an analytical solution for the equilibrium production cutoff, assuming a pareto distribution of productivity draws (see Appendix B).We solve for the average productivity level of firms producing with low technology ($\widetilde{\varphi_l}$) and with high technology ($\widetilde{\varphi_h}$).

Under this distribution, the production cutoff is a function of the skill premium but the aggregate relative skilled labor demand does not depend on the production cutoff and therefore the skill premium is also independent of φ_l^*.

The production cutoff is a decreasing function of the relative skill per unit costs and hence of the skill premium. In Appendix B 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 ($\frac{c_h}{c_l}$), due to an increase in the skill premium ($\frac{\partial \frac{c_h}{c_l}}{\partial \omega} > 0$), 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.

This cutoff (φ_l^*) then determines the level of the technological cutoff (φ_h^*) using equation (11.A). In Appendix B we demonstrate that under the partitioning condition of closed economy $\frac{\partial \varphi_h^*}{\partial \frac{c_h}{c_l}} > 0$. This means that an increase in the relative skill per unit cost will raise the technological cutoff and thereby reduce the number of firms producing with high technology skilled biased.

Capital Market Condition

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. [8]. The price of capital is normalized to one.

The Capital Market Clearing condition is:

$$K = N_l f + N_h (f + \delta f_t) + N_E \delta f_E \qquad (25.A)$$

The number of firms producing with low technology ($N_l = \rho_l N$), those producing with high technology ($N_h = \rho_h N$) and the number of new entrants ($N_E = \frac{\delta N}{1 - G(\varphi_l^*)}$) are determined by the total number of firms and the probabilities which depend on productivity cutoff levels.

The Global Accounting

[8] 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 global accounting condition establishes that the sum of unskilled and skilled revenues and the capital used to paid fixed costs is equal to aggregate revenue of the economy (R).

$$w_h H + w_l L + K = R \qquad (26.A)$$

$R = N\widetilde{r}$
$\widetilde{\pi} = \frac{\widetilde{r}}{\phi} - f - \delta f_t \rho_h$
Using the average profit to obtain the average revenue and plugging it in this condition (eq. 28.A), we obtain the total number of firms.

$$N = \frac{w_h H + w_l L + K}{(\widetilde{\pi} + f + \delta f_t \rho_h)\phi} \qquad (27.A)$$

2.5 Open economy

Countries are symmetric in the open economy equilibrium, indeed 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 (τ) and the relative skill per unit cost ($\frac{c_h}{c_l}$). 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 the domestic market (N_{dl}). 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_{xl}). 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 the 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}).

2.6 Case 1: Extremely High Technological Costs

2.7 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 a set of domestic goods produced with low technology (Ω_{dl}) and two different sets of foreign imported varieties produced with low (Ω_{xl}) and high technology (Ω_{xh}). Consumer‘s preferences are represented by the standard C.E.S. utility function (C) between home and foreign goods.

$$C = \left(\underbrace{\underbrace{\int_{j\in\Omega_{dl}} C_{dl}^{\frac{\phi-1}{\phi}} dj}_{\text{Low technology}}}_{\text{Non traded goods}} + \underbrace{\underbrace{\int_{j\in\Omega_{xl}} C_{xl}^{\frac{\phi-1}{\phi}} dj}_{\text{Low technology}} + \underbrace{\int_{j\in\Omega_{xh}} C_{xh}^{\frac{\phi-1}{\phi}} dj}_{\text{High technology}}}_{\text{Traded goods}} \right)^{\frac{\phi}{\phi-1}}$$

The optimal relative demand functions for each type of firms are:

$$C_i = \left(\frac{P}{p_i}\right)^{\phi} C \qquad \text{for } i = \{dl, xl, xh\} \qquad (1.\text{B})$$

2.8 Production

Similarly to the closed economy equilibrium, the production function using skilled and unskilled labor is represented by a CES function given by :

$$Y_i = \varphi\left((a_h h_i)^{\alpha} + (l_i)^{\alpha}\right)^{\frac{1}{\alpha}} \qquad \text{for } \; i = \{dl, xl, xh\} \qquad (2.\text{B})$$

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.

Since there are iceberg costs of exporting production, when a firm exports a unit of good only a fraction arrives at destination. These iceberg costs represent either tariffs or transportation costs.

The first column in Table 3.3.1 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.

Table 3.3.1 Case 1: High Technological Costs   Case 2: High Trade Costs

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

(3.B) $p_{dl} = \frac{\phi}{\phi-1}\frac{c_l}{\varphi_i}$

(4.B) $c_l = \left((w_l)^{\frac{\alpha}{\alpha-1}} + (w_h)^{\frac{\alpha}{\alpha-1}}\right)^{\frac{\alpha-1}{\alpha}}$

(5.B) $r_{dl} = \left(\frac{P}{p_{dl}}\right)^{\phi-1} R$

(6.B) $\pi_{dl} = p_{dl}Y_{dl} - w_l l_{dl} - w_h h_{dl} - f \quad = \frac{r_{dl}}{\phi} - f$

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

$p_{xl} = p_{dl}\,(1+\tau)$

$r_{xl} = \left(\frac{P}{p_{dl}(1+\tau)}\right)^{\phi-1} R$

$\pi_{dl} + \pi_{xl} = \frac{r_{dl}\left[1+(1+\tau)^{1-\phi}\right]}{\phi} - f - \delta f_x$

2.Non exporters - High Technology (N_{dh})

$p_{dh} = \frac{\phi}{\phi-1}\frac{c_h}{\varphi_i}$

$r_{dh} = \left(\frac{P}{p_{dh}}\right)^{\phi-1} R$

$\pi_{dh} = \frac{r_{dh}}{\phi} - \delta f_t$

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

$r_{xh} = \left(\frac{P}{p_{dh}(1+\tau)}\right)^{\phi-1} R$ $\qquad r_{dh} + r_{xh} = r_{dh}\left[1 + (1+\tau)^{1-\phi}\right]$

$\pi_{dh} + \pi_{xh} = \frac{r_{dh}\left[1+(1+\tau)^{1-\phi}\right]}{\phi} - f - \delta f_x - \delta f_t$

Goods Market Equilibrium

(7.B) $C_i = Y_i$ for $i = \{dl, dh\}$ $\qquad C_i = \frac{Y_i}{(1+\tau)}$ for $i = \{xl, xh\}$

$$\left(\frac{c_h}{c_l}\right) = \left(\frac{(\omega)^{\frac{\alpha}{1-\alpha}}+1}{(\omega)^{\frac{\alpha}{1-\alpha}}+(a_h)^{\frac{\alpha}{1-\alpha}}}\right)^{\frac{1-\alpha}{\alpha}} \qquad (8.B)$$

Since per unit costs (c_l, c_h) are independent of productivity levels, note that equations (4.B) and (8.B) in the open economy scenario are identical to (4.A) and (8.A) in closed economy.

2.9 Production and Export decision

Both the decision to enter the market and the decision to produce remain unchanged relatively to closed economy equilibrium. Therefore, after entered the market firms obtained their productivity draw and they decide whether to produce or not. The marginal firm that decides to stay and produce is the one whose profits are equal to zero:

$$\pi_{dl}\left(\varphi^*_{dl}\right) = 0 \;\Rightarrow\; \frac{r_{dl}\left(\varphi^*_{dl}\right)}{\phi} = f \quad \Rightarrow \varphi^{*\phi-1}_{dl} = f \;\; c_l^{\phi-1}\frac{\phi}{\Psi} \qquad (9.B)$$

Similarly to Melitz (2003), the tradability condition implies that only firms with operating profits that counterweigh the amortized fixed export cost per period (δf_x) will be able to export. The zero cutoff profit condition to enter the export market is given by:

$$\pi_{xl}\left(\varphi^*_{xl}\right) = 0$$

$$\frac{r_{xl}}{\phi} = \delta f_x \qquad \Rightarrow \varphi^{*\phi-1}_{xl} = f_x\left(1+\tau\right)^{\phi-1} c_l^{\phi-1}\frac{\phi}{\Psi} \qquad (10.1.B)$$

The export productivity cutoff is represented by "φ^*_{xl}". This value corresponds to the productivity level of the marginal firm which is able to enter the foreign market.

Combining (9.B) and (10.1.B) yields to the value of φ^*_{xl} as an implicit function of φ^*_{dl} is given by:

$$\frac{r_{xl}\left(\varphi^*_{xl}\right)}{r_{dl}\left(\varphi^*_{dl}\right)} = \frac{\delta f_x \phi}{f\phi} \qquad \Rightarrow \qquad \varphi^*_{xl} = \varphi^*_{dl}\left(\frac{\delta f_x}{f}\right)^{\frac{1}{\phi-1}}\left(1+\tau\right) \qquad (11.1.B)$$

2.10 The decision to adopt High Technology

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. Therefore, 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. This condition is given by:

$$\pi_{dh}(\varphi^*_{xh}) + \;\pi_{xh}(\varphi^*_{xh}) = \pi_{dl}(\varphi^*_{xh}) + \pi_{xl}(\varphi^*_{xh})$$

$$\frac{\left[r_{dh}(\varphi^*_{xh})+r_{xh}(\varphi^*_{xh})\right]-\left[r_{dl}(\varphi^*_{xh})+r_{xl}(\varphi^*_{xh})\right]}{\phi} = \delta f_t$$

$$\varphi_{xh}^{*\phi-1} = \frac{f_t}{\left[1+(1+\tau)^{1-\phi}\right]\left[c_h^{1-\phi}-c_l^{1-\phi}\right]}\ \frac{\phi}{\Psi} \qquad (10.2.B)$$

The productivity cutoff to acquire high technology is represented by "φ_{xh}^*". The value of (φ_{xh}^*) as a function of (φ_{dl}^*) is given by (9.B) and (10.2.B):

$$\varphi_{xh}^* = \varphi_{dl}^*\left(\frac{\delta f_t}{f}\right)^{\frac{1}{\phi-1}} \left[\left[\left(\frac{c_h}{c_l}\right)^{1-\phi} - 1\right]\left[1+(1+\tau)^{1-\phi}\right]\right]^{\frac{1}{1-\phi}} \qquad (11.2.B)$$

In this case, the specific partitioning condition of firms by export and technology status which ensures that $\varphi_{xh}^* > \varphi_{xl}^* > \varphi_{dl}^*$ is:

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

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.

The weighted productivity average of each group of firms ($\widetilde{\varphi_{dl}}, \widetilde{\varphi_{xl}}, \widetilde{\varphi_{xh}}$) are defined using the same type of weighted average function define in (14.A) (Appendix C.1 details the aggregation).

2.11 Labor Market Equilibrium

In the open economy equilibrium, exporting firms producing with low and high technology will increase their skilled and unskilled labor demand to produce for the foreign market. These demands are determined similarly to (18.A) and (19.A), taking into account the domestic final goods demand (C_{dl}, C_{dh}) and the foreign final goods demand (C_{xl}, C_{xh}) of exporting firms.

$$l_{xi} = \frac{[C_{xi}+C_{di}]}{\varphi} c_i^{\frac{1}{1-\alpha}} (w_l)^{\frac{1}{\alpha-1}} \qquad (18.B)$$

$$h_{xi} = \frac{[C_{xi}+C_{di}]}{\varphi} c_i^{\frac{1}{1-\alpha}} (w_h)^{\frac{1}{\alpha-1}} (a_h)^{\frac{\alpha}{1-\alpha}} \qquad (19.B)$$

Where $i = \{l, h\} \qquad a_h > 1$ if $i = h$

Like (20.A) and (21.A) the global demand for unskilled and skilled labor at country level is determined by aggregating firm's demand. In this case we have to take into account firms producing in the domestic market and both types of exporting firms (See Appendix C.1).

$$L^d = \int_{\varphi_{dl}^*}^{\varphi_{xl}^*} N_{dl} l_{dl}(\varphi)\, \mu_{dl}(\varphi) d\varphi + \int_{\varphi_{xl}^*}^{\varphi_{xh}^*} N_{xl} l_{xl}(\varphi)\, \mu_{xl}(\varphi) d\varphi + \int_{\varphi_{xh}^*}^{\infty} N_{xh} l_{xh}(\varphi)\, \mu_{xh}(\varphi) d\varphi \qquad (20.B)$$

$$H^d = \int_{\varphi_{dl}^*}^{\varphi_{xl}^*} N_{dl} h_{dl}(\varphi)\, \mu_{dl}(\varphi) d\varphi + \int_{\varphi_{xl}^*}^{\varphi_{xh}^*} N_{xl} h_{xl}(\varphi)\, \mu_{xl}(\varphi) d\varphi + \int_{\varphi_{xh}^*}^{\infty} N_{xh} h_{xh}(\varphi)\, \mu_{xh}(\varphi) d\varphi \qquad (21.B)$$

The aggregate relative supply and demand of skilled labor jointly determine the skill premium. Like in closed economy, we assume that unskilled labor supply is higher than skilled one ($L^s > H^s$).

$\frac{H^s}{L^s} = \frac{H^d}{L^d} \qquad \Rightarrow \omega = g(\frac{H^s}{L^s}, a_h, N_{dl}, N_{xl}, N_{xh,}\widetilde{\varphi_{dl}}, \widetilde{\varphi_{xl}}, \widetilde{\varphi_{xh}})$

$$\frac{H^s}{L^s} = \omega^{\frac{1}{\alpha-1}} \left[\frac{1+(a_h)^{\frac{\alpha}{1-\alpha}} \left[\frac{N_{xh}\widetilde{\varphi_{xh}}^{\phi-1}\left[1+(1+\tau)^{1-\phi}\right]}{N_{dl}\widetilde{\varphi_{dl}}^{\phi-1}+N_{xl}\widetilde{\varphi_{xl}}^{\phi-1}\left[1+(1+\tau)^{1-\phi}\right]} \right] A}{1+\left[\frac{N_{xh}\widetilde{\varphi_{xh}}^{\phi-1}\left[1+(1+\tau)^{1-\phi}\right]}{N_{dl}\widetilde{\varphi_{dl}}^{\phi-1}+N_{xl}\widetilde{\varphi_{xl}}^{\phi-1}\left[1+(1+\tau)^{1-\phi}\right]} \right] A} \right] \qquad (22.B)$$

In the case of the Pareto distributed productivities the aggregate relative skilled labor demand as well as the skill premium are independent of the cutoff productivity level (φ_l^*).

Under Pareto distribution of productivity draws and the specific partitioning condition of case 1, both the aggregate relative demand of skill labor and the skill premium are a decreasing function of tariffs (we show and explain this result in Appendix C.1 and in section 4).

2.12 Case 1: Open Economy Equilibrium conditions

This subsection summarizes the open equilibrium conditions of the case 1. 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.1).

The equilibrium level of the productivity cutoff is determined by the Free Entry, the new Zero Cutoff Profit condition and the Labor Market equilibrium (determined by equation 22.B), just as in closed economy equilibrium. FE remains unchanged. In the zero cutoff profit condition

of the open economy equilibrium, we have to take into account the average profits of exporters producing with low and high technology.

FE: $\widetilde{\pi} = \frac{\delta f_E}{\left(1-G(\varphi_{dl}^*)\right)} \qquad (23.B)$

ZCP:$\widetilde{\pi} = \pi_{dl}(\widetilde{\varphi_{dl}})\rho_{dl} + \rho_{xl}\left[\pi_{dl}(\widetilde{\varphi_{xl}}) + \pi_{xl}(\widetilde{\varphi_{xl}})\right] + \rho_{xh}\left[\pi_{dh}(\widetilde{\varphi_{xh}}) + \pi_{xh}(\widetilde{\varphi_{xh}})\right] (24.B)$

Where

$\rho_l = 1 - \frac{1-G(\varphi_{xh}^*)}{1-G(\varphi_{dl}^*)} \qquad \rho_{xh} = \frac{1-G(\varphi_{xh}^*)}{1-G(\varphi_{dl}^*)}$

$\rho_{xl} = \frac{1-G(\varphi_{xl}^*)}{1-G(\varphi_{dl}^*)} - \frac{1-G(\varphi_{xh}^*)}{1-G(\varphi_{dl}^*)} \qquad \rho_x = \frac{1-G(\varphi_{xl}^*)}{1-G(\varphi_{dl}^*)}$

The variables "$\rho_l, \rho_{xh}, \rho_{xl}, \rho_x$"represent the probability of being a low technology firm including domestic and exporting firms (ρ_l) , of being an exporting high technology firm (ρ_{xh}), an exporting low technology firm (ρ_{xl}) and finally the probability of being an exporting firm including low and high technology firms (ρ_x), all probabilities are defined conditional on survival.

ZCP=FE $\varphi^*_{dl} = f(a_h, \omega, \delta f_E, f, \delta f_x, \delta f_t, \tau)$

LMC $\frac{H^s}{L^s} = \frac{H^d}{L^d} \quad \Rightarrow \omega = g(\frac{H^s}{L^s}, a_h, f, \tau, f_x, f_t, \delta)$

This cutoff (φ^*_{dl}) then determines the export cutoff (φ^*_{xl}) using equation (11.1.B) and the technological cutoff (φ^*_{xh}) using equation (11.2.B).

Capital Market and Global Accounting Conditions

Capital market clearing condition as well as the global accounting condition have to take into account trade costs of firms exporting on the foreign market with low and high technology.

$$K = N_{dl} f + N_{xl}\left(f + \delta f_x\right) + N_{xh}\left(f + \delta f_x + \delta f_t\right) + N_E f_E \tag{25.B}$$

$$w_h H + w_l L + K = R \tag{26.B}$$

$$N = \frac{w_h H + w_l L + K}{[\widetilde{\pi} + f + \delta f_x \rho_{xl} + (\delta f_x + \delta f_t)\rho_{xh}]\phi} \tag{27.B}$$

2.13 Case 2: Extremely High Trade Costs

2.14 Households Consumption

In case 2, the representative household allocates consumption between two different sets of available domestic varieties (Ω_{dl}, Ω_{dh}) and one set of foreign varieties (Ω_{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:

$$C = \left(\underbrace{\underbrace{\int_{j\in\Omega_{dl}} C_{dl}^{\frac{\phi-1}{\phi}} dj}_{\text{Low technology}} + \underbrace{\int_{j\in\Omega_{dh}} C_{dh}^{\frac{\phi-1}{\phi}} dj}_{\text{High technology}}}_{\text{Non traded goods}} + \underbrace{\underbrace{\int_{j\in\Omega_{xh}} C_{xh}^{\frac{\phi-1}{\phi}} dj}_{\text{High technology}}}_{\text{Traded goods}} \right)^{\frac{\phi}{\phi-1}}$$

2.15 Production

As in the previous case the production function is represented by $Y_i = \varphi\left((a_h h_i)^\alpha + (l_i)^\alpha\right)^{\frac{1}{\alpha}}$, 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 3.3.1 summarizes the revenues, profits and prices of firms producing in this specific case.

As in the previous case, the decision to enter the market and then stay and produce or exit remains unchanged relatively to closed economy equilibrium (equation 9.A=9.B). In case 2, since fixed technology costs are lower than trade costs, the technology adoption condition is also exactly the same as in the case of a closed economy equilibrium (equations (10.A) and (11.A)).

Indeed, in the next section, we will only analyze the decision to export.

2.16 Export decision

After more productive firms among producers have adopted the 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 :

$$\pi_{xh}(\varphi^*_{xh}) = 0$$

$$\frac{r_{xh}}{\phi} = \delta f_x \qquad \Rightarrow \qquad \varphi_{xh}^{\phi-1} = \delta f_x (1+\tau)^{\phi-1}\ c_h^{\phi-1} \frac{\phi}{\Psi} \qquad (10.3.B)$$

The export productivity cutoff is represented by "φ^*_{xh}". Using (9.B) and (10.3.B) the value of the export cutoff "φ^*_{xh}" as a function of the productivity cutoff " φ^*_{dl}"is given by:

$$\frac{r_{xh}(\varphi^*_{xt})}{r_{dl}(\varphi^*_{dl})} = \frac{\delta f_x \phi}{f\phi} \qquad \Rightarrow \varphi_{xh} = \varphi^*_{dl}\left(\frac{\delta f_x}{f}\right)^{\frac{1}{\phi-1}}\left(\frac{c_h}{c_l}\right)(1+\tau) \qquad (11.3.B)$$

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

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

2.17 Case 2: Open Economy Equilibrium conditions

FE: $\widetilde{\pi} = \frac{\delta f_E}{\left(1-G(\varphi^*_{dl})\right)}$

ZCP: $\widetilde{\pi} = \rho_{dl}\pi_{dl}(\widetilde{\varphi_{dl}}) + \rho_{dh}\pi_{dh}(\widetilde{\varphi_{dh}}) + \rho_{xh}\left[\pi_{dh}(\widetilde{\varphi_{xh}}) + \pi_{xh}(\widetilde{\varphi_{xh}})\right]$

$\rho_{dl} = 1 - \frac{1-G(\varphi^*_{dh})}{1-G(\varphi^*_{dl})} \qquad \rho_{dh} = \frac{1-G(\varphi^*_{dh})}{1-G(\varphi^*_{dl})} - \frac{1-G(\varphi^*_{xh})}{1-G(\varphi^*_{dl})} \qquad \rho_{xt} = \frac{1-G(\varphi^*_{xh})}{1-G(\varphi^*_{dl})}$

FE=ZCP $\Rightarrow$ $\varphi^*_{dl} = f(a_h, \omega, f_E, f, \delta f_t, \delta f_x, \tau)$

LMC $\left(\frac{H}{L}\right)^S = \left(\frac{H}{L}\right)^D = \frac{H_{dl}+H_{dh}+H_{xh}}{L_{dl}+L_{dh}+L_{xh}} \qquad \Rightarrow \omega = g(\frac{H^s}{L^s}, a_h, f, f_t, f_x, \tau, \delta)$

KMC: $K = N_{dl}f + N_{dh}\left(f + \delta f_t\right) + N_{xh}\left(f + \delta f_x + \delta f_t\right) + N_E f_E$

$N = \frac{w_h H + w_l L + K}{[\widetilde{\pi} + f + \delta f_t \rho_{dh} + (\delta f_t + \delta f_x)\rho_{xh}]\phi}$

Appendix C.2 shows the aggregation, the labor market condition, the parametrization of the productivity draws assuming a pareto distribution and the equilibrium cutoff for case 2. In this Appendix we also demonstrate that under Pareto distribution and the partitioning condition of case 2, the aggregate relative skilled labor demand is a decreasing function of tariffs. Since the aggregate supply is fixed, the skilled premium will also be a decreasing function of tariffs.

3 Results of the model

3.0.1 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 variable trade costs 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).

Table 3 and Figure 1 summarize the main results. The production cutoff depends on the skill premium and this variable is determined in the labor market equilibrium (equation 22.B.). The aggregate relative skilled labor demand and the skill premium are both a decreasing function of variable trade costs.[9] Therefore, in order to study the impact of a tariff reduction on the productivity cutoff we run simulations of the equilibrium cutoff function (determined in Appendix

[9] In Appendix C. 1 we demonstrate that under the specific partitioning condition of case 1, the aggregate relative demand of skilled labor is a decreasing function of tariffs. Graph 3 (Appendix D) shows the simulation results of the impact of a tariff reduction on the aggregate relative demand of skilled labor and on the skill premium. These results remain robust for different parameters values (fixed costs, variable trade costs and skill efficiency) respecting the specific partitioning condition.

C.1) under the partitioning condition of case 1 [10]. In these simulations we assume that unskilled labor supply is higher than skilled one. Graph 1 and 2 (Appendix D) detail these simulation results.

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" developed in Melitz (2003). The entry of most productive foreign exporters in the domestic market after trade liberalization reduces domestic market shares of all firms selling in the domestic market. All firms lose a portion of their domestic sales, inducing the exit of the least productive ones 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.

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. This increase in export profitability creates incentives to adopt new and high technology. Therefore the raise 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.[11]

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 and unskilled intensive technology, they will benefit from a reduction of the relative wage of unskilled labor (the raise of the skill premium) . 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.

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

[10]These simulations take into account the global effect of tariffs on firms decisions (including the effects of the skill premium on the productivity cutoffs). These results remain robust for different parameters values. In Graph 1 and 2 (Appendix D) we specify the parameters values used.

[11]The exit of least productive unskilled intensive firms will reduce the aggregate unskilled labor demand but the increase in the number of exporters using low technology unskilled biased will raise this demand. On the other hand, the increase in the number of firms using high technology will raise the aggregate skilled labor demand. Since high technology firms are the most productive ones, they have a larger demand of final goods than firms producing with low technology. At the end there will be a raise in the relative aggregate skilled labor demand.

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, Appendix D). 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. 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

Domestic cutoff φ^*_{dl}	**Export cutoff** φ^*_{xl}	**Technology cutoff** φ^*_{xh}
$\frac{\partial \varphi^*_{dl}}{\partial \tau}$ = F.C + ω effect	$\frac{\partial \varphi^*_{xl}}{\partial \tau}$ =X.S+ω effect > 0	$\frac{\partial \varphi^*_{xh}}{\partial \tau}$ = X.S +ω effect
First Order Effect		
Foreign Competition (FC) (-)	Export selection effect (X.S) (+)	Extensive margin Tech (X.S) (+)
Second Order Effect	$\frac{\partial \frac{H}{L}}{\partial \tau} < 0 \Rightarrow \Uparrow \left(\frac{H}{L}\right)^d \Uparrow \omega$	
Skill premium effect (+) $\frac{\partial \varphi^*_{dl}}{\partial \left(\frac{c_h}{c_l}\right)} < 0$	Skill premium effect (+) $\frac{\partial \varphi^*_{xl}}{\partial \left(\frac{c_h}{c_l}\right)} < 0$	Skill premium effect (-) $\frac{\partial \varphi^*_{xh}}{\partial \left(\frac{c_h}{c_l}\right)} > 0$
Final effect on φ^*_{dl}	**Final effect on** φ^*_{xl}	**Final effect on** φ^*_{xh}
$\frac{\partial \varphi^*_{dl}}{\partial \tau} < 0$	$\frac{\partial \varphi^*_{xl}}{\partial \tau} > 0$	$\frac{\partial \varphi^*_{xh}}{\partial \tau} > 0$

"The effects of tariffs reduction on the cutoff productivity levels"

Figure1: **Case 1**

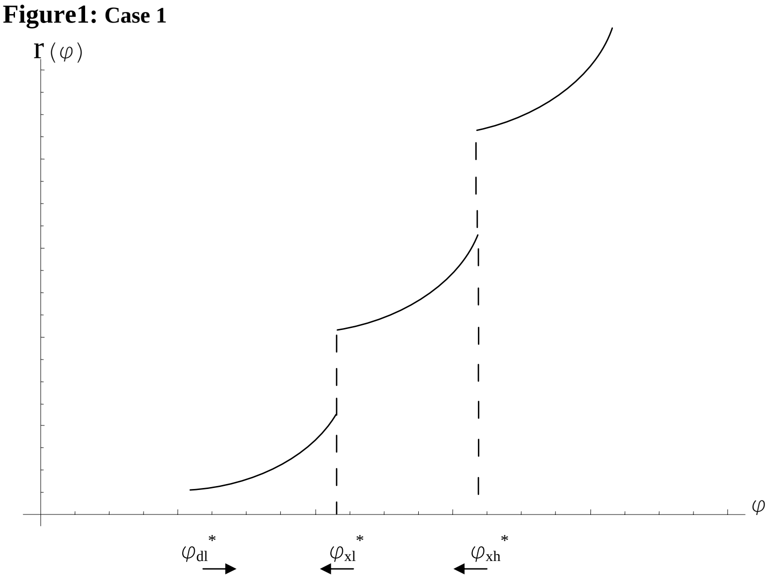
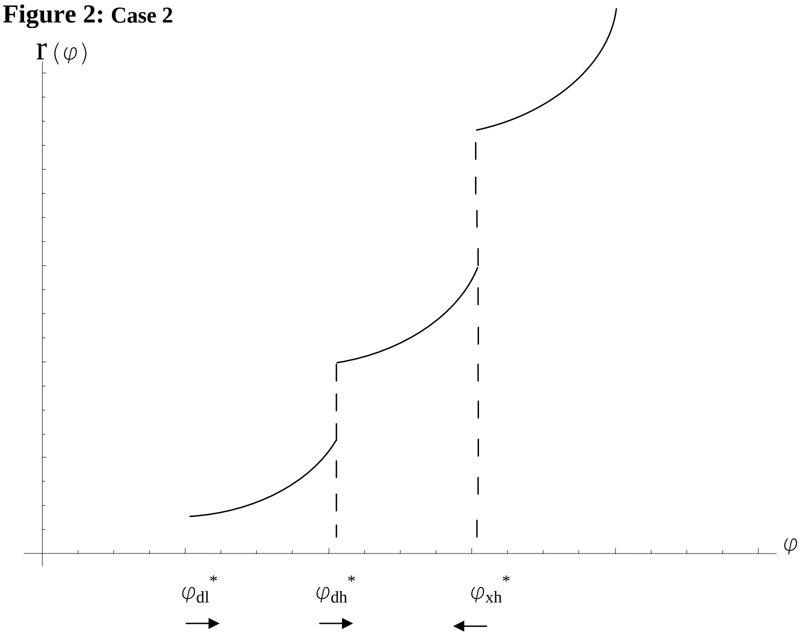


Figure 2: **Case 2**



3.0.2 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.

Table 4 and Figure 2 show the main results of the effects of variable trade costs reductions on firm's decisions in the second case. Graph 4, 5a, 5b and 6 (Appendix D) show the simulation results [12] of the impact of tariffs reduction on the relative demand of skilled labor and on the skill premium, on the production cutoff and on 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 the 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 biaised 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 5a, 5b and 6 Appendix D). The increase in the number of firms selling abroad and producing with high technology (the reduction of the export productivity cutoff) is higher than the reduction of the number of domestic firms using high technology (the increase in the technology productivity cutoff). 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.[13]

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

[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: $f_x\ (1+\tau)^{\phi-1}\left(\frac{c_h}{cl}\right)^{\phi-1} > \frac{f_t}{\left[\left(\frac{c_h}{c_l}\right)^{1-\phi}-1\right]} > f$. These results also remain robust for different parameters values (fixed costs, variable trade costs and skill efficiency) respecting the specific partitioning condition of case 2. Each graph specifies the parameters values used in these simulations.

[13] At the same time, the reduction of domestic market shares of all domestic firms due to fiercer foreign competition reduces the unskilled labor demand of firms selling only in the domestic market.

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: The impact of variable trade cost (τ) in case 2

Domestic cutoff φ^*_{dl}	**Technology cutoff** φ^*_{dh}	**Export cutoff** φ^*_{xh}
$\frac{\partial \varphi^*_{dl}}{\partial \tau}$ =F.C + ω effect	$\frac{\partial \varphi^*_{dh}}{\partial \tau}$ =F.C + ω effect < 0	$\frac{\partial \varphi^*_{xh}}{\partial \tau}$ =X.S.+ω effect
First Order Effect		
Foreign Competition (FC) **(-)**	Foreign Competition (FC) **(-)**	Export selection effect (X.S) **(+)**
Second Order Effect		
Skill premium effect **(+)**	Skill premium effect **(-)**	Skill premium effect **(-)**
$\frac{\partial \varphi^*_{dl}}{\partial \left(\frac{c_h}{c_l}\right)} < 0$	$\frac{\partial \varphi^*_{dh}}{\partial \left(\frac{c_h}{c_l}\right)} > 0$	$\frac{\partial \varphi^*_{xh}}{\partial \left(\frac{c_h}{c_l}\right)} > 0$
Final effect on φ^*_{dl}	**Final effect on** φ^*_{dh}	**Final effect on** φ^*_{xh}
$\frac{\partial \varphi^*_{dl}}{\partial \tau} < 0$	$\frac{\partial \varphi^*_{dh}}{\partial \tau} < 0$	$\frac{\partial \varphi^*_{xh}}{\partial \tau} > 0$

4 Empirical evidence

4.1 Data and descriptive analysis

In this section we provide some evidence supporting the key assumption of the theoretical model, namely that the advanced technology is skill-biased. Since the theoretical 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 Estadisticas de Chile) [14].

[14]This survey is a comprehensive manufacturing census of Chilean covering all 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 deflectors 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 that equals 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 the domestic one. [15].

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% of the sample, therefore exporters are an average of 21%. Within exporters, 40% of plants are large and 36% are of medium size, while only 20% are small firms. [16]. 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.[17].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%) 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. 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 variation within industries. The between indicator is negative and extremely small [18] 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

[15]Unfortunately, we cannot 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

[16]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

[17]We follow the standard classification of the ownership structure: a foreign plant is one which reports that more than 50% of the total asses are foreigners

[18]Similar results hold at 2 digit industry level and at firm level.

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 skill intensity.

4.2 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, 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 test this relationship in three different sub-samples distinguishing between firms belonging to export oriented, import competing and the non-traded sector.[19] 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 minimize 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 2 digit industry and year dummies instead of relative wages. We also control for possible agglomeration effects using area indicators. We estimate the following equation:

$$(2)\ S_{it} = \beta_1 + \beta_y \ln(Y_{it}) + \beta_k \ln(K_{it}/Y_{it}) + \beta_t TECH + \beta_i IND + \beta_a AREA + \beta_t YEAR + \epsilon_{it}$$

The dependant variable (Sit) is the share of skilled workers in wage bill, $ln\,(K/Y)$ 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

[19]We use the same classification of Pavnick (2002). Plants belonging to 3 digit industry which have more than 15% of exports over total production are classified as exported oriented plants; while plants belonging to 3 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.

full sample. After controlling by 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.[20]

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 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 still positive and significant.

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 advanced 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.

[20]We also run the same regressions using the skill premium as a dependant 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

5 Conclusions

This paper has explored how technology choice is determined by firm's productivity level, in order 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 empirical estimations provide evidence for the case of Chile supporting the key theoretical assumption: high technology is skill biased.

Concerning policy implications, trade liberalization through tariffs reduction 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, tariffs reduction will encourage the adoption of high technology. In this case, the rise in export revenues allows the most productive exporters to switch to high technology, increasing the extensive margin of technology. However, if trade costs are extremely higher than fixed technology costs, trade liberalization will diminish 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.

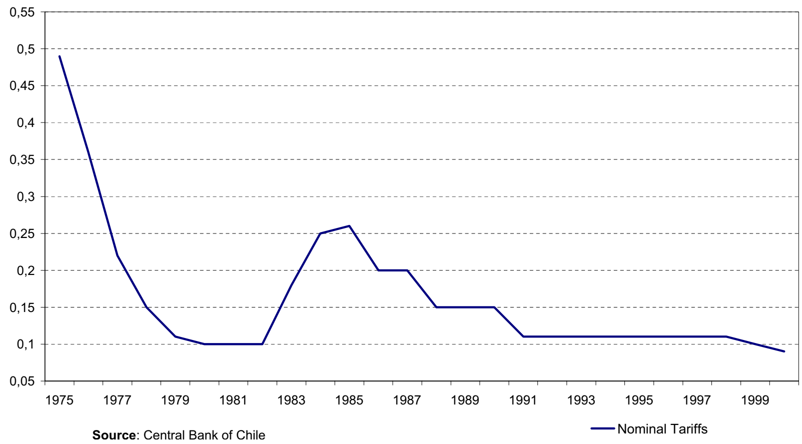
In both cases, tariff reductions increase inequalities between skilled and unskilled labor. In the first case, the increase in the number of firms producing with high technology enhances the relative demand of skilled labor and boosts up the skill premium. In the second case, despite the reduction of the extensive margin of technology, there is also a rise in the skill premium. Trade reforms improve 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 the 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 paper to the existing literature is to propose a model that links the increase in regional trade with the rise in the skill premium in developing countries. The classical framework of H-O-S is not appropriate to explain these facts. 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 after trade reforms. Trade integration between symmetric countries will raise the relative demand of skilled labor complementary with high technology and thereby will enhance inequalities in both countries.

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

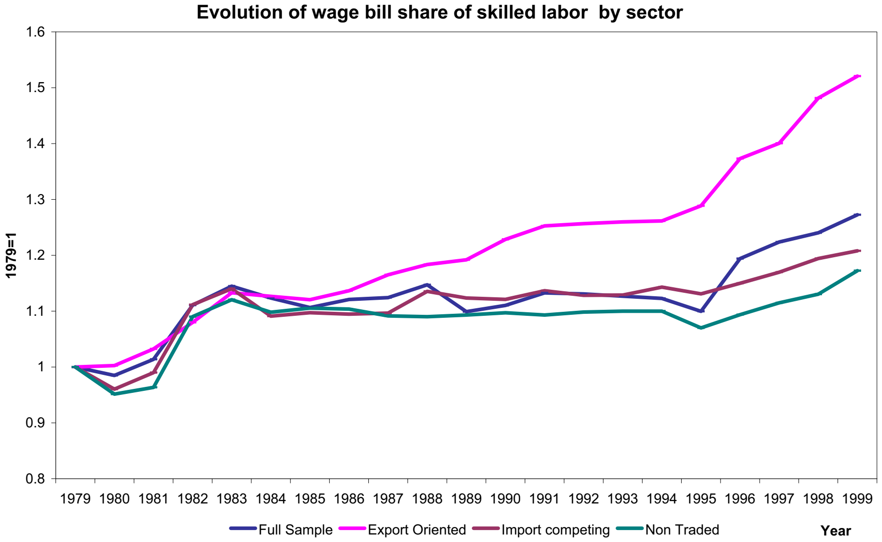


Table 1

Characteristics (Averages 1990-1999)	**Exporters**	**Domestic firms Non exporters**
Number of Firms	7940 (21%)	30668 (79%)
Continuing exporters	4980 (13%)	
New exporters	1540 (4%)	
Stops exporting	1420 (4%)	
Size %		
Large (more 150)	40	6
Medium (50-149)	36	20
Small (10-49)	24	74
TFP (average)	1021	777
Type of Ownership		
% Foreign	11	1
% Domestic	89	99
Foreing Technology		
% FTA	14	3
Continuing exporters	87	
New exporters	12	
Stops exporting	1	

Table 2

% of Plants that use different kinds of technology measures

Year	**FTA**	**Patent**	**Imported Inputs**
1979	4	64	22
1980	4	63	21
1981	4	67	23
1982	4	70	22
1983	4	76	23
1984	5	76	24
1985	5	78	24
1986	5	80	25
1987	6	83	26
1988	6	84	26
1989	5	85	23
1990	5	84	23
1991	5	85	25
1992	5	85	25
1993	6	85	23
1994	6	85	25
1995	5	85	26
1996	6	85	27
1997	5	86	28
1998	6	86	28
1999	6	89	28

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

Relative Demand of Skilled Labor

	1979 - 1999				**1979 - 1986**				**1990 - 1999**			
	Total	Between	Within	Within/Total	Total	Between	Within	Within/Total	Total	Between	Within	Within/Total
Industries at 2 digit	0.0792	-0.0144	0.0935	1.1817	0.3778	0.1100	0.2678	0.7088	0.0564	0.0010	0.0554	0.9831
Industries at 3 digit	0.2019	-0.0046	0.2065	1.0228	0.2388	-0.0336	0.2724	1.1406	0.0689	0.0021	0.0668	0.9690
Firms	0.2270	0.0687	0.1584	0.6976	0.3173	0.1738	0.1435	0.4522	0.0449	-0.0830	0.1279	2.8464

Relative Skilled Wage

	1979 - 1999				**1979 - 1986**				**1990- 1999**			
	Total	Between	Within	Within/Total	Total	Between	Within	Within/Total	Total	Between	Within	Within/Total
Industries at 2 digit	0.0147	-0.0081	0.0228	1.5494	0.1271	0.0025	0.1246	0.9805	0.1570	-0.0386	0.1956	1.2459
Industries at 3 digit	0.3242	0.0410	0.2832	0.8736	0.5180	-0.0106	0.5287	1.0205	0.5634	-0.2953	0.8587	1.5241
Firms	1.5181	0.4641	1.0540	0.6943	0.7522	0.3394	0.4129	0.5489	0.6399	0.1000	0.5399	0.8437

Appendix B: closed economy equilibrium

Relative skill per unit cost

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

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

$$\frac{\partial \frac{c_h}{c_l}}{\partial \omega} = \left(\frac{1-\alpha}{\alpha}\right) \left(\left(\frac{c_h}{c_l}\right)^{\frac{\alpha}{1-\alpha}} \right)^{\frac{1-\alpha}{\alpha}-1} \left[\frac{\left(\frac{\alpha}{1-\alpha}\right)(\omega)^{\frac{\alpha}{1-\alpha}-1}\left[(a_h)^{\frac{\alpha}{1-\alpha}}-1\right]}{\left[(\omega)^{\frac{\alpha}{1-\alpha}}+(a_h)^{\frac{\alpha}{1-\alpha}}\right]^2} \right]$$

$$\frac{\partial \frac{c_h}{c_l}}{\partial \omega} > 0 \qquad \text{since } (a_h)^{\frac{\alpha}{1-\alpha}} - 1 > 0 \qquad \text{and} \qquad 0 < \alpha < 1$$

Aggregation

Using price rule defined in equation 3.A and plugging it into aggregate price index yields

$$P^{1-\phi} = \left(\frac{\phi}{\phi-1}\right)^{1-\phi} (c_l)^{1-\phi} \left[N_l \left(\widetilde{\varphi_l}\right)^{\phi-1} + N_h \left(\frac{c_h}{c_l}\right)^{1-\phi} \left(\widetilde{\varphi_h}\right)^{\phi-1} \right]$$

$$P = N^{\frac{1}{1-\phi}} p\left(\widetilde{\varphi_T}\right)$$

Where

$$p\left(\widetilde{\varphi_T}\right) = \frac{\phi}{\phi-1} \frac{c_l}{\widetilde{\varphi_T}}$$

$$\widetilde{\varphi_T}^{\phi-1} = \frac{1}{N} \left[N_l \left(\widetilde{\varphi_l}\right)^{\phi-1} + N_h \left(\frac{c_h}{c_l}\right)^{1-\phi} \left(\widetilde{\varphi_h}\right)^{\phi-1} \right]$$

Aggregate Revenu

$$R = N_l \int_{\varphi_l^*}^{\varphi_h^*} r_l(\varphi)\mu_l(\varphi)d\varphi + N_h \int_{\varphi_h^*}^{\infty} r_h(\varphi)\mu_h(\varphi)d\varphi$$

$$R = N_l r_l(\widetilde{\varphi_l}) + N_h r_h(\widetilde{\varphi_h})$$

$$R = N_l r_l(\widetilde{\varphi_l}) + N_h r_l(\widetilde{\varphi_h}) \left(\frac{c_h}{c_l}\right)^{1-\phi} \qquad \text{Where} \qquad r_h(\widetilde{\varphi_h}) = r_l(\widetilde{\varphi_h}) \left(\frac{c_h}{c_l}\right)^{1-\phi}$$

$$R = N \underbrace{\left[\frac{N_l}{N} r_l(\widetilde{\varphi_l}) + \frac{N_h}{N} r_l(\widetilde{\varphi_h}) \left(\frac{c_h}{c_l}\right)^{1-\phi} \right]}_{r(\widetilde{\varphi_T})} = N r\left(\widetilde{\varphi_T}\right)$$

Labor Market condition

Plugging firm's final good demands (1.A) into (18.A) and (19.A), firm's indiviudual demand

of skilled (h_l, h_h) and unskilled labor of both types of firms are:

$$l_i = \left(\frac{P}{p_i}\right)^{\phi} \frac{C}{\varphi} \left(\left(\frac{\omega}{a_h}\right)^{\frac{\alpha}{\alpha-1}} + 1\right)^{-\frac{1}{\alpha}} \qquad (18.A')$$

$$h_i = \left(\frac{P}{p_i}\right)^{\phi} \frac{C}{\varphi a_h} \left(\left(\frac{a_h}{\omega}\right)^{\frac{\alpha}{\alpha-1}} + 1\right)^{-\frac{1}{\alpha}} \qquad (19.A')$$

Where $i = \{l, h\}$ $\qquad a_h > 1 \qquad$ if $i = h$

Plugging firm's prices (3.A) in (18.A') and (19.A') and then into aggregate skilled and un-

skilled labor demand using (20.A) and (21.A), we obtain the aggregate relative demand of skilled labor (22.A) which determines the skill premium.

Averages productivities assuming Pareto distribution

We follow Melitz and Ghironi (2005) and Melitz and Ottaviano (2005) and we assume that productivity draws are distributed according to a Pareto distribution $g(\varphi) = \frac{k(\varphi_{\min})^k}{(\varphi)^{k+1}}$ with a lower bound $\varphi_{\min}$ 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 $\varphi_{\min}$. We assume that $\varphi_{\min} = 1$ and the condition that ensures a finite mean of firm size is $k > \phi - 1$. The cumulative distribution function is $G(\varphi_i) = 1 - \left(\frac{\varphi_{\min}}{\varphi_i}\right)^k$

Using this specific distribution of productivity draws we solve for the average productivities $(\widetilde{\varphi_l}, \widetilde{\varphi_h})$ determines by equations 14.A and 15.A and also the probabilities (ρ_l, ρ_h) defined in equation 24 and 25.

Average productivity of firms producing with low technology

$$\widetilde{\varphi_l} \equiv \upsilon \varphi_l^* \left[\frac{1-(\xi)^{-k+\phi-1}}{1-\xi^{-k}}\right]^{\frac{1}{\phi-1}} \qquad \text{if} \qquad \varphi_l^* < \varphi < \varphi_h^*$$

Where $\qquad \upsilon = \left[\frac{k}{k-(\phi-1)}\right]^{\frac{1}{\phi-1}} \qquad \xi = \left(\frac{\delta f_t}{f}\right)^{\frac{1}{\phi-1}} \left[\left(\frac{c_h}{c_l}\right)^{1-\phi} - 1\right]^{\frac{1}{1-\phi}}$

Average productivity of firms producing with high technology

$\widetilde{\varphi_h} \equiv \upsilon\varphi_h^* \qquad \text{if} \qquad \varphi > \varphi_h^*$

Determination of probabilities:

$$\underbrace{0 \qquad\qquad \varphi_l^*}\underbrace{\qquad\qquad \varphi_h^*}_{\rho_l}\underbrace{\qquad\qquad\qquad}_{\rho_h}\infty$$

$\rho_l = 1 - \frac{1-G(\varphi_h^*)}{1-G(\varphi_l^*)} = 1 - \left(\frac{\varphi^*}{\varphi_h^*}\right)^k$

$\rho_h = \frac{1-G(\varphi_h^*)}{1-G(\varphi_l^*)} = \left(\frac{\varphi^*}{\varphi_h^*}\right)^k$

We use these averages and probabilities to solve the aggregate relative demand of skilled labor and the skill premium. Under Pareto distribution of productivity draws, the aggregate relative demand of skilled labor is independent of the production cutoff.

Determination of closed economy equilibrium

LMC (22.A), FE (23.A) and ZCP (24.A) conditions jointly determine the equilibrium cutoff level (φ^*). Plugging into equation 24.A: the averages productivities, the technology cutoff defined in equation (11.A) and the probabilities of being each type of firm; and then inserting in the FE condition the probability of having a productivity draw higher than the cutoff, we obtain the production cutoff level as a function of the skill premium:

$$\underbrace{\frac{\delta f_E}{(1-G(\varphi_l^*))}}_{\textbf{F.E.}} = \underbrace{\rho_l\pi_l(\widetilde{\varphi_l}) + \rho_h\pi_h(\widetilde{\varphi_h})}_{\textbf{Z.C.P}}$$

$\frac{\delta f_E}{(1-G(\varphi_l^*))} = \frac{1}{N}\left[\frac{1}{\phi}\left[N_l\int_{\varphi^*}^{\varphi_h^*} r_l(\varphi)\mu_l(\varphi)d\varphi + N_h\int_{\varphi_h^*}^{\infty} r_h(\varphi)\mu_h(\varphi)d\varphi\right] - Nf - N_hf_t\right]$

Putting $N_l = \rho_l N$, $N_h = \rho_h N$, $r_l = \Psi c_l^{1-\phi}\varphi_i^{\phi-1}$, $r_h = \Psi c_h^{1-\phi}\varphi_i^{\phi-1}$

Where $\qquad \Psi = P^{\phi-1}R\left(\frac{\phi}{\phi-1}\right)^{1-\phi}$

$\frac{\delta f_E}{(1-G(\varphi_l^*))} = \left[\frac{\Psi}{\phi}\left[\rho_l c_l^{1-\phi}\widetilde{\varphi_l}^{\phi-1} + \rho_h c_h^{1-\phi}\widetilde{\varphi_h}^{\phi-1}\right] - (f + \rho_h f_t)\right]$

Using equation (9.A) to determine $\frac{\Psi}{\phi} = f \quad c_l^{\phi-1}\varphi_l^{*1-\phi}$, in order to express average profits as a function of the production cutoff, yields to:

$\varphi_l^{*k}\delta f_E = \left[\left[\rho_l\left(\frac{\widetilde{\varphi_l}}{\varphi_l^*}\right)^{\phi-1} + \rho_h\left(\frac{c_l}{c_h}\right)^{\phi-1}\left(\frac{\widetilde{\varphi_h}}{\varphi_l^*}\right)^{\phi-1} - 1\right]f - \rho_h\delta f_t\right]$

$$\varphi_l^* = \left[\frac{f}{\delta f_E} (\upsilon)^{\phi-1} + \left[\left[\left(\frac{c_h}{c_l} \right)^{1-\phi} - 1 \right]^{\frac{k}{\phi-1}} \frac{f_t}{f_E} \left(\frac{\delta f_t}{f} \right)^{\frac{k}{1-\phi}} \left[(\upsilon)^{\phi-1} - 1 \right] \right] - \frac{f}{\delta f_E} \right]^{\frac{1}{k}} \quad (30.A)$$

Since the relative skilled labor per unit cost $\left(\frac{c_h}{c_l}\right)$ depends on the skill premium, equations 30.A and 22.A (LMC) determine the equilibrium production cutoff.

We partially differentiate equation 30.A with respect to $\frac{c_h}{c_l}$, in order to analyze the impact of an exogenous increase in the skill premium on the productivity cutoff.

Partially differentiating (30.A) we find $\frac{\partial \varphi_l^*}{\partial \frac{c_h}{c_l}} < 0$

$$\frac{\partial \varphi_l^*}{\partial \left(\frac{c_h}{c_l}\right)} = (-1) \left(\varphi_l^{*k}\right)^{\frac{1}{k}-1} \left[\left(\frac{c_h}{c_l} \right)^{1-\phi} - 1 \right]^{\frac{k}{\phi-1}-1} \left(\frac{c_h}{c_l} \right)^{-\phi} \left[\frac{f_t}{f_E} \left(\frac{\delta f_t}{f} \right)^{\frac{k}{1-\phi}} \left[(\upsilon)^{\phi-1} - 1 \right] \right] (31.A)$$

$$\frac{\partial \varphi_l^*}{\partial \left(\frac{c_h}{c_l}\right)} < 0 \qquad \text{since } \left(\frac{c_l}{ch}\right)^{\phi-1} > 1 \text{ and } (\upsilon)^{\phi-1} > 1$$

Partially differenciating (11.A) we find $\frac{\partial \varphi_h^*}{\partial \left(\frac{c_h}{c_l}\right)} > 0$

$$\frac{\partial \varphi_h^*}{\partial \left(\frac{c_h}{c_l}\right)} = \frac{\varphi_h^*}{\varphi_l^*} \left[\frac{\partial \varphi_l^*}{\partial \left(\frac{c_h}{c_l}\right)} + \varphi_l^* \left[\left(\frac{c_h}{c_l} \right)^{1-\phi} - 1 \right]^{-1} \left(\frac{c_h}{c_l} \right)^{-\phi} \right] \qquad (32.A)$$

We can demostrate that $\frac{\partial \varphi_h^*}{\partial \left(\frac{c_h}{c_l}\right)} > 0$ since the term in brakets in (32.A) is positive. Plugging (31.A) $\frac{\partial \varphi_l^*}{\partial \left(\frac{c_h}{c_l}\right)}$ into (32.A), the term in brakets in (32.A) can be expressed as follows:

$$\varphi_l^{*k} > \left[\left(\frac{c_h}{c_l} \right)^{1-\phi} - 1 \right]^{\frac{k}{\phi-1}} \left[\frac{f_t}{f_E} \left(\frac{\delta f_t}{f} \right)^{\frac{k}{1-\phi}} \left[(\upsilon)^{\phi-1} - 1 \right] \right]$$

Using (30.A):

$$\frac{f}{\delta f_E} \left[(\upsilon)^{\phi-1} - 1 \right] > 0$$

This result holds since $\frac{f}{\delta f_E} > 0$ and $(\upsilon)^{\phi-1} - 1 > 0$. Indeed, $\frac{\partial \varphi_h^*}{\partial \left(\frac{c_h}{c_l}\right)} > 0$

Appendix C: Open economy equilibrium

C.1: Open economy equilibrium in Case 1

Aggregation

Using price rule defined in equation 3.B and plugging it into aggregate price index yields

$$P = N^{\frac{1}{1-\phi}} p\left(\widetilde{\varphi_T}\right)$$

Where

$$p\left(\widetilde{\varphi_T}\right) = \frac{\phi}{\phi-1}\frac{c_l}{\widetilde{\varphi_T}}$$

$$\widetilde{\varphi_T}^{\phi-1} = \frac{1}{N}\left[N_l\left(\widetilde{\varphi_l}\right)^{\phi-1} + N_{xh}\left(\widetilde{\varphi_{xh}}\right)^{\phi-1}\left(\frac{c_h}{c_l}\right)^{1-\phi}\left[1+(1+\tau)^{1-\phi}\right] + (1+\tau)^{1-\phi} N_{xl}\left(\widetilde{\varphi_{xl}}\right)^{\phi-1}\right]$$

Labor Market condition

Plugging firm's final good demands (1.B) into (18.B) and (19.B), firm's indiviudual demand of skilled (h_{xl}, h_{xh}) and unskilled labor (l_{xl}, l_{xh}) of exporting firms with low and high technology are:

$$l_{xi} = \left(\frac{P}{p_{di}}\right)^{\phi}\frac{C}{\varphi}\left[1+(1+\tau)^{1-\phi}\right]\left(\left(\frac{\omega}{a_h}\right)^{\frac{\alpha}{\alpha-1}}+1\right)^{-\frac{1}{\alpha}} \quad (18.B')$$

$$h_{xi} = \left(\frac{P}{p_{di}}\right)^{\phi}\frac{C}{\varphi a_h}\left[1+(1+\tau)^{1-\phi}\right]\left(\left(\frac{a_h}{\omega}\right)^{\frac{\alpha}{\alpha-1}}+1\right)^{-\frac{1}{\alpha}} \quad (19.B')$$

The term "$\left[1+(1+\tau)^{1-\phi}\right]$"reflects the fact that exporting firms have to hire both type of workers to produce to both domestic and foreign markets.

Plugging firm's prices (3.B) in (18.B') and (19.B') and then into aggregate skilled and unskilled labor demand using (20.B) and (21.B), we obtain the aggregate relative demand of skilled labor (22.B) which determines the skill premium.

Averages productivities assuming Pareto distribution

Using a similar distribution $\mu(\varphi)$ of productivity draws levels as defined in 12.A and the pareto distribution of productivity draws yields to the following weighted productivity averages and probabilities.

Average productivity of firms (non exporters and exporters) producing with low technology:

$$\widetilde{\varphi_l}^{\phi-1} \equiv \frac{1}{G(\varphi_{xh}^*)-G(\varphi_{dl}^*)}\int_{\varphi_{dl}^*}^{\varphi_{xh}^*}(\varphi)^{\phi-1} g(\varphi)d\varphi$$

$$\widetilde{\varphi_l} \equiv \upsilon\varphi_{dl}^*\left[\frac{1-(\varepsilon)^{-k+\phi-1}}{1-\varepsilon^{-k}}\right]^{\frac{1}{\phi-1}}$$

Where $\upsilon = \left[\frac{k}{k-(\phi-1)}\right]^{\frac{1}{\phi-1}}$

$$\varepsilon = \left(\frac{f_t}{f}\right)^{\frac{1}{\phi-1}} \left[\left[\left(\frac{c_h}{c_l}\right)^{1-\phi} - 1\right]\left[1 + (1+\tau)^{1-\phi}\right]\right]^{\frac{1}{1-\phi}}$$

Average productivity of firms (exporters) producing with high technology:

$$\widetilde{\varphi_{xh}}^{\phi-1} \equiv \frac{1}{1-G(\varphi^*_{xh})} \int_{\varphi^*_{xh}}^{\infty} (\varphi)^{\phi-1}\, g(\varphi) d\varphi \qquad \text{if} \qquad \varphi > \varphi^*_{xh}$$

$$\widetilde{\varphi_{xh}} \equiv \upsilon \varphi^*_{xh}$$

Average productivity of non exporters firms producing with low technology:

$$\widetilde{\varphi_{dl}}^{\phi-1} \equiv \frac{1}{G(\varphi^*_{xl})-G(\varphi^*_{dl})} \int_{\varphi^*_{dl}}^{\varphi^*_{xl}} (\varphi)^{\phi-1}\, g(\varphi) d\varphi$$

if $\quad \varphi^*_{dl} < \varphi < \varphi^*_{xl}$

$$\widetilde{\varphi_{dl}} \equiv \upsilon \varphi^*_{dl} \left[\frac{1-(\vartheta)^{-k+\phi-1}}{1-\vartheta^{-k}}\right]^{\frac{1}{\phi-1}}$$

Where $\quad \vartheta = \left(\frac{f_x}{f}\right)^{\frac{1}{\phi-1}} (1+\tau)$

Average productivity of exporters producing with low technology:

$$(\widetilde{\varphi_{xl}})^{\phi-1} \equiv \frac{1}{G(\varphi^*_{xh})-G(\varphi^*_{xl})} \int_{\varphi^*_{xl}}^{\varphi^*_{xh}} (\varphi)^{\phi-1}\, g(\varphi) d\varphi$$

if $\quad \varphi^*_{xl} < \varphi < \varphi^*_{xh}$

$$\widetilde{\varphi_{xl}} \equiv \upsilon \varphi^*_{xl} \left[\frac{1-(\Omega)^{-k+\phi-1}}{1-\Omega^{-k}}\right]^{\frac{1}{\phi-1}}$$

Where $\quad \Omega = (1+\tau)^{-1} \left(\frac{f_t}{f_x}\right)^{\frac{1}{\phi-1}} \left[\left[\left(\frac{c_h}{c_l}\right)^{1-\phi} - 1\right]\left[1 + (1+\tau)^{1-\phi}\right]\right]^{\frac{1}{1-\phi}}$

Determination of probabilities:

$$\underbrace{\underbrace{\varphi^*_{dl} \qquad\qquad}_{\rho_{dl}=1-\frac{1-G(\varphi^*_{xl})}{1-G(\varphi^*_{dl})}} \varphi^*_{xl} \underbrace{\qquad\qquad}_{\rho_{xl}=\left[\frac{1-G(\varphi^*_{xl})}{1-G(\varphi^*_{dl})}\right]-\left[\frac{1-G(\varphi^*_{xh})}{1-G(\varphi^*_{dl})}\right]}}_{1-\rho_{xh}=1-\frac{1-G(\varphi^*_{xh})}{1-G(\varphi^*)}} \varphi_{xh}{}^* \underbrace{\qquad\qquad}_{\rho_{xh}=\frac{1-G(\varphi^*_{xh})}{1-G(\varphi^*_{dl})}} \infty$$

ρ_l is the probability of being a low technology firm (non exporter and exporter) conditional on surviving; ρ_x is the probability of being an exporting firm (low and high technology) conditional on surviving; ρ_{dl} is the probability of being a non exporting firm producing with low technology conditional on surviving; ρ_{xl} is the probability of being an exporting firm producing with low technology conditional on surviving; $\rho_{xh}$is the probability of adopting high technology conditional on surviving

$$\rho_l = 1 - \rho_{xh} = 1 - \left(\frac{\varphi^*_{dl}}{\varphi^*_{xh}}\right)^k = 1 - \varepsilon^{-k}$$

$$\rho_x = \left[\frac{1-G(\varphi^*_{xl})}{1-G(\varphi^*_{dl})}\right] = \left(\frac{\varphi^*_{dl}}{\varphi^*_{xl}}\right)^k = \vartheta^{-k}$$

$$\rho_{dl} = \left[1 - \left(\frac{\varphi^*}{\varphi^*_{xl}}\right)^k\right] = \left[1 - \vartheta^{-k}\right]$$

$$\rho_{xl} = \left(\frac{\varphi^*_{dl}}{\varphi^*_{xl}}\right)^k - \left(\frac{\varphi^*_{dl}}{\varphi^*_{xh}}\right)^k = \left[\vartheta^{-k} - \varepsilon^{-k}\right]$$

$$\rho_{xh} = \left(\frac{\varphi^*_{dl}}{\varphi^*_{xh}}\right)^k = \varepsilon^{-k}$$

The impact of tariffs reduction on the aggregate relative skilled labor demand

Plugging in the equation (22.B) the average productivity levels and the number of firms (solved using the pareto distribution), the aggregate relative skilled labor demand can be expressed as a follows:

$$\frac{H^d}{L^d} = \omega^{\frac{1}{\alpha-1}} \left[\frac{1+a_h^{\frac{\alpha}{1-\alpha}} AX}{1+AX}\right]$$

Where

$$X(\tau) = \frac{\varepsilon^{-k+\phi-1}\left[1+(1+\tau)^{1-\phi}\right]}{\left[1-(\vartheta)^{-k+\phi-1}\right]+\left[\vartheta^{-k}-\varepsilon^{-k}\right]\left[\frac{1-(\Omega)^{-k+\phi-1}}{1-\Omega^{-k}}\right]\vartheta^{\phi-1}\left[1+(1+\tau)^{1-\phi}\right]}$$

$$A = \left(\frac{c_h}{c_l}\right)^{-\phi}\left(\frac{(\omega)^{\frac{\alpha}{\alpha-1}}+1}{\left(\frac{\omega}{a_h}\right)^{\frac{\alpha}{\alpha-1}}+1}\right)^{\frac{1}{\alpha}}$$

Note that $\varepsilon(\tau), \vartheta(\tau), \Omega(\tau)$ are also functions of τ. These variables were defined in the previous section.

To determinate whether the aggregate relative skilled labor demand is a decreasing function of tariffs, we will first analyze the $\frac{H^d}{L^d}$ in function of X . Figure 1 shows $\frac{H^d}{L^d}(X)$.

i) $\lim_{X\to\infty} \frac{H^d}{L^d}(\tau) = \omega^{\frac{1}{\alpha-1}} a_h^{\frac{\alpha}{1-\alpha}} \Rightarrow \qquad \lim_{X\to\infty} \frac{H^d}{L^d}(\tau) > 0$

ii) $\lim_{X\to 0} \frac{H^d}{L^d}(\tau) = \omega^{\frac{1}{\alpha-1}}$

iii) $\lim_{X\to\frac{-1}{\varkappa}} \frac{H^d}{L^d}(\tau) = \infty$

First we demostrate that $X(\tau) > 0$ under the partitioning condition of case 1:
$\frac{\delta f_t}{\left[1+(1+\tau)^{1-\phi}\right]\left[\left(\frac{c_h}{c_l}\right)^{1-\phi}-1\right]} > \delta f_x (1+\tau)^{\phi-1} > f$

The numerator is positive since $c_l > c_h$ and $\phi > 1$. Moreover, under this partitioning condition the denominator will also be positive since:

$(1)\delta f_x (1+\tau)^{\phi-1} > f$

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

$1 - (\vartheta)^{-k+\phi-1} > 0$

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

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

$\vartheta^{-k} - \varepsilon^{-k} > 0$

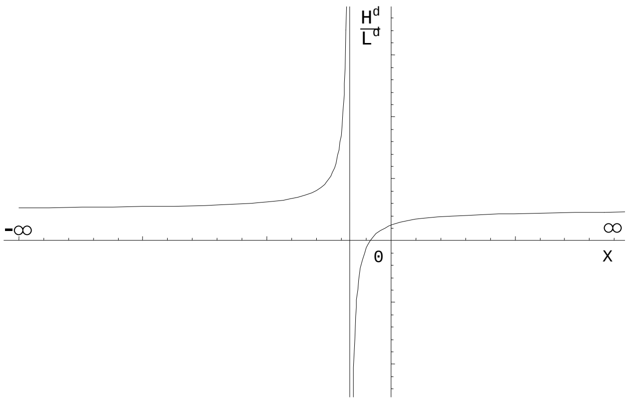
(3) $\frac{\delta f_t}{\left[\left[\left(\frac{c_h}{c_l}\right)^{1-\phi}-1\right]\left[1+(1+\tau)^{1-\phi}\right]\right]} > \delta f_x (1+\tau)^{\phi-1}$

$1 - \Omega^{-k+\phi-1} > 0$ and $1 - \Omega^{-k} > 0$

Hence, $X(\tau)$ is positive and consequently it will be in the first quadrant of figure 1 in which $\frac{H^d}{L^d}$ is an increasing function of $X(\tau)$.

Then we analyze $X(\tau)$ for $\tau = 0$ and $\tau = 1$. $X(0) > X(1)$. For different parameters values under the partitioning condition of case 1, $\frac{\partial X}{\partial \tau} < 0$. Under these conditions $X(\tau)$ is a decreasing function of τ. Indeed, a reduction of τ will increase $X(\tau)$ and the raise in $X(\tau)$ will increase $\frac{H^d}{L^d}$. Therefore, the aggregate relative skilled labor demand is a decreasing function of tariffs (τ).

Figure 1



Determination of the equilibrium

Like in the closed economy equilibrium, LMC (eq. 22.B), FE and ZCP conditions jointly determine the equilibrium cutoff level. Plugging in the ZCP condition the following variables: $\widetilde{\varphi_d}, \widetilde{\varphi_x}, \widetilde{\varphi_{xt}}, \rho_d, \rho_x\ \rho_{xt}$ and $\varphi_x^*, \varphi_{xt}^*$, we obtain the production cutoff level as a function of the skill premium and the parameters of the model (all fixed costs, trade variable costs and the skill efficiency parameter).

$$\underbrace{\frac{\delta f_E}{(1-G(\varphi^*))}}_{\textbf{F.E.}} = \underbrace{\pi_{dl}(\widetilde{\varphi_{dl}})\rho_{dl} + \rho_{xl}\left[\pi_{dl}(\widetilde{\varphi_{xl}}) + \pi_{xl}(\widetilde{\varphi_{xl}})\right] + \rho_{xh}\left[\pi_{dh}(\widetilde{\varphi_{xh}}) + \pi_{xh}(\widetilde{\varphi_{xh}})\right]}_{\textbf{Z.C.P}}$$

$$\frac{\delta f_E}{(1-G(\varphi^*))} = f\left[\rho_l\left(\frac{\widetilde{\varphi}_l}{\varphi_{dl}^*}\right)^{\phi-1} + \ \rho_{xh}\left(\frac{c_h}{c_l}\right)^{1-\phi}\left(\frac{\widetilde{\varphi_{xh}}}{\varphi_{dl}^*}\right)^{\phi-1} - 1\right] - \rho_{xh} f_t$$
$$+ f_x\rho_x\left[\frac{\rho_{xl}}{\rho_x}\left(\frac{\widetilde{\varphi_{xl}}}{\varphi_{xl}^*}\right)^{\phi-1} + \frac{\rho_{xh}}{\rho_x}\left(\frac{c_h}{c_l}\right)^{1-\phi}\left(\frac{\widetilde{\varphi_{xh}}}{\varphi_{xl}^*}\right)^{\phi-1} - 1\right]$$

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

$$\varphi^{*k}\delta f_E = f\ \ (\upsilon)^{\phi-1}\left[1-(\varepsilon)^{-k+\phi-1}\right] + f_x\vartheta^{-k}\left[\left[1-\left(\frac{\vartheta}{\varepsilon}\right)^k\right](\upsilon)^{\phi-1}\left[\frac{1-(\Omega)^{-k+\phi-1}}{1-\Omega^{-k}}\right] - 1\right] +$$
$$\varepsilon^{-k} f_t\left[\frac{(\upsilon)^{\phi-1}}{\left[1-\left(\frac{c_h}{c_l}\right)^{\phi-1}\right]} - 1\right] - f$$

Where

$$\varepsilon = \left(\frac{f_t}{f}\right)^{\frac{1}{\phi-1}} \left[\left[\left(\frac{c_h}{c_l}\right)^{1-\phi} - 1\right]\left[1 + (1+\tau)^{1-\phi}\right]\right]^{\frac{1}{1-\phi}}$$

$$\vartheta = \left(\frac{f_x}{f}\right)^{\frac{1}{\phi-1}} (1+\tau)$$

$$\Omega = (1+\tau)^{-1} \left(\frac{f_t}{f_x}\right)^{\frac{1}{\phi-1}} \left[\left[\left(\frac{c_h}{c_l}\right)^{1-\phi} - 1\right]\left[1 + (1+\tau)^{1-\phi}\right]\right]^{\frac{1}{1-\phi}}$$

In section 3 we study the effects of a reduction of variable trade costs on the production productivity cutoff. To do so, we run simulations of this equation taking into account the equilibrium value of the skill premium determined by equation 22.B.

C.2. Open economy equilibrium in Case 2

Aggregation

Using price rule defined in equation 3.B and plugging it into aggregate price index yields $P = N^{\frac{1}{1-\phi}} p\left(\widetilde{\varphi_T}\right)$

Where
$p\left(\widetilde{\varphi_T}\right) = \frac{\phi}{\phi-1}\frac{c_l}{\widetilde{\varphi_T}}$

$$\widetilde{\varphi_T}^{\phi-1} = \frac{1}{N}\left[N_{dl}\left(\widetilde{\varphi_{dl}}\right)^{\phi-1} + N_{dh}\left(\widetilde{\varphi_h}\right)^{\phi-1}\left(\frac{c_h}{c_l}\right)^{1-\phi} + (1+\tau)^{1-\phi} N_{xh}\left(\frac{c_h}{c_l}\right)^{1-\phi}\left(\widetilde{\varphi_{xh}}\right)^{\phi-1}\right]$$

Labor Market condition

The individual labor demands of firms producing with low technology to the domestic market (l_{dl}, l_{dh}) are the same as in the case of closed economy (18.A' and 19.A'), whereas the labor

demand of firms producing with high technology to the foreign market (l_{xh}) is similar to the previous case 1 in the open economy (19.B')).

$$L^d = \int_{\varphi^*_{dl}}^{\varphi^*_{dh}} N_{dl} l_{dl}(\varphi)\,\mu_{dl}(\varphi) d\varphi_i + \int_{\varphi^*_{dh}}^{\varphi^*_{xh}} N_{dh} l_{dh}(\varphi)\,\mu_{xl}(\varphi) d\varphi_i + \int_{\varphi^*_{xh}}^{\infty} N_{xh} l_{xh}(\varphi)\,\mu_{xh}(\varphi) d\varphi_i$$

$$H^d = \int_{\varphi^*_{dl}}^{\varphi^*_{dh}} N_{dl} h_{dl}(\varphi)\,\mu_{dl}(\varphi) d\varphi_i + \int_{\varphi^*_{dh}}^{\varphi^*_{xh}} N_{dh} h_{dh}(\varphi)\,\mu_{xl}(\varphi) d\varphi_i + \int_{\varphi^*_{xh}}^{\infty} N_{xh} h_{xh}(\varphi)\,\mu_{xh}(\varphi) d\varphi_i$$

$$\frac{H^s}{L^s} = \frac{H^d}{L^d} \qquad \Rightarrow \omega = g\left(\frac{H^s}{L^s}, a_h, N_{dl}, N_{dh}, N_{xh}, \widetilde{\varphi_{dl}}, \widetilde{\varphi_{dh}}, \widetilde{\varphi_{xh}}\right)$$

$$\frac{H^s}{L^s} = (\omega)^{\frac{1}{\alpha-1}} \left[\frac{1 + (a_h)^{\frac{\alpha}{1-\alpha}}\left[\frac{N_{dh}\left(\widetilde{\varphi_{dh}}\right)^{\phi-1} + N_x\left(\widetilde{\varphi_{xh}}\right)^{\phi-1}\left[1+(1+\tau)^{1-\phi}\right]}{N_{dl}\left(\widetilde{\varphi_{dl}}\right)^{\phi-1}}\right] A}{1 + \left[\frac{N_{dh}\left(\widetilde{\varphi_{dh}}\right)^{\phi-1} + N_x\left(\widetilde{\varphi_{xh}}\right)^{\phi-1}\left[1+(1+\tau)^{1-\phi}\right]}{N_{dl}\left(\widetilde{\varphi_{dl}}\right)^{\phi-1}}\right] A}\right]$$

Averages productivities assuming Pareto distribution

Average productivity of non exporters firms producing with low technology:

$\widetilde{\varphi_{dl}}^{\phi-1} \equiv \frac{1}{G(\varphi_{dh}^*)-G(\varphi_{dl}^*)} \int_{\varphi_{dl}^*}^{\varphi_{dh}^*} (\varphi)^{\phi-1}\, g(\varphi)d\varphi$

if $\quad \varphi_{dl}^* < \varphi_i < \varphi_{dh}^*$

$\widetilde{\varphi_{dl}} \equiv \upsilon\varphi_{dl}^* \left[\frac{1-(\xi)^{-k+\phi-1}}{1-\xi^{-k}}\right]^{\frac{1}{\phi-1}}$

Where
$\xi = \left(\frac{f_t}{f}\right)^{\frac{1}{\phi-1}} \left[\left(\frac{c_h}{c_l}\right)^{1-\phi} - 1\right]^{\frac{1}{1-\phi}}$

Average productivity of non exporters firms producing with high technology:

$\widetilde{\varphi_{dh}}^{\phi-1} \equiv \frac{1}{G(\varphi_{xh}^*)-G(\varphi_{dh}^*)} \int_{\varphi_{dh}^*}^{\varphi_{xh}^*} (\varphi)^{\phi-1}\, g(\varphi)d\varphi$

if $\quad \varphi_{xh}^* < \varphi < \varphi_{dh}^*$

$\widetilde{\varphi_{dh}} \equiv \upsilon\varphi_{dh}^* \left[\frac{1-(\chi)^{-k+\phi-1}}{1-\chi^{-k}}\right]^{\frac{1}{\phi-1}}$

Where $\quad \chi = \left[\left(\frac{c_h}{c_l}\right)^{1-\phi} - 1\right]^{\frac{1}{\phi-1}} \left(\frac{c_h}{c_l}\right) \left(\frac{f_x}{f_t}\right)^{\frac{1}{\phi-1}} (1+\tau)$

Average productivity of exporters producing with high technology:

$(\widetilde{\varphi_{xh}})^{\phi-1} \equiv \frac{1}{1-G(\varphi_{xh}^*)} \int_{\varphi_{xh}^*}^{\infty} (\varphi_i)^{\phi-1}\, g(\varphi)d\varphi \qquad$ if $\quad \varphi > \varphi_{xh}^*$

$\widetilde{\varphi_{xh}} \equiv \upsilon\varphi_{xh}^*$

Determination of the probabilities:

$$\varphi_{dl}^* \underbrace{\qquad\qquad\qquad}_{\rho_{dl}=1-\frac{1-G(\varphi_{dh}^*)}{1-G(\varphi_{dl}^*)}} \varphi_{dh}^* \underbrace{\qquad\qquad\qquad}_{\rho_{xl}=\left[\frac{1-G(\varphi_{dh}^*)}{1-G(\varphi_{dl}^*)}\right]-\left[\frac{1-G(\varphi_{xh}^*)}{1-G(\varphi_{dl}^*)}\right]} \varphi_{xh}^* \underbrace{\qquad\qquad\qquad}_{\rho_{xh}=\frac{1-G(\varphi_{xh}^*)}{1-G(\varphi_{dl}^*)}} \infty$$

Probability of having a productivity draw higher than the production cutoff

$\rho_{dl} = 1 - \left(\frac{\varphi_{dl}^*}{\varphi_{dh}^*}\right)^k$

Probability of adopting high technology conditional on surviving

$$\rho_{dh} = \left(\frac{\varphi^*_{dl}}{\varphi^*_{dh}}\right)^k - \left(\frac{\varphi^*_{dl}}{\varphi^*_{xh}}\right)^k$$

Probability of exporting conditional on surviving

$$\rho_{xh} = \left(\frac{\varphi^*_{dl}}{\varphi^*_{xh}}\right)^k$$

The impact of tariffs reduction on the aggregate relative skilled labor demand

Similarly to case 1, we plug in the aggregate relative skilled labor demand the averages productivity levels and the number of firms (solved using the pareto distribution), $\frac{H^d}{L^d}(\tau)$ can also be expressed as follows:

$$\frac{H^d}{L^d}(\tau) = \omega^{\frac{1}{\alpha-1}} \left[\frac{1+a_h^{\frac{\alpha}{1-\alpha}} AZ(\tau)}{1+AZ(\tau)}\right]$$

Where in this case:

$$Z(\tau) = \frac{\left[\xi^{-k+\phi-1} - \gamma^{-k}\xi^{\phi-1}\right]\left[\frac{1-(\chi)^{-k+\phi-1}}{1-\chi^{-k}}\right] + \gamma^{-k+\phi-1}\left[1+(1+\tau)^{1-\phi}\right]}{\left[1-(\xi)^{-k+\phi-1}\right]}$$

$$\xi = \left(\frac{f_t}{f}\right)^{\frac{1}{\phi-1}} \left[\left(\frac{c_h}{c_l}\right)^{1-\phi} - 1\right]^{\frac{1}{1-\phi}}$$

$$\gamma = \left(\frac{f_x}{f}\right)^{\frac{1}{\phi-1}} (1+\tau) \left(\frac{c_h}{c_l}\right)$$

$$\chi = \left[\left(\frac{c_h}{c_l}\right)^{1-\phi} - 1\right]^{\frac{1}{\phi-1}} \left(\frac{c_h}{c_l}\right) \left(\frac{f_x}{f_t}\right)^{\frac{1}{\phi-1}} (1+\tau)$$

As in the case 1, $Z(\tau)$ has the same characteristics as $X(\tau)$. Furthermore, $\lim_{Z\to\infty} \frac{H^d}{L^d}(\tau) = \omega^{\frac{1}{\alpha-1}} a_h^{\frac{\alpha}{1-\alpha}}$, $\lim_{Z\to 0} \frac{H^d}{L^d}(\tau) = \omega^{\frac{1}{\alpha-1}}$ and $\lim_{Z\to \frac{-1}{Z}} \frac{H^d}{L^d}(\tau) = \infty$.

Under the partitioning condition of case 2: $\delta f_x (1+\tau)^{\phi-1} \ \left(\frac{c_h}{cl}\right)^{\phi-1} > \frac{\delta f_t}{\left[\left(\frac{c_h}{c_l}\right)^{1-\phi} - 1\right]} > f$,

$Z(\tau) > 0$ since:

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

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

$1 - (\xi)^{-k+\phi-1} > 0$

$(2)\delta f_x \left(1+\tau\right)^{\phi-1} \ \left(\frac{c_h}{cl}\right)^{\phi-1} > \frac{\delta f_t}{\left[\left(\frac{c_h}{c_l}\right)^{1-\phi}-1\right]}$

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

$\xi^{-k+\phi-1} - \gamma^{-k}\xi^{\phi-1} > 0$

$(3) f_x \left(1+\tau\right)^{\phi-1} \left(\frac{c_h}{cl}\right)^{\phi-1} > \frac{f_t}{\left[\left(\frac{c_h}{cl}\right)^{1-\phi}-1\right]}$

$1 - \left[\frac{1}{1-\left(\frac{c_h}{c_l}\right)^{\phi-1}}\right]^{\frac{k-(\phi-1)}{\phi-1}} \left(\frac{f_t}{fx}\right)^{\frac{k-(\phi-1)}{\phi-1}} \left(\frac{1}{1+\tau}\right)^{k-(\phi-1)} > 0$

$1 - (\chi)^{-k+\phi-1} > 0$

And similarly we can prove that $1-\chi^{-k} > 0$.

For $\tau = 0$ and $\tau = 1$, $Z(0) > Z(1)$ and for different parameters values under the partitioning condition of case 2, $\frac{\partial Z}{\partial \tau} < 0$. Under these conditions, $Z(\tau)$is a decreasing function of τ. Indeed, a reduction of tariffs increases $Z(\tau)$ and thereby, the raise in $Z(\tau)$ will increase $\left(\frac{H}{L}\right)^{d}$.

Determination of the equilibrium

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

$$\underbrace{\frac{\delta f_E}{(1-G(\varphi^*))}}_{\textbf{F.E.}} = \underbrace{\widetilde{\pi} = \pi_{dl}(\widetilde{\varphi_{dl}})\rho_{dl} + \rho_{dh}\pi_{dh}(\widetilde{\varphi_{dh}}) + \rho_{xh}\left[\pi_{dh}(\widetilde{\varphi_{xh}}) + \pi_{xh}(\widetilde{\varphi_{xh}})\right]}_{\textbf{Z.C.P}}$$

$$\frac{\delta f_E}{(1-G(\varphi^*))} = f\left[\rho_{dl}\left(\frac{\widetilde{\varphi_{dl}}}{\varphi^*_{dl}}\right)^{\phi-1} + \rho_h\left(\frac{c_h}{c_l}\right)^{1-\phi}\left(\frac{\widetilde{\varphi_h}}{\varphi^*_{dl}}\right)^{\phi-1} - 1\right]$$
$$-\rho_h f_t + f_x \rho_{xh}\left[\left(\frac{\widetilde{\varphi_{xh}}}{\varphi^*_{xh}}\right)^{\phi-1} - 1\right]$$

$$\varphi^*_l = \left[\frac{1}{f_E}\left[A + \left[\left(\frac{c_h}{c_l}\right)^{1-\phi} - 1\right]^{\frac{k}{\phi-1}} B + E \ \left(\frac{c_h}{c_l}\right)^{-k} - f\right]\right]^{\frac{1}{k}}$$

Where

$A = \frac{f}{\delta f_E}\left(\upsilon\right)^{\phi-1}$

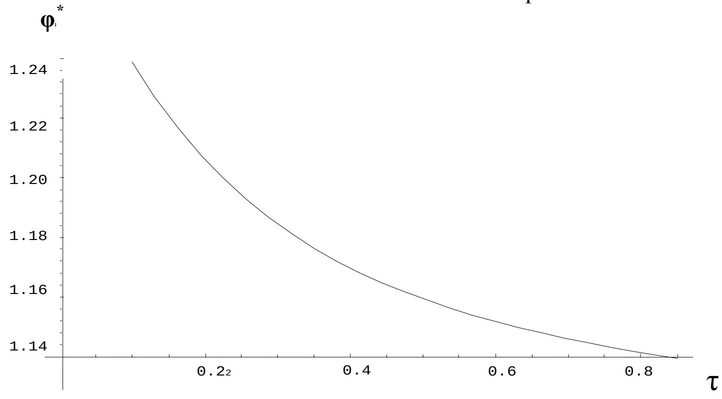
$B = \frac{f^{\frac{k}{\phi-1}}}{\delta f_E} f_t^{\frac{-k+\phi-1}{\phi-1}} \left[(\upsilon)^{\phi-1} - 1\right]$

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

Appendix D: Simulations results

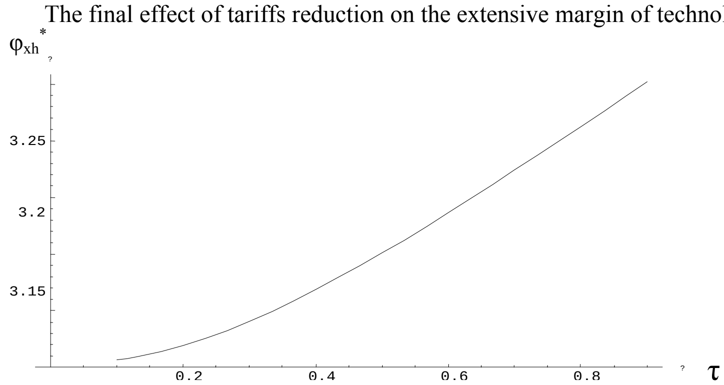
Case 1: The impact of trade liberalization

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



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

Graph 2:
The final effect of tariffs reduction on the extensive margin of technology



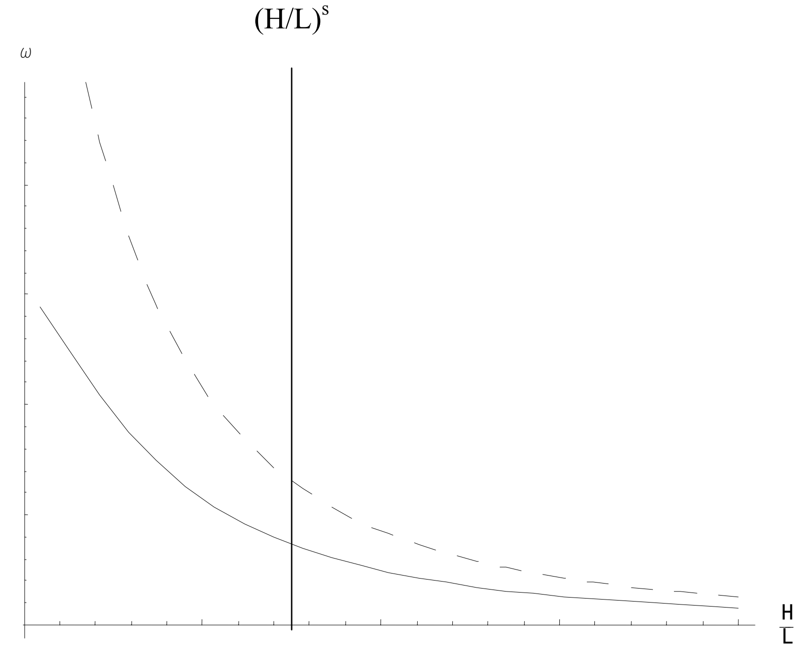
"Extensive margin of technology": a reduction of tariffs increases market shares and profits of all exporters allowing new firms to adopt high technology. The increase in export profitability compensates the negative impact of the raise in the skill premium on the technology adoption decision.

Partitioning condition:

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

Parameters values: $\phi=3$; $k=5$; $\alpha=0.6$; $a_h = 2$; $f_t=500$, $f_x=80$, $f=4$, $\delta=0.06$, $f_e=50$, $H^s/L^s=1/3$

Graph 3:
The impact of a reduction of variable trade cost (τ)
on the skill premium (Case 1)



_____ τ = 0.9 ----- τ = 0.5

Parameters values:

$\phi=3$; k =5; $\alpha=0.6$; a_h = 2; f_t=500, f_x=80,f=4, δ=0.06

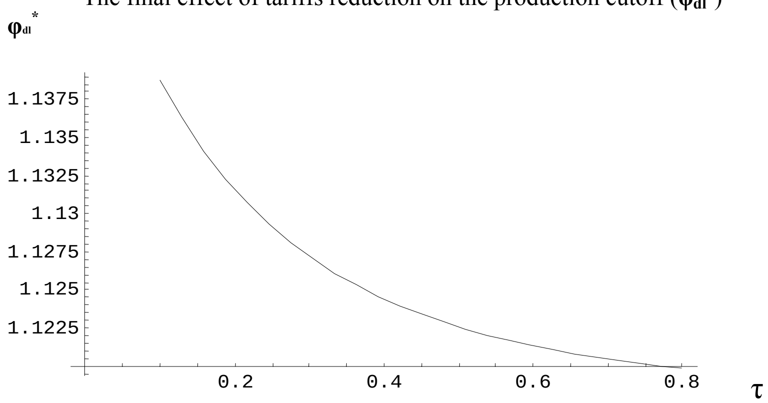
Partitioning condition case 1:

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

Case 2: The impact of trade liberalization

Graph 4:

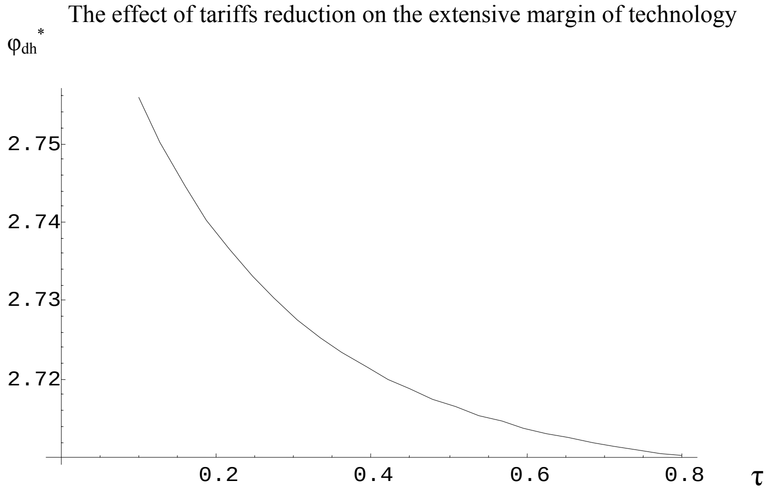
The final effect of tariffs reduction on the production cutoff (φ_{dl}^{*})



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

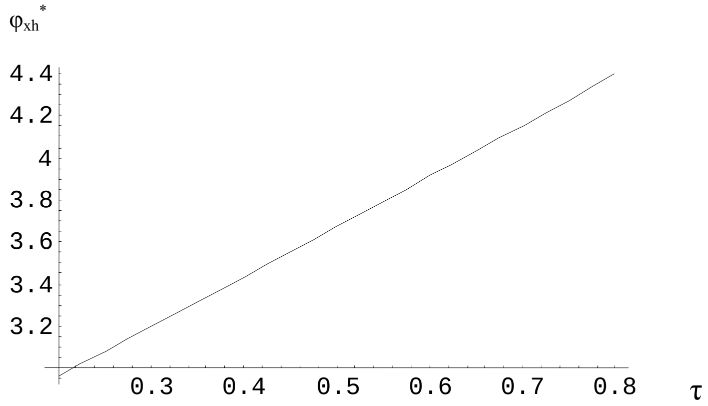
Graph 5a:

The effect of tariffs reduction on the extensive margin of technology



Graph 5b:

The final effect of tariffs reduction on the extensive margin of trade



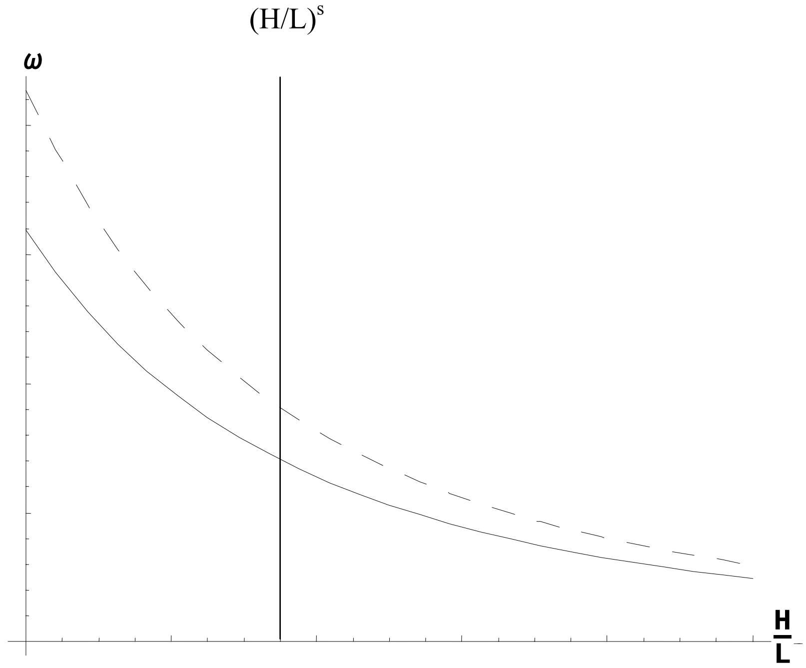
"Extensive margin of trade": a reduction of tariffs increases market shares and profits of all exporters allowing new firms to export. The increase in export profitability compensates the negative impact of the raise in the skill premium on the technology adoption decision.

Partitioning condition:

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

Parameters values: $\phi=3$; k =5; $\alpha=0.6$; a_h = 2; f_t=200, f_x=500,f=4, δ=0.06, f_e=50, H^s/L^s=1/3

Graph 6:
The impact of a reduction of variable trade cost (τ)
on the skill premium (Case 2)



_____ τ = 0.9 - - - - - τ = 0.5

Parameters values:

$\phi=3$; k =5; $\alpha=0.6$; a_h = 2; f_t=200, f_x=500,f=4, δ=0.06

Partitioning condition:

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

Appendix E: Empirical results

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

OLS	**[Export Oriented]**	**[Import Competing]**	**[Non Traded]**	**[Full Sample]**
ln(K/VA)	0.017***	0.015***	0.011***	0.015***
	(0.001)	(0.001)	(0.001)	(0.001)
ln(VA)	0.047***	0.049***	0.045***	0.047***
	(0.001)	(0.001)	(0.001)	(0.001)
FTA	0.031***	0.015**	0.013**	0.018***
	(0.007)	(0.006)	(0.006)	(0.004)
Imported	0.092***	0.052***	0.048***	0.061***
Input	(0.005)	(0.003)	(0.004)	(0.002)
Plant_Ind	NO	NO	NO	NO
Industry_Ind	YES	YES	YES	YES
Area_Ind	YES	YES	YES	YES
YEAR_Ind	YES	YES	YES	YES
Number Obs	23088	20216	14672	58016
R2	0.281	0.250	0.399	0.329

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)

F.E.	**[Export Oriented]**	**[Import Competing]**	**[Non Traded]**	**[Full Sample]**
ln(K/VA)	0.003**	0.010***	0.001	0.003**
	(0.001)	(0.002)	(0.002)	(0.001)
ln(VA)	0.003	0.014***	0.001	0.003**
	(0.002)	(0.002)	(0.003)	(0.001)
FTA	0.015**	0.007	0.005	0.010***
	(0.007)	(0.006)	(0.006)	(0.004)
Imported	0.021***	0.017***	0.011***	0.019***
Input	(0.005)	(0.003)	(0.002)	(0.002)
Plant_Ind	YES	YES	YES	YES
YEAR_Ind	YES	YES	YES	YES
Number Obs	23088	20216	14672	58016
R2	0.157	0.162	0.169	0.118

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)

	[OLS]	**[OLS]**	**[F.E.]**	**[F.E.]**
ln(K/VA)	0.011***	0.008***	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
ln(VA)	0.003**	0.014***	0.001	0.003**
	(0.001)	(0.001)	(0.001)	(0.001)
FTA	0.070***	0.061***	0.014**	0.013**
	(0.005)	(0.006)	(0.005)	(0.005)
Imported Input	0.140***	0.135***	0.005*	0.004*
Continuing_X		0.071***		0.011**
		(0.004)		(0.005)
New_cont		0.060***		0.005
		(0.007)		(0.006)
New_stop		0.044***		0.012*
		(0.010)		(0.007)
Stop_X		0.029***		0.008
		(0.007)		(0.006)
Plant_Ind	NO	NO	YES	YES
Industry_Ind	YES	NO	NO	NO
Area_Ind	YES	YES	NO	NO
YEAR_Ind	YES	YES	YES	YES
Number Obs	27120	27120	27120	27120
R2	0.207	0.213	0.145	0.150

Note: Huber White Standard errors in parentheses
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 4: Dependant variable: Skill premium (1979-1999)

OLS	**[Export Oriented]**	**[Import Competing]**	**[Non Traded]**	**[Full Sample]**
ln(K/VA)	0.222***	0.069***	0.103***	0.144***
	(0.023)	(0.019)	(0.025)	(0.013)
ln(VA)	0.941***	0.936***	0.977***	0.994***
	(0.027)	(0.029)	(0.055)	(0.020)
FTA	0.290***	0.535***	0.024	0.297***
	(0.089)	(0.207)	(0.169)	(0.088)
Imported	0.607***	0.432***	0.422***	0.480***
Input	(0.154)	(0.084)	(0.100)	(0.061)
Plant_Ind	NO	NO	NO	NO
Industry_Ind	YES	YES	YES	YES
Area_Ind	YES	YES	YES	YES
YEAR_Ind	YES	YES	YES	YES
Number Obs	21729	19572	14292	55633
R2	0.260	0.230	0.247	0.247

Note: Huber White Standard errors in parentheses
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 5: Dependant variable: Skill premium (1979-1999)

F.E.	**[Export Oriented]**	**[Import Competing]**	**[Non Traded]**	**[Full Sample]**
ln(K/VA)	0.030	0.205***	0.054	0.110***
	(0.044)	(0.040)	(0.051)	(0.026)
ln(VA)	0.441***	0.597***	0.564***	0.533***
	(0.063)	(0.053)	(0.061)	(0.034)
FTA	0.722***	0.073	0.154	0.145
	(0.052)	(0.211)	(0.112)	(0.149)
Imported	0.341*	0.245***	0.132	0.246***
Input	(0.178)	(0.089)	(0.107)	(0.067)
Plant_Ind	YES	YES	YES	YES
YEAR_Ind	YES	YES	YES	YES
Number Obs	21729	19572	14292	55633
R2	0.161	0.154	0.159	0.148

Note: Huber White Standard errors in parentheses
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

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