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Trade, Technology Adoption and Wage Inequalities: Theory and Evidence

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Abstract

This paper develops a model of trade that features heterogeneous firms, technology choice and different types of skilled labor in a general equilibrium framework. Its main contribution is to explain the impact of trade integration on technology adoption and wage inequalities. It also provides empirical evidence to support the model's predictions using plant-level panel data from Chile's manufacturing sector (1990-1999). The theoretical framework offers a possible explanation of the puzzling increase in skill premium in the developing countries. The key mechanism is found in the effects of trade policy on the number of new firms upgrading technology and on the skill-intensity of labor. Trade liberalization pushes up export revenues, raising the probability that the most productive exporters will upgrade their technology. These firms then increase their relative demand for skilled labor, thereby raising inequalities.

Keywords: Firm heterogeneity, trade reforms, technology adoption, skill premium, plant panel data
JEL Classifications: F10, F12 and F41

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1 Introduction

This paper develops a theoretical model of trade, skill-biased technology adoption and heterogeneous firms that reproduces a number of observations described in the empirical literature on international trade. Recent empirical plant-level studies confirm the existence of heterogeneous characteristics among firms in the same industry. They demonstrate that exporters are more productive, larger, more intensive in skilled labor and pay higher wages than firms selling only to the domestic market. [1] There is also empirical evidence of growing wage inequalities between skilled and unskilled labor due to a higher proportion of skilled workers within industries following trade liberalization. [2]

We construct a trade model that links both empirical facts. The skill premium growth in all industries, even in those unskilled intensive, is explained by the argument of trade-induced skill-biased technological change in a model with firm heterogeneity. The main contribution to the existing theoretical literature is to investigate the differentiated impact of trade on firms' technology choice and its effect on the evolution of the skill premium in a general equilibrium framework of heterogeneous firms.

A fixed technology adoption cost and both skilled and unskilled labor are introduced into Melitz (2003) model of monopolistic competition and heterogeneous firms. His model is based on the assumption of homogeneous labor. The introduction of different types of skilled labor and skill-intensity differences between firms enables us to explain the effects of trade integration on the skill premium. We introduce two sources of cross-plant productivity variation. The first is an exogenous Hicks-neutral productivity factor, which is drawn from a continuous distribution. The second is an endogenous skilled-labor-augmenting productivity factor, which is binary. The high-productivity value of this factor is available to firms that are willing to pay a fixed technology adoption cost. In this sense, this model can be interpreted as a generalization of Melitz (2003) to skill-biased productivity.

Trade liberalization changes the scope for profits in the domestic and foreign markets. The reduction of variable trade costs makes low productivity firms worse off and high productivity firms better off, as shown by Melitz's model ("selection effect"). Following the implementation of trade reforms, the increase in export revenues raises the probability that the most productive low technology exporters will upgrade their technology. These firms increase their relative demand for skilled labor, thereby raising the skill premium. The latter effect is beneficial to low-technology firms compared with high-technology firms. Since the increase in the skill premium is a second

[1] Roberts and Tybout (1997), Clerides, Lach and Tybout (1998), Bernard and Jensen (1995, 1999, 2004) and Aw, Chung and Roberts (2000) all find that exporters perform better than non-exporters.

[2] Berman et al., 1998), Maurin, Thesmar and Thoenig (2002), Muendler et al. (2003), Sanchez-Paramo and Schady (2003), Attanasio, Goldberg and Pavcnik (2004), Bustos (2005), Verhoogen (2008).

order effect, the "net effect" of reductions in trade frictions on both the extensive margin of trade and the extensive margin of technology is positive.

In the final section, we provide empirical evidence in support of the theoretical predictions based on plant level panel data from Chile's manufacturing sector for the period 1990-1999. We test the following predictions: (1) technology choice is determined by past productivity levels, size and previous export status, (2) the new high-technology exporters increase their relative demand for skilled labor, (3) whether trade cost reduction encourages exporters to upgrade their technology and (4) whether these exporters have a higher relative demand for skilled labor following trade liberalization.

This paper contributes to a theoretical literature that studies the mechanisms by which trade policy affects the relative demand for skilled labor and skill premium. Two types of arguments can be identified, depending on whether they focus mainly on technological change or on the impact of international trade.[3].

The first type of argument is based on skill-biased technological change (SBTC). These models have been developed mainly by Acemoglu (2003) and Thoenig and Verdier (2003). International trade prompts innovation and SBTC, thereby raising the relative demand for skilled labor and hence the skill premium.

On the other hand, recent theoretical studies on international trade focus on the channels through which trade integration affects the relative demand of skilled labor and the skill premium. Chun Zhu and Trefler (2005) develop a ricardian model to explain the growth of the skill premium in developing countries. The main mechanism through which trade raises the relative demand of skilled labor in developing countries is the technological catch-up of the South.

Based on a Hecksher-Ohlin-Samuelson framework, Bernard, Redding and Schott (BRS) (2007) develop a two-sector trade model introducing heterogeneous firms in each sector. The main difference is that the key mechanism explaining the rise in wage inequalities in our model is based on the existence of a fixed skill-biased technology cost. Thereby, the level of skill intensity required by firms is determined by their endogenous decision to upgrade technology, while the level of skill intensity in the BRS model is exogenously determined.

Some theoretical studies link both arguments: trade-induced skill-biased technological change. In Ekholm and Midelfart (2005) model trade openness increases the market access of firms, creating incentives to upgrade skill-intensive technology and raising the skill premium. To investigate the differentiated effects of trade on firms' decisions to upgrade technology, our model introduces firms that are heterogeneous in terms of their productivity gains.

[3]Some studies focus on outsourcing as the main mechanism explaining the rise in skill premium in industrialized and developing countries. See Feenstra and Hanson (1999, 2000).

The model developed in this paper is closely related to Yeaple (2005), who develops a framework that also takes into account both explanations. He constructs a trade model of ex-ante homogeneous firms, heterogeneous skills and technology choice.[4] Trade reduces the relative fixed costs of high technology and thus increases the share of skilled labor and the skill premium. Unlike Yeaple (2005), the firms in our model are heterogeneous even before they start producing and each firm employs both skilled and unskilled workers. Trade liberalization encourages technology adoption in unskilled-intensive sectors, thereby raising their skilled labor demand. Another important departure from Yeaple's model is that we take into account the effects of the skill premium on firm's decisions.

Finally, Bustos (2005) expands on Melitz (2003) and Yeaple (2005) to explain the skill upgrading prompted by technology adoption that follows the implementation of trade reforms in developing countries. Using Argentinean firm level data, she finds empirical evidence supporting the argument of trade-induced skill-biased technological change. Based on a partial equilibrium framework, Bustos (2005) considers neither the firm's entry-exit process nor the reallocation of resources among firms or the impact of relative wages on price indexes and other aggregate variables. Moreover, skilled and unskilled labor are employed in fixed proportions and thereby the skill premium is exogenous. Therefore, trade policy has no impact on inequalities in that framework.

Conversely, in our model skilled and unskilled labor are combined by a CES production function and the aggregate relative demand of skilled labor is endogenously determined as well as the skill premium. Another important difference with Bustos (2005) is that we develop a general equilibrium framework which takes into account the effects of trade policy on the relative wage of skilled labor and its impact on aggregate variables and on the selection process into the domestic and foreign markets.

The rest of the paper is structured as follows. Section 2 shows how the model is set up. Section 3 presents the main theoretical findings and predictions. Section 4 presents the empirical estimations. Section 5 contains the conclusion.

2 Setup of the model

2.1 Closed economy equilibrium

2.2 Households Consumption

The representative household allocates consumption from among the range of domestic goods (j) produced using low technology (Ω_l) and those produced using more advanced and skill-biased technology (Ω_h). The standard CES utility function (C) represents the consumer preferences. The

[4] In Yeaple's model, firm heterogeneity is an endogenous result of the distribution of skilled workers and technology upgrading.

elasticity of substitution between low and high technology goods is $\sigma > 1$:

$$C = \left(\int_{j\in\Omega_l} C_{lj}^{\frac{\sigma-1}{\sigma}} dj + \int_{j\in\Omega_h} C_{hj}^{\frac{\sigma-1}{\sigma}} dj \right)^{\frac{\sigma}{\sigma-1}}$$

The optimal relative demand functions are:

$$C_i = \left(\frac{P}{p_i} \right)^{\sigma} C \qquad i = \{l, h\} \tag{1.A}$$

The subscript "l" represents firms producing with low technology and "h" those using high technology.

2.3 Production

There is a continuum of firms, each producing a different range of goods, in monopolistic competition. Production requires two different types of labor: unskilled (l_i) and skilled (h_i) inelastically supplied. Heterogeneous firms with different productivity levels (φ) are introduced, in keeping with Melitz (2003). We adopt a CES production technology that combines skilled and unskilled labor to produce output.

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

The coefficient "a_h " represents the efficiency of high technology, corresponding to skilled labor. The elasticity of substitution between the two types of labor is $\theta = \frac{1}{1-\alpha}$. We assume that skilled and unskilled labor are imperfect substitutes, hence $0 < \alpha < 1$ and $1 \leq \theta \leq \infty$.

There are three types of fixed costs in a closed economy: (1) a fixed sunk entry cost (f_E), that firms have to pay to enter the market (e.g. costs to develop a blueprint); (2) a fixed per-period cost (f) that all firms incur, such as that associated with investment in local distribution; and (3) a fixed per-period technology adoption cost (f_t), which represents investment in new and more advanced skill-biased technology. To make the model tractable, all fixed costs are measured in units of imported capital and their price is normalized to one. Two groups of domestic firms can be identified in a closed economy equilibrium: (1) low productivity firms without enough profits to assume the fixed technology costs (N_l); and (2) the most productive firms, which have acquired new technology (N_h). The first-order conditions of monopolistic firms is such that prices reflect a constant markup over marginal cost. Firms face the same demand curve with constant elasticity σ and they set a markup equal to $\frac{\sigma}{\sigma-1}$. In this model, marginal costs can be divided into an intrinsic productivity term (φ) and the unit cost of production (c_l or c_h), which reflects the ratio of skilled (w_h) to unskilled (w_l) wages paid by the firm.

Low technology firms (N_l) | **High technology firms (N_h)**

$$p_l = \frac{\sigma}{\sigma-1}\frac{c_l}{\varphi_i} \qquad p_h = \frac{\sigma}{\sigma-1}\frac{c_h}{\varphi_i} \tag{3.A}$$

$$c_l = \left((w_l)^{\frac{\alpha}{\alpha-1}} + (w_h)^{\frac{\alpha}{\alpha-1}}\right)^{\frac{\alpha-1}{\alpha}} \qquad c_h = \left((w_l)^{\frac{\alpha}{\alpha-1}} + \left(\frac{w_h}{a_h}\right)^{\frac{\alpha}{\alpha-1}}\right)^{\frac{\alpha-1}{\alpha}} \tag{4.A}$$

$$r_l = \left(\frac{P}{p_l}\right)^{\sigma-1} R \qquad r_h = \left(\frac{P}{p_h}\right)^{\sigma-1} R \tag{5.A}$$

$$r_l = r_h \left(\frac{c_h}{c_l}\right)^{\sigma-1} \qquad r_h = r_l \left(\frac{c_h}{c_l}\right)^{1-\sigma}$$

$$\pi_l = p_l Y_l - w_l l_l - w_h h_l - f \qquad \pi_h = p_h Y_h - w_l l_h - w_h h_h - f - \delta f_t \tag{6.A}$$

$$\pi_l = \frac{r_l}{\sigma} - f$$

$$\textbf{Goods Market Equilibrium} \qquad Y_i = C_i \qquad for \ \ i = \{l, h\} \tag{7.A}$$

High-technology firms have to pay a fixed technology adoption cost (f_t), but have a lower marginal cost since skill efficiency "$a_h > 1$" reduces the unit cost (c_h). Note that "a_h" is not heterogeneous, since all firms that upgrade their technology reduce their unit cost by the same proportion. Even if two firms have the same productivity level, the revenues of the firm using the more advanced technology are higher than those of the low-technology firm ($c_l > c_h \Rightarrow r_l < r_h$). Hence, firms that decide to upgrade technology increase their revenues by $\left(\frac{c_h}{c_l}\right)^{1-\sigma}$. Otherwise, the firm employs low technology, where $a_h = 1$. The introduction of heterogeneous firms in terms of productivity levels determines the endogenous technological status of the firms. Only the most productive firms can switch to high technology and become even more efficient. The term $\left(\frac{c_h}{c_l}\right)$ represents the relative unit cost of skilled labor and is determined by both the skill premium $\omega(\frac{w_h}{w_l})$ and skill efficiency "a_h". This relative skilled labor unit cost is an increasing function of the skill premium $\frac{\partial \frac{c_h}{c_l}}{\partial \omega} > 0$ since $0 < \alpha < 1$ (See Appendix 1).

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

2.4 Firm's decisions

2.4.1 The decision to exit or stay and produce

Firms have to pay a sunk entry cost to enter the market before they know what their productivity level will be. Entrants then derive their productivity "φ" from common distribution density $g(\varphi)$, with support $0, \infty)$ and cumulative distribution $G(\alpha)$.[5] Since there is a fixed production cost (f), only those firms with enough profits to pay this cost can produce. The profits of the marginal firm that decides to stay and produce are equal to zero:$\pi_l\,(\varphi_l^*) = 0$. The value φ_l^* is the productivity cutoff to produce.

[5] These functions are defined in the following section.

$$\frac{r_l\,(\varphi_l^*)}{\sigma}=f \qquad \Rightarrow \qquad \varphi_l^{*\sigma-1}=f\ c_l^{\sigma-1}\frac{\sigma}{\Psi} \qquad\qquad \text{Where } \Psi=P^{\sigma-1}R\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} \tag{9.A}$$

2.4.2 The decision to adopt high technology

If a firm decides to stay in the market once it has received its productivity draw, it may also decide to upgrade its technology to reduce its unit costs on the basis of its profitability. 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. The firms that do will be those whose increase in domestic revenues due to their adoption of high technology enables them to pay the fixed technology costs. The condition to acquire the new and more advanced technology is given by: $\pi_h(\varphi_h^*)=\pi_l(\varphi_h^*)$

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

φ_h^* is the minimum productivity level for the marginal firm able to adopt high technology. By combining equation (9.A) with (10.A), we obtain φ_h^* as an implicit function of φ_l^*.

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

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. The partitioning condition that sustains the closed economy equilibrium is written:

$$\frac{\delta f_t}{\left[\left(\frac{c_h}{c_l}\right)^{1-\sigma}-1\right]}>f \tag{11'.A}$$

2.5 Aggregation

The distribution of the productivity levels of low- and high-technology firms is represented by $\mu_l(\varphi)$ and $\mu_h(\varphi)$, respectively. 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 $[\varphi_h^*,\infty)$.

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

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

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 the firms' productivity levels as functions of the cutoffs.

$$\widetilde{\varphi_l}^{\sigma-1} \equiv \frac{1}{G(\varphi_h^*) - G(\varphi_l^*)} \int_{\varphi_l^*}^{\varphi_h^*} (\varphi)^{\sigma-1} g(\varphi) d\varphi; \qquad \widetilde{\varphi_h}^{\sigma-1} \equiv \frac{1}{1 - G(\varphi_h^*)} \int_{\varphi_h^*}^{\infty} (\varphi)^{\sigma-1} g(\varphi) d\varphi \tag{14.A 15.A}$$

$\widetilde{\varphi_h}$ represents the ex-ante weighted average productivity level of high-technology firms before they decide to adopt the technology. The ex-post productivity average of high-technology firms has to take into account the increase in the firms' efficiency due to the acquisition of the more advanced technology that allows them to reduce their unit costs and raise their market shares by this term $\left(\frac{c_h}{c_l}\right)^{1-\sigma}$ since $r_h(\widetilde{\varphi_h}) = r_l(\widetilde{\varphi_h}) \left(\frac{c_h}{c_l}\right)^{1-\sigma}$. Therefore, the weighted average productivity index of the economy $(\widetilde{\varphi_T})$ represents the market shares of all the firms. [6]

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

2.6 Labor Market Equilibrium and the 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 their productivity level, all firms pay the same skilled 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.

Firms' skilled and unskilled labor demands are determined by profit maximization. By plugging equation 2.A (production function) into equation 6.A (profit function), the profit maximization process yields the following relationship between skilled labor, unskilled labor and the skill premium:

$$\frac{h_i}{l_i} = \omega^{\frac{1}{\alpha-1}} (a_h)^{\frac{\alpha}{1-\alpha}} \qquad for i = \{l, h\} \qquad a_h > 1 \quad if \quad i = h \tag{17.A}$$

Firms producing with more advanced skill-biased technology will have a higher relative skilled labor demand than firms using low technology. In monopolistic competition, firms anticipate their final demand. Plugging equation 17.A into 2.A and then into the goods market equilibrium equation (7.A) yields the firms' skilled and unskilled labor demands.

$$l_i = \frac{C_i}{\varphi} c_i^{\frac{1}{1-\alpha}} (w_l)^{\frac{1}{\alpha-1}} \qquad for \quad i = \{l, h\} \tag{18.A}$$

[6] The low- and high-technology average productivity levels and the aggregate productivity index define all the aggregate variables (see Appendix 1).

$$h_i = \frac{C_i}{\varphi} c_i^{\frac{1}{1-\alpha}} (w_h)^{\frac{1}{\alpha-1}} (a_h)^{\frac{\alpha}{1-\alpha}} \qquad for \quad i = \{l, h\} \tag{19.A}$$

Where C_i is the demand for a good produced with low (l) or high (h) technology, and c_i is per unit cost. The overall national demand for unskilled and skilled labor is determined by aggregating the firms' individual demands (see Appendix 1).

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

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

The skill premium (ω) is determined by the equality between aggregate relative skilled labor demand and supply. $\frac{H^s}{L^s} = \frac{H^d}{L^d} \qquad \Rightarrow \omega = g(\frac{H^s}{L^s}, a_h, N_l, N_h, \frac{\widetilde{\varphi}_h}{\widetilde{\varphi}_l})$

$$\frac{H^s}{L^s} = \omega^{\frac{1}{\alpha-1}} \left(\frac{1 + (a_h)^{\frac{\alpha}{1-\alpha}} \left(\frac{N_h}{N_l}\right) \left(\frac{\widetilde{\varphi}_h}{\widetilde{\varphi}_l}\right)^{\sigma-1} A}{1 + \left(\frac{N_h}{N_l}\right) \left(\frac{\widetilde{\varphi}_h}{\widetilde{\varphi}_l}\right)^{\sigma-1} A} \right) \qquad \text{where } A = \left(\frac{c_h}{c_l}\right)^{-\sigma} \left(\frac{(\omega)^{\frac{\alpha}{\alpha-1}} + 1}{\left(\frac{\omega}{a_h}\right)^{\frac{\alpha}{\alpha-1}} + 1} \right)^{\frac{1}{\alpha}} \tag{22.A}$$

2.7 Closed Economy Equilibrium Conditions

Unlike Melitz's model, the equilibrium productivity cutoff level to produce (φ_l^*) depends on the skill premium, which is determined by equation 22.A. In this model, therefore, the equilibrium value of φ_l^* is determined by three conditions: the free entry condition (FE), the zero cutoff profits condition (ZCP) and the labor market clearing condition (LMC). The value of φ_l^* at equilibrium will then pin down the rest of the model's variables.

The Free Entry Condition (FE): before entering the market and knowing their productivity level, firms calculate the present value of average profit flows to decide whether to enter the domestic market. All firms except the marginal firms earn positive profits. Hence, average profit level $\widetilde{\pi}$ is positive. As 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: $v^E = (1 - G(\varphi_l^*)) \widetilde{v} - \delta f_E = \frac{1-G(\varphi_l^*)}{\delta} \widetilde{\pi} - \delta f_E$. FE states that the value of entry is equal to zero.[7]

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

[7].The factor of discount is modeled following Melitz with a Poisson death shock probability.

The Zero Cutoff Profit Condition (ZCP): also determines a relation between average profits and the productivity level of the marginal firm. $\rho_l = 1 - \frac{1-G(\varphi_h^*)}{1-G(\varphi_l^*)}$ and $\rho_h = \frac{1-G(\varphi_h^*)}{1-G(\varphi_l^*)}$

represent the ex-ante probability of using low and high technology, respectively.

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

Assumption 1: *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 *(see Appendix 1).*

Proposition 1: *Under Assumption 1 and the partitioning condition (eq. 11'.A), there exists a unique equilibrium cutoff* (φ_l^*) *determined by ZCP, FE and LMC.*

Proof. *See Appendix 1* ■.

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

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

Proposition 2: *Under Assumption 1 and the partitioning condition (eq. 11'.A),* φ_l^* *is a decreasing function of the skill premium but the aggregate relative skilled labor demand does not depend on* φ_l^* *and therefore the skill premium is independent of this cutoff.*[8] $\frac{\partial \varphi_l^*}{\partial \frac{c_h}{c_l}} < 0$.

Proof. *See Appendix 1* ■.

This implies that an increase in the relative skilled labor unit cost ($\frac{c_h}{c_l}$), due to an increase in the skill premium ($\frac{\partial \frac{c_h}{c_l}}{\partial \omega} > 0$), reduces the productivity cutoff. Hence, an increase in the skill premium benefits the least productive unskilled-intensive firms. This cutoff (φ_l^*) then determines the technological cutoff level (φ_h^*) using equation (11.A).

Proposition 3: *Under Assumption 1 and the partitioning condition (eq. 11'.A), the technological cutoff* (φ_h^*) *is an increasing function of the relative skilled per unit cost and of the skill premium. An increase in the relative skill per unit cost reduces the number of firms producing with high technology skilled biased:* $\frac{\partial \varphi_h^*}{\partial \frac{c_h}{c_l}} > 0$.

Proof. *See Appendix 1* ■.

The Capital Market Condition: imported capital is required to pay fixed entry costs and production and technology adoption costs. It is supplied inelastically by the rest of the world

[8] In the general case, the aggregate relative skilled labor demand depends on the average productivities and thereby on the cutoffs. There is a unique solution (ω,φ_l^*) determined by the intersection between Free Entry-ZCP condition and the Labor Market Condition. In this case the impact of trade variable costs is ambiguous. Therefore I assume the Pareto distribution to get an analytical solution of the equilibrium cutoff.

under the assumption that capital markets operate independently from labor markets.[9] Its price is normalized to one. The capital market clearing condition is[10]:

$$K = N_l f + N_h \left(f + \delta f_t\right) + N_E \delta f_E \tag{25.A}$$

The Global Accounting condition:establishes that the sum of unskilled and skilled revenues and the capital used to paid fixed costs is equal to the aggregate revenue of the economy (R).

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

$R = N\widetilde{r}$ and $\widetilde{\pi} = \frac{\widetilde{r}}{\sigma} - f - \delta f_t \rho_h$. The total number of firms is obtained by using the average profit to obtain average revenue and plugging it into this condition (eq. 26.A).

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

2.8 Open economy

Countries are symmetric in the open economy equilibrium. Aggregate variables (prices, consumption and revenues) are equivalent in both countries. So there are no differences in the notation of variables for home and foreign countries. In an open economy equilibrium, there are two different cases depending on the relation between the fixed technology cost (f_t), fixed (f_x) and variable trade costs (τ) and the relative skilled labor 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. Under these conditions, there are three groups of firms: (1) the least productive firms selling only on the domestic market and producing with low technology (N_{dl}); (2) exporters producing with low technology (N_{xl}); and (3) the most productive firms capable of exporting and upgrading their technology (N_{xh}). In the second case, fixed and variable trade costs are higher than the fixed technology cost. All exporters produce with high technology and there are two different types of domestic firms. Since the Chile data patterns fit the first case better (see Section 4), we only derive the equilibrium for this case.[11]

[9] 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.

[10] 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.

[11] The derivation of the second open economy equilibrium is available in the author's PhD dissertation.

2.9 Set-up of the open economy equilibrium

2.10 Households Consumption

Goods produced by domestic firms can be traded or not and produced using low or high technology depending on the firm's profitability. The representative household allocates consumption from among 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}). Consumers preferences are represented by the standard C.E.S. utility function:

$$C = \left(\int_{j\in\Omega_{dl}} C_{dl}^{\frac{\sigma-1}{\sigma}} dj + \int_{j\in\Omega_{xl}} C_{xl}^{\frac{\sigma-1}{\sigma}} dj + \int_{j\in\Omega_{xh}} C_{xh}^{\frac{\sigma-1}{\sigma}} dj \right)^{\frac{\sigma}{\sigma-1}}$$

The optimal relative demand functions are:

$$C_i = \left(\frac{P}{p_i} \right)^{\sigma} C \qquad fori = \{dl, xl, xh\} \tag{1.B}$$

The subscript "dl" represents varieties produced by low technology firms selling on the domestic market, "xl" those using low technology and selling on the foreign markets and "xh" exporters producing with high technology.

2.11 Production

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

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

Only the most productive exporters will be able to switch to high technology. Since high technology is skilled biased, the firms that acquire this technology will have greater skilled labor efficiency ($a_h > 1$) and a lower marginal cost ($c_h < c_l$). More productive firms have lower unit costs and are thereby able to set lower prices and have higher revenues as well as greater profits.

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

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

(4.B) $c_l = \left((w_l)^{\frac{\alpha}{\alpha-1}} + (w_h)^{\frac{\alpha}{\alpha-1}} \right)^{\frac{\alpha-1}{\alpha}}$ (6.B) $\pi_{dl} = p_{dl} Y_{dl} - w_l l_{dl} - w_h h_{dl} - f \quad = \frac{r_{dl}}{\sigma} - f$

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

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

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

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

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

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

$r_{dh} + r_{xh} = r_{dh} \left[1 + (1+\tau)^{1-\sigma} \right]$

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

Goods Market Equilibrium $\quad C_i = Y_i \quad$ for $\; i = \{dl, dh\}\,;\; C_i = \dfrac{Y_i}{(1+\tau)} \qquad$ for $\; i = \{xl, xh\}$ (7.B)

Given that unit costs (c_l, c_h) are independent of productivity levels, note that equation (4.B) in the open economy scenario is identical to (4.A). The relative unit costs remain unchanged (equation 8.B = 8.A).

2.12 Firm's decisions

2.12.1 Production and Export decision

Both the decision to enter the market and to produce remain unchanged relatively to the closed economy equilibrium:

$$\pi_{dl}\left(\varphi_{dl}^{*}\right) = 0 \;\Rightarrow\; \frac{r_{dl}\left(\varphi_{dl}^{*}\right)}{\sigma} = f \quad \Rightarrow \varphi_{dl}^{*\sigma-1} = f\; c_l^{\sigma-1}\frac{\sigma}{\Psi} \tag{9.B}$$

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

$$\pi_{xl}\left(\varphi_{xl}^{*}\right) = 0 \qquad \Rightarrow \frac{r_{xl}}{\sigma} = \delta f_x \qquad\qquad \Rightarrow \varphi_{xl}^{*\sigma-1} = \delta f_x\,(1+\tau)^{\sigma-1}\, c_l^{\sigma-1}\frac{\sigma}{\Psi} \tag{10.1.B}$$

Where φ_{xl}^{*} corresponds to the productivity level of the marginal firm able to enter the foreign market. Combining (9.B) and (10.1.B) leads to the definition of φ_{xl}^{*} as an implicit function of φ_{dl}^{*} :

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

2.12.2 The decision to adopt High Technology

Given that, in this case, the fixed technology costs are higher than the 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 upgrade to high technology. They will be those exporters whose increase in domestic and export sales due to their adoption of high technology will enable them to pay the fixed technology costs. This condition is given by: $\pi_{dh}(\varphi_{xh}^{*}) + \; \pi_{xh}(\varphi_{xh}^{*}) = \pi_{dl}(\varphi_{xh}^{*}) + \pi_{xl}(\varphi_{xh}^{*})$

$$\frac{[r_{dh}(\varphi_{xh}^*) + r_{xh}(\varphi_{xh}^*)] - [r_{dl}(\varphi_{xh}^*) + r_{xl}(\varphi_{xh}^*)]}{\sigma} = \delta f_t \Rightarrow \ \varphi_{xh}^{*\sigma-1} = \frac{\delta f_t}{\left[1+(1+\tau)^{1-\sigma}\right]\left[c_h^{1-\sigma} - c_l^{1-\sigma}\right]}\frac{\sigma}{\Psi} \tag{10.2.B}$$

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):

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

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

$$\frac{\delta f_t}{\left[1+(1+\tau)^{1-\sigma}\right]\left[\left(\frac{c_h}{c_l}\right)^{1-\sigma} - 1\right]} > (1+\tau)^{\sigma-1}\delta f_x > f \tag{11'.B}$$

This condition establishes that adopting high technology is more expensive than exporting and thereby suggests that only the most productive exporters can upgrade their technology. The weighted productivity average of each group of firms $(\widetilde{\varphi_{dl}}, \widetilde{\varphi_{xl}}, \widetilde{\varphi_{xh}})$ is defined using the same type of weighted average function defined in equations 12.A -16.A (Appendix 2 details the aggregation).

2.13 Labor Market Equilibrium and the Skill Premium in the Open Economy

In the open economy equilibrium, exporters 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 demand for final goods (C_{dl}, C_{dh}) and the exporting firms' foreign demand for final goods (C_{xl}, C_{xh}). Equation 17.A remains unchanged (17.A=17.B).

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

$$h_{xi} = \frac{[C_{xi} + C_{di}]}{\varphi} c_i^{\frac{1}{1-\alpha}} (w_h)^{\frac{1}{\alpha-1}} (a_h)^{\frac{\alpha}{1-\alpha}} \qquad \text{Where } i = \{l, h\} \qquad a_h > 1 \ if i = h \tag{19.B}$$

Like (20.A) and (21.A), the overall national demand for unskilled and skilled labor is determined by aggregating the firms' individual demands. Here, we have to take into account firms producing in the domestic market and both types of exporting firms.

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

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

The aggregate relative skilled labor supply and demand jointly determine the skill premium (see Appendix 2 for a presentation of the aggregate demands).

$$\frac{H^s}{L^s} = \frac{H^d}{L^d} \qquad \Rightarrow \omega = g(\frac{H^s}{L^s}, a_h, N_{dl}, N_{xl}, N_{xh,}\widetilde{\varphi_{dl}}, \widetilde{\varphi_{xl}}, \widetilde{\varphi_{xh}}) \qquad (22.B)$$

2.14 Open Economy Equilibrium Conditions

As in the closed economy equilibrium, we obtain an analytical solution for the productivity, technological and export cutoffs using a Pareto distribution of productivity draws (see Appendix 2). The equilibrium level of the productivity cutoff is determined by the FE, the new ZCP and LMC conditions, just as in the closed economy equilibrium. FE remains unchanged. Under the ZCP condition for the open economy equilibrium, we have to take into account the average profits of low- and high-technology exporters.[12]

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

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

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

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

Similar to the closed economy, under pareto distribution of productivity draws the skill premium is independent of the productivity cutoff (φ_{dl}^*). It is determined by the parameters of the model.

Proposition 4: *Under Assumption 1 and the partitioning condition of open economy (eq. 11'.B), there exists a unique costly trade equilibrium cutoff (φ_{dl}^*).*

[12] The variables "$\rho_l, \rho_{xh}, \rho_{xl}, \rho_x$" represent the probabilities of being a low technology firm (ρ_l), an exporting high technology firm (ρ_{xh}), an exporting low technology firm (ρ_{xl}) and finally an exporting firm (ρ_x)(See Appendix 2).

Proof. *See Appendix 2.* ∎

Capital Market and Global Accounting Conditions: [13]

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

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

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

3 The model's findings and predictions

3.1 The impact of trade liberalization

This section looks at the impact of trade liberalization on firms' decisions. In order to analyze the impact of trade on firms' decision to produce we compare the productivity cutoff of the marginal firm in the open economy equilibrium, as determined by equation 28.B, to its autarky level, as determined by equation 28.A. This cutoff is determined by the free entry condition and the zero cutoff profit condition (ZCP). The free entry condition remains unchanged, but the ZCP is higher in the open economy equilibrium. Indeed, trade liberalization induces an increase in the productivity cutoff level of the marginal firm. This is the selection effect in the domestic market, as presented by Melitz (2003). When the economy opens up to trade, the entry of the most productive foreign exporters onto the domestic market reduces all the firms' domestic profits, prompting the exit of the least productive firms.

Proposition 5: *Comparing the productivity cutoff of the open economy φ^*_{dl}, as determined in equation 28.B, to its autarky level φ^*_l, as determined in equation 28.A, we can prove that trade liberalization leads to a higher productivity cutoff.*

Proof. *See Appendix 2.*∎

This model sets out to introduce yet another channel based on the effects of trade on the extensive margin of technology adoption. Trade integration raises expected export profits and has a positive impact on both the extensive margin of trade (the number of new exporters) and of technology adoption (the number of new firms upgrading technology). The increase in export profitability induced by trade liberalization creates incentives to upgrade technology.

[13] Both conditions have to take into account trade costs.

Proposition 6: *Average profits of high technology exporters increase with a reduction of trade variable costs, for a given level of the skill premium.*

Proof. *See Appendix 2.*■

Therefore, the most productive low-technology exporters adopt high technology and raise their relative demand for skilled labor. Trade liberalization increases the number of firms using high technology skilled bias and thereby, raises the aggregate relative demand of skilled labor and inequalities between skilled and unskilled labor.

Proposition 7: *Under Assumption 1 and the partitioning condition of open economy (eq. 11'.B), both the aggregate relative demand of skilled labor and thereby the skill premium are decreasing functions of trade variable costs:* $\frac{\partial\left(\frac{H}{L}\right)^d}{\partial\tau} < 0$.

Proof. *See Appendix 2.*■

The last trade liberalization channel is the skill premium effect. In the general equilibrium, an upturn in the skill premium has a different impact on firms' decisions depending on their intensity in skilled and unskilled labor. However, this is an effect stemming from the increase in the extensive margin of technology induced by selection. The low-technology unskilled-intensive firms benefit from the reduction in the relative unskilled labor wage (skill premium appreciation) compared with the most productive, skilled-intensive workers. Opposite forces affect both the production and technology productivity cutoff: (1) the domestic and export selection effect, and (2) the skill premium effect. In order to determine which effect dominates, I run simulations of the impact of trade variable costs reduction on the equilibrium productivity cutoff taking into account the variations of the skill premium (See Appendix 2 and 3). Under the specific partitioning condition, the effects of trade reforms are quite unambiguous. Given that the increase in skill premium is a second-order effect, the net effect of trade reforms on the productivity cutoff is negative (Graph 1 in Appendix 3). The impact of variable trade costs is unambiguous and positive for the extensive margin of trade. New unskilled-intensive firms find it profitable to start exporting. Lastly, the net effect of trade liberalization on the extensive margin of technology is also positive. The increase in export profitability offsets the increase in the skill premium (Graph 2).

3.2 Testable predictions

The results analyzed in the previous section yield a set of testable predictions concerning the determinants of technology choice and the relative demand of skilled labor, and the differentiated impact of trade integration on firms' decisions. Compared to a model of homogeneous firms, this model predicts that:

Testable prediction 1: Only the most productive and larger exporters are able to upgrade technology.

In the theoretical framework the probability that a firm with productivity φ upgrades technology is determined by:

$$P(TECH_{it} > 0) = [[r_{dh}(\varphi^*_{xh}) + r_{xh}(\varphi^*_{xh})] - [r_{dl}(\varphi^*_{xh}) + r_{xl}(\varphi^*_{xh})] > f_t\sigma]$$

This probability is an increasing function of φ. This prediction is tested by estimating the determinants of the probability that firm i adopts foreign technology at time t, using the following reduced form:

$$\text{(I) } Prob(TECH_{it} > 0) = 1$$
$$if\ \alpha_1 + \alpha_2 TFP_{i(t-1)} + \alpha_3 Size_{i(t-1)} + \alpha_4 Z_{i(t-1)} + \upsilon_t + \mu_i + \epsilon_{it} > 0$$

Where $TECH_{it}$ is a dummy variable equal to one if the firm i uses high technology, $TFP_{i(t-1)}$ is the log of plant total factor productivity in the previous year, $Size_{i(t-1)}$ is the log of plant total employment in the previous year; and $Z_{i(t-1)}$ is a vector of control variables of plant characteristics such as capital intensity (the log of capital stock over total employment), an indicator of foreign status (FDI)[14] and a financial indicator, which identifies plants that do not face credit constraints.[15] In order to address the potential simultaneity problems between technology choice and firms' observable characteristics, we lag all control variables one year. This strategy is similar to previous works on the probability of exporting developed by Bernard and Jensen (2004). ϵ_{it} is an unobserved component. We introduce year fixed effects (υ_t) to control for macroeconomic shocks and specific plant fixed effects (μ_i) to control for the unobservable plant characteristics. In the specifications without plant fixed effects we also control by industry indicators at the 3-digit industry level.

Testable prediction 2: Only those firms that have adopted the high technology increase their relative demand for skilled labor.

This prediction is directly derived from the assumption that high technology is skilled bias. Firms that upgrade technology have a larger relative demand for skilled labor:

$$\frac{h_i}{l_i} = \omega^{\frac{1}{\alpha-1}} (a_h)^{\frac{\alpha}{1-\alpha}} \qquad a_h > 1 \quad \text{if the firm upgrades technology.}$$

[14]To control for the presence of multinational firms, a dummy variable equal to one is introduced when the percentage of foreign capital is higher than 50% (FDI indicator).

[15]"Credit" is a dummy variable equal to one if the plant reports having paid a loan tax in year "t" indicating that they are not subject to financial constraints. Industry affiliation (three-digit ISIC level) and year dummies are also introduced.

This prediction is tested by estimating a model in first differences in order to investigate whether those exporters that have adopted the high technology upgrade skilled labor. We estimate the following model:

(II)$\Delta \ln \left(\frac{H_{it}}{L_{it}}\right) = \beta_1 + \beta_2 \Delta Exporter\_TECH_{it} + \beta_3 \Delta Exporter\_Only_{it} + \beta_4 \Delta TECH\_non\_exporter_{it} + \beta_5 \Delta Z_{it} + \upsilon_t + \mu_i + \Delta e_{it}$

The dependant variable is the number of skilled workers over unskilled workers $\left(\frac{H_{it}}{L_{it}}\right)$. Exporter_TECH is an interaction term between export and technology status. It is a dummy variable equal to one if the firm i exports and also switchs to foreign-high technology in time t. *Exporter_Only* is a dummy variable equal to one if the firm i exports but does not adopt high technology. $TECH\_non\_exporter$ is a dummy variable equal to one if the firm uses high technology but does not export. The omitted category corresponds to non exporters that do not upgrade technology. Therefore, all results are interpreted relative to these firms selling only in the domestic market and producing with low technology. Z_{it} is a vector of control variables of plant characteristics (plant TFP, capital intensity, credit, foreign status). e_{it} is an unobserved component. We introduce year fixed effects (υ_t) to control for macroeconomic shocks and specific plant fixed effects (μ_i) to control for the unobservable plant characteristics. In the specifications without plant fixed effects we also control by industry indicators at the 3-digit industry level.

Testable prediction 3: A reduction in variable trade costs encourages only those firms who are already exporters to upgrade their technology.

We test the impact of changes in trade variable costs on the probability of adopting foreign technology using the following linear probability model with plant fixed effects:

(III.A) $Prob(TECH_{it} > 0) = 1$
$if\ \gamma_1 + \gamma_2 \Delta TX_s + \gamma_3 TFP_{i(t-1)} + \gamma_4 Size_{i(t-1)} + \gamma_5 Z_{i(t-1)} + \upsilon_t + \mu_i + \epsilon_{it} > 0$

Where $TECH_{it}$ is a dummy variable equal to one if the firm i uses foreign technology at time t, TX is the export barrier, which varies across time. Similar to previous regressions we control for plant observable characteristics in the previous year, time indicators (υ_t) and plant fixed effects (μ_i).

As a robustness check, we also test this prediction by estimating the impact of a reduction in export barriers on the evolution in foreign technology spending for different export status using the following framework:

(III.B) $lnTECH\_S_{it} = \delta_1 + \delta_2(Export_i) + \delta_3(TX_{st}) + \delta_4(TX_{st} * Export_i) + \delta_c Z_{it} + \upsilon_t + \eta_s + \epsilon_{it}$

Where $TECH\_S_{it}$ is foreign technology spending; export is a vector of the dummy variables indicating the export status of the plants (always, starter, switcher, stopper)[16]; and Z_{it} is a vector of the control variables.[17] υ_t are time fixed effects and η_s 3-digit industry fixed effects. The omitted categories are non-exporters, the year 1990 and sector 390 (other industries).

Testable prediction 4: After a fall in variable trade costs, only the new high-technology exporters increase their relative demand for skilled labor.

In order to test this prediction, we first estimate the impact of a change in trade variable costs on a change in the relative demand of skilled labor in the full sample and also in the subsample of high-technology exporters:

(IV.A) $\Delta \ln\left(\frac{H_{it}}{L_{it}}\right) = \chi_1 + \chi_2 \Delta TX_{st} + \chi_3 \Delta Z_{it} + \upsilon_t + \eta_s + \Delta e_{it}$

The dependant variable is the number of skilled workers over unskilled workers $\left(\frac{H_{it}}{L_{it}}\right)$, TX is the export barrier and and Z_{it} is a vector of the control variables. υ_t are time fixed effects and η_s 3-digit industry fixed effects.

Similar to the previous prediction, as a robustness check, we estimate the effect of a reduction in variable trade costs on the relative demand for skilled labor by firm export status using the following specification with interaction terms between trade barriers and export status:

(IV.B) $\ln\left(\frac{H_{it}}{L_{it}}\right) = \lambda_1 + \lambda_2(Export_i) + \lambda_3(TX_{st}) + \lambda_4(TX_{st} * Export_i) + \lambda_5 Z_{it} + \upsilon_t + \eta_s + e_{it}$

4 Empirical evidence

4.1 Data and descriptive analysis

This section provides some evidence in support of the theoretical predictions. This evidence draws on a database of Chilean plants provided by the ENIA Survey, a comprehensive manufacturing census covering all plants with more than 10 employees from 1979 to 1999. The data used covers value-added, investment in new capital equipment, foreign technology assistance (FTA),imported inputs, expenditures on patent use and skilled and unskilled labor, and the share of skilled and unskilled labor in the wage bill. Export sales are reported from 1990 onwards. The plants' TFP was estimated as a residual of factor contributions (capital, skilled and unskilled labor) by Bas

[16] Always is a firm that exports in all years of the period, starter is the firm that becomes an exporter during the period and does not reswitch, switcher is the one that changes its export status more than once and stopper is the one that exits the export market during the period.

[17] The control variables are plant size (measured by staff numbers in the initial year), capital intensity in the initial year, an foreing status indicator and one of the credit constraints. Industry affiliation (three-digit ISIC level) and year dummies are also introduced.

and Ledezma (2007) based on the semi-parametric estimations by Levinsohn and Petrin (2003).[18] Given that Chile is a developing country highly dependent on imported capital equipment and intermediate inputs, we consider that the most appropriate proxies for high technology are foreign technology measures. This measure comprises expenditure on foreign technological assistance (FTA) similar to Pavcnik (2003). Those firms that report expenditures on FTA are considered as firms with access to foreign technology. As a robustness check we use alternative technology measures such as expenditures on patent use and investment in new machinery. Table 10 (Appendix 4) summarizes the variables and data requirements.

We use as a measure of variable trade costs faced by Chilean exporters an average of import tariffs on chilean exports at the three-digit industry level (1991-1999) set by Chile's main Latin American trading partners. This data draws on the Trade and Production Database (World Bank and CEPII). The reduction of average import tariff is 8% in the period.[19]

Table 11 (Appendix 4) summarizes the firms' main characteristics (3,900 plants per year). Exporters (31%) are larger[20], more productive (higher TFP) and more skilled and capital intensive. The proportion of exporters using FTA, investing on new machinery, using patent rights and imported inputs is much higher than the percentage of non-exporters. The features of the open economy equilibrium described in the previous section fit the descriptive evidence for the case of Chile. In order to test the assumption of heterogeneous firms in terms of productivity levels, we estimate the export premia. As in Bernard and Jensen (2004) we classified export status in 5 firm export types (always, starter, switcher, stopper and never exporters) in order to test their impact on plants' TFP .Table 12 (Appendix 4) reports on these findings. The omitted category corresponds to those firms that never export. Once we have controlled for initial size, foreign status and financial constraint indicators (column 4), only continuing, new exporters and switchers are more productive than those firms that sell solely on the domestic market. Among the exporters, the most productive are those that exported throughout the entire period. Continuing exporters are 28% more productive than non-exporters, while new exporters and switchers are 17% more productive (column 4). Those firms using foreign technology are more productive (31%) than the ones using domestic technology (column 5).

Our analysis of growth in the relative skilled labor demand and skill premium uses the decomposition approach developed by Machin and Van Reenen (1998) (Tables 13 and 14 Appendix 4). From 1979 to 1999, the relative demand for skilled labor rose 20% at the three-digit industry level. This increase is entirely explained by the within-industry variation. The between indicator is

[18] Several specific sector-level deflators (Isic-3dig Rev2 1992) are applied to value-added, technological measures, materials and investment.

[19] The Latin American countries are Argentina, Brazil, Bolivia, Colombia, Mexico, Peru, Uruguay and Venezuela.

[20] Size classification: large firms have more than 150 workers, medium firms have more than 50 and up to 149 workers and small firms have more than 10 and up to 49.

negative and extremely small. [21] During the debt crisis (1979-1986), skill intensity rose to 37% at the two-digit industry level. A full 26% of this increase is explained by the within estimator, while only 11% is explained by the between indicator. In the 1990s, there was also a rise in the relative demand for skilled labor, which is entirely explained by the within estimator. Similar findings hold for relative skilled wages in all periods.

4.2 Testing the predictions of the model

Prediction 1: Technology choice determinants

The model's first prediction concerns the determinants of technology choice. The model predicts that only the most productive and larger exporters upgrade technology. Table 1 presents the results of the estimation of equation (I) using foreign technological assistance (FTA) as a proxy of technology adoption for the subsample of firms that export in the period. Column 1 reports the results on logit estimations with year and industry fixed effects and column 2 presents the results on conditional Logit estimations with plant fixed effects. Since there is bias in the coefficients of conditional Logit estimations with plant fixed effects, as a robustness check columns 3 to 4 present the results of the linear probability model. As expected the coefficients of the linear probability model are smaller than those of the conditional logit. Once we control for observable plant characteristics, using the linear probability model (column 3), productivity increases the probability of upgrading technology of 3%, size (employment) of 7%, capital intensity and financial access of 2% and foreign status (FDI) of 10%. Once we control by observed and unobserved plant characteristics (column 2 and 4), in both specifications, the main determinant of foreign technology choice is total factor productivity in the previous year.

As a robustness check we use alternative technology measures. Columns 1 and 2 of table 2 show the results using as a dependant variable a dummy variable equal to one if the firm i reports expenditures on patent use at time t. Under the linear probability model with plant fixed effects, size raises the probability that exporters upgrade technology (patent use) of 5%, plant TFP of 2% and the access to credit 4% (column 2). Columns 3 and 4 of table 2 report the results using as a dependant variable a dummy variable equal to one if the firm i invests in new machinery at time t as a proxy of technology choice. Under the linear probability model with plant fixed effects, size raises the probability that exporters invest in new machinery of 7%, plant TFP of almost 5% (column 4).

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

To conclude, we find robust empirical evidence supporting the first prediction of the model. This evidence shows that plant productivity and size are the main determinants of technology choice for those firms that are engaged in the export market.

Prediction 2: New high-technology exporters increase their relative demand for skilled labor

The model also predicts that those firms that have adopted the high technology increase their relative demand of skilled labor since technology is skilled-biased. This prediction is tested by estimating equation (II) using a model in first differences. Table 3 reports the results using foreign technological assistance (FTA) as a proxy of technology adoption. The coefficient of interest is β_2. It measures the impact of those exporters using low technology at time t-1 who switch to high technology at time t, on changes in skill upgrading from time t-1 to t relative to non exporters that do not upgrade technology. This coefficient is positive and significant indicating that exporters who adopt foreign technology are more skilled intensive than firms selling on the domestic market and producing with low technology. However, the coefficient of $Exporter\_Only$ indicator is positive but not significant once we control for plant fixed effects (column 5) . As predicted by the model, those exporters that have not switched to high technology will not upgrade skill since they are unskilled intensive. Finally, as predicted by the model the coefficient of $TECH\_non\_exporter$ is not significant in all specifications.

In the first column we control for changes on plant TFP and in the second one for changes on capital intensity. As expected an increase in productivity levels as well as in capital intensity raise the relative skilled labor demand. Those firms that do not face credit constraint also upgrade skills (column 3). The change on foreign status is not significant (column 4). In the last column we introduce plant fixed effects. Once we control for plant unobservable characteristics, the coefficient of $Exporter\_TECH$ indicator is still positive and significant, while the coefficient of $Exporter\_Only$ is not significant. Therefore, only exporters that upgrade technology will increase their relative demand of skilled labor.

As a robustness check, we test the impact of patent use and investment in new machinery on skill upgrading. Table 4 reports the results using patent indicator as an alternative measure of technology adoption. Columns 1 to 3 show the results once we control by year and industry fixed effects for the full sample (column 1), the subsample of never exporters (column 2) and those of exporters (column 3). Columns 4 to 6 report the results controlling by plant fixed effects. Once we control for the unobservable plant characteristics, the impact of patent indicator on the relative demand of skilled labor is positive and significant only for the full sample and the subsample of exporters. Table 5 shows the results using investment in new machinery indicator. In this case, the impact of technology on the growth of the relative demand of skilled labor is only positive and significant in the case of exporters.

This evidence confirms that only exporters that upgrade technology increase their relative demand of skilled labor as it is predicted by the model.

Prediction 3: The impact of trade liberalization on technology adoption

One of the model's prediction concerns the impact of trade liberalization on the extensive margin of technology adoption. A reduction in variable trade costs encourages some exporters to switch to more advanced technology. This prediction is tested using a linear probability model with plant fixed effects. Table 6 reports estimations of equation (III.A). The model predicts a negative coefficient (γ_2) of the change in export barriers indicating that a reduction of trade frictions increases the probability of upgrading technology. Columns 1 to 4 report the results for the full sample. Once we control for observable and unobservable plant characteristics, the reduction of tariffs has a positive effect on the probability of adopting high technology (-0.189). In the last column we run the same regression on the sample of those firms that export during the whole period (1990-1999) or those that start exporting. In this case, the impact of tariff reductions on technology choice is larger since the coefficient of the change in tariffs is much higher (-0.537).

As a robustness check, we also test this prediction by estimating equation (III.B). This equation disentangles the growth in foreign technology expenditure due to changes in trade costs depending on the export status of the firm. We are mainly interested in the estimates of the vector coefficient δ_4. These are the coefficients of the interaction terms between export barriers and export status. A negative and significant coefficient is expected, meaning that a reduction in trade costs triggers a greater increase in foreign technology expenditure by exporters compared with non-exporters. The results of the estimation of equation (III.B) by OLS with standard errors clustered at plant level are presented in Table 7. In columns 2 to 5, we control by initial plant TFP and capital intensity, foreign status and financial indicator (credit) in the previous year. However, after controlling by means of these alternative explanations the coefficients of the interaction term between continuing exporters (Always) and average tariffs is still negative and significant. Within the same industry, continuing exporters have a higher level of foreign technology than non-exporters after a reduction in trade barriers. Since the average reduction of the average import tariff is 7%, compared with non-exporters, continuing exporters raise their foreign technology expenditure from a range of 7%.

Prediction 4: The impact of trade liberalization on the relative skilled labor demand

Finally, this model predicts that, after trade liberalization, exporters producing with high technology will raise their relative demand for skilled labor. Since more advanced technology is complementary with skilled labor, exporters that upgrade technology following trade reform will also upgrade skilled labor.

We estimate equation (IV.A), columns 1 to 4 in table 8 present the results of these estimations for the full sample. After controlling for changes in plant productivity, capital intensity, foreign and financial status, a reduction in tariffs has a significant and positive effect on the growth of the relative demand of skilled labor (column 4). In the last column we report the results for the subsample of those continuing exporters that have adopted high technology during the period. In this case the positive impact of tariff cut on skill upgrading is much higher. Trade liberalization induces a raise in the relative demand of skilled labor of high technology exporters of 17% log points.

As a robustness check, table 9 reports the estimations of equation (IV.B) by OLS with Huber White standard errors clustered at plant level. After controlling for the plant's initial productivity, capital intensity and foreign status, differences in skill upgrading between continuing exporters and firms selling only on the domestic market increase as export barriers decrease. The trade-liberalization-induced increase in the relative demand for skilled labor by continuing exporters compared with non-exporters ranges from 2%.

5 Conclusions

This paper explores the changes in the extensive margin of technology adoption and its effect on wage inequalities following trade liberalization. The mechanism is based on the impact of the technology-upgrading decision on the relative demand for skilled labor and hence on the skill premium. In terms of policy implications, a reduction in variable trade costs raises the number of firms selling abroad and encourages the most productive firms to switch to high technology. This enhances the relative demand for skilled labor and boosts the skill premium. The main contribution of this paper to the existing literature is to propose a general equilibrium model that links trade, firms' technology choice and wage inequalities in a framework of heterogeneous firms. This theoretical framework also explains the extensive empirical evidence: firms selling on foreign markets are not only more productive, but also use modern technologies and are more skill-intensive than firms selling only on the domestic markets. We provide evidence in support of the model's key predictions, drawing on plant level panel data for Chile's manufacturing sector.

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6 Appendix 1: closed economy equilibrium

The relative skill per unit cost is an increasing function of the skill premium (equation 8.A):

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

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

Aggregation. Using price rule (eq. 3.A) and plugging it into the aggregate price index yields:

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

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

Aggregate Revenue

$$R = N_l\int_{\varphi_l^*}^{\varphi_h^*} r_l(\varphi)\mu_l(\varphi)d\varphi + N_h\int_{\varphi_h^*}^{\infty} r_h(\varphi)\mu_h(\varphi)d\varphi = N\underbrace{\left[\frac{N_l}{N}r_l(\widetilde{\varphi_l}) + \frac{N_h}{N}r_l(\widetilde{\varphi_h})\left(\frac{c_h}{c_l}\right)^{1-\sigma}\right]}_{r(\widetilde{\varphi_T})} = Nr\left(\widetilde{\varphi_T}\right)$$

Averages productivities assuming Pareto distribution. Similar to Melitz and Ottaviano (2008), 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. Since we assume that $\varphi_{\min} = 1$ and the condition that ensures a finite mean of firm size is $k > \sigma - 1$. The cumulative distribution function is $G(\varphi_i) = 1 - \left(\frac{\varphi_{\min}}{\varphi_i}\right)^k$.

Average productivity of low technology firms

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

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

Average productivity of high technology firms $\widetilde{\varphi_h} \equiv \upsilon\varphi_h^* \qquad$ if $\qquad \varphi > \varphi_h^*$

Determination of probabilities: $\rho_l = 1 - \frac{1-G(\varphi_h^*)}{1-G(\varphi_l^*)} = 1 - \left(\frac{\varphi^*}{\varphi_h^*}\right)^k \qquad \rho_h = \frac{1-G(\varphi_h^*)}{1-G(\varphi_l^*)} = \left(\frac{\varphi^*}{\varphi_h^*}\right)^k$

Labor Market Condition: Plugging firms' final good demands (1.A) into (18.A) and (19.A) and using (4.A) to express c_l, c_h, firms' demand of skilled (h_l, h_h) and unskilled labor is:

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

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

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

Plugging firms' prices (3.A) into (18.A') and (19.A') and then into aggregate skilled and unskilled labor demands using (20.A) and (21.A), we obtain the aggregate relative demand for skilled labor (22.A).

Proof of Proposition 1: Determination of closed economy equilibrium.

Proof. LMC (22.A), FE (23.A) and ZCP (24.A) conditions jointly determine the equilibrium cutoff level (φ_l^*). In order to obtain this cutoff, we plug into eq. 24.A the averages productivities, the technology cutoff (eq. 11.A) and the probabilities using assumption 1 and we obtain:

$$\varphi_{la}^{*k} \delta f_E = f \; \left[(\upsilon)^{\sigma-1} - 1\right] + \left[\left[\left(\frac{c_h}{c_l}\right)^{1-\sigma} - 1\right]^{\frac{k}{\sigma-1}} f_t \left(\frac{f_t}{f}\right)^{\frac{k}{1-\sigma}} \left[(\upsilon)^{\sigma-1} - 1\right]\right] \; (28.A)$$

Since the relative skilled labor unit cost $\left(\frac{c_h}{c_l}\right)$ depends on the skill premium, equations 28.A and 22.A (LMC) determine the equilibrium production cutoff.■

Proof of Proposition 2: We partially differentiate equation 28.A with respect to $\frac{c_h}{c_l}(\omega)$, in order to analyze the impact of an exogenous increase in the skill premium on the productivity cutoff. Partially differentiating (28.A) we find $\frac{\partial \varphi_l^*}{\partial \frac{c_h}{c_l}(\omega)} < 0$.

$$\frac{\partial \varphi_l^*}{\partial \frac{c_h}{c_l}(\omega)} = (-1)\left(\varphi_l^{*k}\right)^{\frac{1}{k}-1} \left[\left(\frac{c_h}{c_l}\right)^{1-\sigma} - 1\right]^{\frac{k}{\sigma-1}-1} \left(\frac{c_h}{c_l}\right)^{-\sigma} \left[\frac{f_t}{f_E}\left(\frac{\delta f_t}{f}\right)^{\frac{k}{1-\sigma}} \left[(\upsilon)^{\sigma-1} - 1\right]\right] (29.A)$$

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

Proof of Proposition 3: Partially differenciating (11.A) with respect to $\frac{c_h}{c_l}(\omega)$, we find

$$\frac{\partial \varphi_h^*}{\partial \frac{c_h}{c_l}(\omega)} = \frac{\varphi_h^*}{\varphi_l^*}\left[\frac{\partial \varphi_l^*}{\partial\left(\frac{c_h}{c_l}\right)} + \varphi_l^* \left[\left(\frac{c_h}{c_l}\right)^{1-\sigma} - 1\right]^{-1} \left(\frac{c_h}{c_l}\right)^{-\sigma}\right] > 0 \qquad (30.A)$$

We can demostrate that $\frac{\partial \varphi_h^*}{\partial \frac{c_h}{c_l}(\omega)} > 0$ since the term in brakets in (30.A) is positive. Plugging (29.A) $\frac{\partial \varphi_l^*}{\partial \frac{c_h}{c_l}(\omega)}$ into (30.A), the term in brakets in (30.A) can be expressed as follows:

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

Using (28.A): $\frac{f}{\delta f_E}\left[(\upsilon)^{\sigma-1} - 1\right] > 0$. This result holds since $\frac{f}{\delta f_E} > 0$ and $(\upsilon)^{\sigma-1} - 1 > 0$. Indeed, $\frac{\partial \varphi_h^*}{\partial\left(\frac{c_h}{c_l}\right)} > 0$. ■

7 Appendix 2: Open Economy Equilibrium

Averages productivities assuming Pareto distribution.

$\mu_{dl}(\varphi) = \frac{g(\varphi)}{G(\varphi_{xl}^*) - G(\varphi_{dl}^*)}$ if $\varphi_{dl}^* < \varphi_i < \varphi_{xl}^*$ (12.B);

$\mu_{xl}(\varphi) = \frac{g(\varphi)}{G(\varphi_{xh}^*) - G(\varphi_{xl}^*)}$ if $\varphi_{xl}^* < \varphi_i < \varphi_{xh}^*$ (13.1.B);

$\mu_{xh}(\varphi) = \frac{g(\varphi)}{1 - G(\varphi_{xh}^*)}$ if $\varphi_i > \varphi_{xh}^*$ (13.2.B)

Average productivity of low technology firms (non exporters and exporters) in the open economy

$\widetilde{\varphi_l}^o \equiv \upsilon \varphi_{dl}^* \left[\frac{1-(\varepsilon)^{-k+\sigma-1}}{1-\varepsilon^{-k}}\right]^{\frac{1}{\sigma-1}}$ Where $\upsilon = \left[\frac{k}{k-(\sigma-1)}\right]^{\frac{1}{\sigma-1}}$ (14.B)

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

Average productivity of non exporters firms producing with low technology

$$\widetilde{\varphi_{dl}}^{\sigma-1} \equiv \frac{1}{G(\varphi_{xl}^*) - G(\varphi_{dl}^*)} \int_{\varphi_{dl}^*}^{\varphi_{xl}^*} (\varphi)^{\sigma-1} g(\varphi) d\varphi = \upsilon \varphi_{dl}^* \left[\frac{1-(\vartheta)^{-k+\sigma-1}}{1-\vartheta^{-k}}\right]^{\frac{1}{\sigma-1}}$$

if $\varphi_{dl}^* < \varphi < \varphi_{xl}^*$ Where $\vartheta = \left(\frac{f_x}{f}\right)^{\frac{1}{\sigma-1}}(1+\tau)$

Average productivity of exporters producing with low technology

$$(\widetilde{\varphi_{xl}})^{\sigma-1} \equiv \frac{1}{G(\varphi_{xh}^*) - G(\varphi_{xl}^*)} \int_{\varphi_{xl}^*}^{\varphi_{xh}^*} (\varphi)^{\sigma-1} g(\varphi) d\varphi = \upsilon \varphi_{xl}^* \left[\frac{1-(\Omega)^{-k+\sigma-1}}{1-\Omega^{-k}}\right]^{\frac{1}{\sigma-1}}$$

if $\varphi_{xl}^* < \varphi < \varphi_{xh}^*$ Where $\Omega = \frac{\varepsilon}{1+\tau}\left(\frac{f}{f_x}\right)^{\frac{1}{\sigma-1}}$

Average productivity of high technology exporters

$\widetilde{\varphi_{xh}}^{\sigma-1} \equiv \frac{1}{1-G(\varphi_{xh}^*)} \int_{\varphi_{xh}^*}^{\infty} (\varphi)^{\sigma-1} g(\varphi) d\varphi \equiv \upsilon \varphi_{xh}^* \qquad \text{if} \qquad \varphi > \varphi_{xh}^*$ (15.B)

Determination of probabilities $\rho_l^o = 1 - \varepsilon^{-k};\ \ \rho_x = \left(\frac{\varphi_{dl}^*}{\varphi_{xl}^*}\right)^k = \vartheta^{-k};\ \rho_{dl} = \left[1 - \vartheta^{-k}\right];$

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

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

$P = N^{\frac{1}{1-\sigma}} p\left(\widetilde{\varphi_T}\right) \qquad \text{Where } p\left(\widetilde{\varphi_T}\right) = \frac{\sigma}{\sigma-1} \frac{c_l}{\widetilde{\varphi_T}}$

$\widetilde{\varphi_T}^{\sigma-1} = \frac{1}{N}\left[N_l^o \left(\widetilde{\varphi}_l{}^o\right)^{\sigma-1} + N_{xh}\left(\widetilde{\varphi_{xh}}\right)^{\sigma-1}\left(\frac{c_h}{c_l}\right)^{1-\sigma}\left[1+(1+\tau)^{1-\sigma}\right] + (1+\tau)^{1-\sigma} N_{xl}\left(\widetilde{\varphi_{xl}}\right)^{\sigma-1}\right]$
(16.B)

Labor Market Condition

Plugging firms' final good demands (1.B) into (18.B) and (19.B), individual demand for skilled (h_{xl}, h_{xh}) and unskilled labor (l_{xl}, l_{xh}) by exporting firms with low and high technology is:

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

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

Exporters have to hire both types of workers to produce for both domestic and foreign markets. Plugging prices (3.B) into (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 for skilled labor (22.B), which determines the skill premium.

$$\frac{H_t^s}{L_t^s} = (\omega_t)^{\frac{1}{\alpha-1}}\left[\frac{1+(a_h)^{\frac{\alpha}{1-\alpha}}\left[\frac{N_{xh}}{N_l}\left(\frac{\widetilde{\varphi_{xh}}}{\widetilde{\varphi_l}^o}\right)^{\sigma-1}\right]A}{1+\left[\frac{N_{xh}}{N_l}\left(\frac{\widetilde{\varphi_{xh}}}{\widetilde{\varphi_l}^o}\right)^{\sigma-1}\right]A}\right] \qquad (22.B)$$

In the open economy the number of domestic and exporting firms using low technology and its average productivity is determined by: $N_l^o\left(\widetilde{\varphi}_l{}^o\right)^{\sigma-1} = N_{dl}\left(\widetilde{\varphi_{dl}}\right)^{\sigma-1} + N_{xl}\left(\widetilde{\varphi_x}\right)^{\sigma-1}\left[1+(1+\tau)^{1-\sigma}\right]$

Proof of Proposition 4: Determination of the open economy 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: $\widetilde{\varphi_{dl}}, \widetilde{\varphi_{xl}}^{o}, \widetilde{\varphi_{xh}}, \rho_l, \rho_{xl}$ ρ_{xh} and $\varphi^*_{xl}, \varphi^*_{xh}$, we obtain the production cutoff level as a function of the skill premium and the parameters of the model.

$$\widetilde{\pi} = \rho_l \widetilde{\pi}_{dl} + \rho_{xl}\widetilde{\pi}_{xl} + \rho_{xh}\left[\widetilde{\pi}_{dh} + \widetilde{\pi}_{xh}\right]$$

$$\varphi^{*k}_{dl}\delta f_E = f\left[(\upsilon)^{\sigma-1} - 1\right] + \varepsilon^{-k}\left[\frac{f\upsilon^{\sigma-1}\left[1+(1+\tau)^{1-\sigma}\right]}{\varepsilon^{1-\sigma}\left(\frac{c_h}{c_l}\right)^{\sigma-1}} - f_t\right] + \frac{f_x\left[\frac{1-(\Omega)^{-k+\sigma-1}}{1-\Omega^{-k}}\right]}{(\upsilon)^{1-\sigma}\left[\vartheta^{-k} - \varepsilon^{-k}\right]^{-1}} - \frac{f_x}{\vartheta^k} - \frac{f\upsilon^{\sigma-1}}{\varepsilon^{k-(\sigma-1)}} \quad (28.B) \blacksquare$$

Proof of Proposition 5:

Comparing the productivity cutoff of the open economy φ^*_{dl}, as determined in equation 28.B, to its autarky level φ^*_l as determined in equation 28.A, we can prove that $\varphi^*_{dl} > \varphi^*_l$.

Plugging $\varepsilon = \left(\frac{f_t}{f}\right)^{\frac{1}{\sigma-1}}\left[\left[\left(\frac{c_h}{c_l}\right)^{1-\sigma} - 1\right]\left[1 + (1+\tau)^{1-\sigma}\right]\right]^{\frac{1}{1-\sigma}}$ into the second term of equation 28.B yields to:

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

Then we compare the second term of 28.B with the second term of 28.A and

$$\frac{\left[1+(1+\tau)^{1-\sigma}\right]^{\frac{k}{\sigma-1}}\left[\upsilon^{\sigma-1} - \left[1 - \left(\frac{c_h}{c_l}\right)^{\sigma-1}\right]\right]}{\left[1 - \left(\frac{c_h}{c_l}\right)^{\sigma-1}\right]\left[(\upsilon)^{\sigma-1} - 1\right]} > 1$$

The first term of equation 28.A and 28.B is the same. The third term of equation 28.B corresponds to average profits of low technology exporters is positive and superior to the last terms. Therefore, since the second term of equation 28.B is superior to the second term of equation 28.A, the productivity cutoff of the open economy (φ^*_{dl}) is higher than the productivity cutoff of the closed economy (φ^*_l). $\blacksquare$

Proof of Proposition 6:

Average profits of high technology exporters increase with a reduction of trade variable costs. Partially differenciating $\rho_{xh}\left[\widetilde{\pi}_{dh} + \widetilde{\pi}_{xh}\right] = \frac{\varepsilon^{-k+\sigma-1} f\upsilon^{\sigma-1}\left[1+(1+\tau)^{1-\sigma}\right]}{\left(\frac{c_h}{c_l}\right)^{\sigma-1}} - \varepsilon^{-k} f_t$.with respect to τ taking

$\overline{\frac{c_h}{c_l}}$ and $\overline{\omega}$ as given.

$$\frac{\partial \rho_{xh}[\widetilde{\pi}_{dh}+\widetilde{\pi}_{xh}]}{\partial \tau} = \frac{\partial \varepsilon}{\partial \tau}\varepsilon^{-k-1}kf_t\left[1-\frac{1}{\left[1-\left(\frac{c_h}{c_l}\right)^{\sigma-1}\right]}\right]+(1-\sigma)\frac{\varepsilon^{-k+\sigma-1}f\upsilon^{\sigma-1}(1+\tau)^{-\sigma}}{\left(\frac{c_h}{c_l}\right)^{\sigma-1}}$$

$\frac{\partial \rho_{xh}[\widetilde{\pi}_{dh}+\widetilde{\pi}_{xh}]}{\partial \tau} < 0$.The first term is negative since $0 < \left(\frac{c_h}{c_l}\right)^{\sigma-1} < 1$ and the second term is also negative since $\sigma > 1$.■

Proof of proposition 7: The impact of trade costs reduction on the aggregate relative skilled labor demand.

Plugging $N_l^o = \rho_l^o N \quad N_{xh} = \rho_{xh}N; \quad \frac{\rho_{xh}}{\rho_l^o} = \frac{\varepsilon^{-k}}{1-\varepsilon^{-k}}; \quad \frac{\widetilde{\varphi_{xh}}}{\widetilde{\varphi_l}^o} \equiv \varepsilon\left[\frac{1-\varepsilon^{-k}}{1-(\varepsilon)^{-k+\sigma-1}}\right]^{\frac{1}{1-\sigma}}$, into equation 22.B, the aggregate relative skilled labor demand can be expressed as follows:

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

Where: $X(\tau) = \left[\frac{1}{\xi^{k-(\sigma-1)}\left[1+(1+\tau)^{1-\sigma}\right]^{\frac{-k+(\sigma-1)}{\sigma-1}}-1}\right]; \quad A = \left(\frac{c_h}{c_l}\right)^{-\sigma}\left(\frac{(\omega)^{\frac{\alpha}{\alpha-1}}+1}{\left(\frac{\omega}{a_h}\right)^{\frac{\alpha}{\alpha-1}}+1}\right)^{\frac{1}{\alpha}}$

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

Similar to the closed economy equilibrium, under the Pareto distribution of productivity draws the aggregate relative demand of skilled labor is independent of the productivity cutoff. To determine whether the aggregate relative skilled labor demand is a decreasing function of variable trade costs, we partial differenciate $\frac{H_t^d}{L_t^d}(\tau)$ with respect to τ .

$$\frac{\partial \frac{H_t^d}{L_t^d}}{\partial \tau} = (\omega_t)^{\frac{1}{\alpha-1}}\left[\frac{(a_h)^{\frac{\alpha}{1-\alpha}}A\frac{\partial X}{\partial \tau}[1+AX(\tau)]-A\frac{\partial X}{\partial \tau}\left[1+(a_h)^{\frac{\alpha}{1-\alpha}}AX(\tau)\right]}{[1+AX(\tau)]^2}\right]$$

$$\frac{\partial \frac{H_t^d}{L_t^d}}{\partial \tau} = (\omega_t)^{\frac{1}{\alpha-1}}A\frac{\partial X}{\partial \tau}\left[\frac{\left[(a_h)^{\frac{\alpha}{1-\alpha}}-1\right]}{[1+AX(\tau)]^2}\right] \qquad \text{where} \qquad (a_h)^{\frac{\alpha}{1-\alpha}} > 1$$

Partially differenciating $X(\tau)$with respect to τ

$$\frac{\partial X}{\partial \tau} = \frac{-[k-(\sigma-1)]\xi^{k-(\sigma-1)}\left[1+(1+\tau)^{1-\sigma}\right]^{\frac{-k+(\sigma-1)}{\sigma-1}-1}(1+\tau)^{-\sigma}}{\left[\xi^{k-(\sigma-1)}\left[1+(1+\tau)^{1-\sigma}\right]^{\frac{-k+(\sigma-1)}{\sigma-1}}-1\right]^2} < 0 \qquad \text{Where } \; k > (\sigma-1)$$

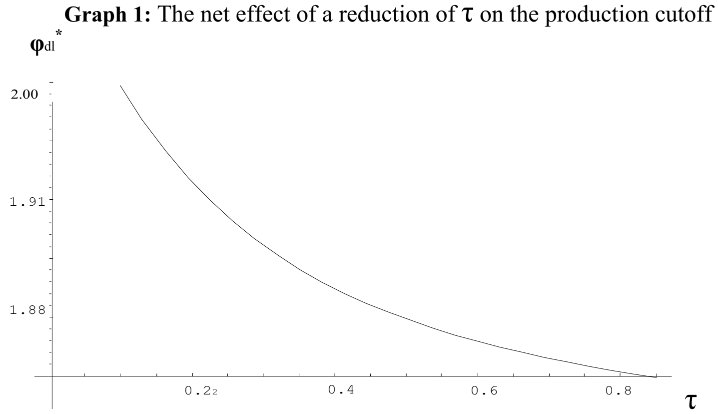
Under the partitioning condition, $X(\tau)$ is a decreasing function of τ.Indeed the aggregate relative skilled labor demand is a decreasing function of trade variable costs :$\frac{\partial\left(\frac{H}{L}\right)^d}{\partial\tau} < 0$. Since the relative skilled labor supply is fixed, a reduction in variable trade costs will push up the aggregate relative skilled labor demand and hence raise the skill premium. $\frac{\partial\omega}{\partial\tau} < 0$.

8 Appendix 3:

[22]

Case 1: The impact of trade liberalization

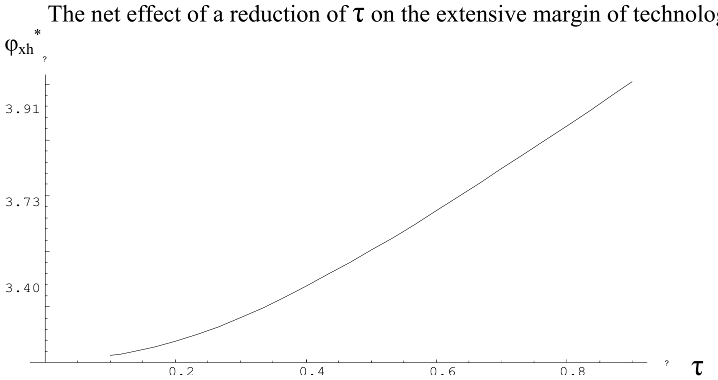
Graph 1: The net effect of a reduction of τ on the production cutoff



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

Graph 2:

The net effect of a reduction of τ on the extensive margin of technology



"Extensive margin of technology": a reduction of trade frictions 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: These results remain robust for different parameters values well established in the literature: $\phi=3/4$ (Bernard et al., 2004); α=0.5/0.6 (Acemoglu ,2002); k =3,4/5. Following Bernard, Redding and Schott (2004): f_e=1/2; f=0,1/0,2; δf_x=0,2/0,3 and δf_t=0,9/1,25; a_h = 2/3.

[22] In order to find the equilibrium value of the skill premium, I used the FindRoot command of Matematica which uses a root-finding algorithm. The results remain robust for different parameters values well established in the literature.

9 Appendix 4: Empirical results

Table 1: Prediction 1: The determinants of technology choice. DV: Foreign Technology (FTA) 0/1. Subsample of Exporters

	(1)	**(2)**	**(3)**	**(4)**
	Logit model	**Logit model**	**Linear probability**	**Linear probability**
TFP(t-1)	0.400***	0.272*	0.030***	0.010*
	(0.094)	(0.151)	(0.007)	(0.006)
Size(t-1)	0.753***	0.291	0.068***	0.010
	(0.076)	(0.265)	(0.008)	(0.011)
Capital Intensity(t-1)	0.264***	-0.049	0.021***	-0.003
	(0.064)	(0.150)	(0.005)	(0.007)
credit(t-1)	0.376**	0.136	0.022*	0.006
	(0.148)	(0.215)	(0.012)	(0.010)
FDI(t-1)	0.687***	0.251	0.102***	0.015
	(0.220)	(0.367)	(0.033)	(0.021)
Year fixed effects	yes	yes	yes	yes
Industry isic-3 Ind	yes	no	yes	no
Plant fixed effects	no	yes	no	yes
Number of Obs	7379	1750	7465	7465
Adjusted R-Sq.			0.133	0.008

Note: Huber White Standard errors clustered by firm.
The intercept is not reported
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 2: Prediction 1: Robustness checks. Alternative measures of technology. Subsample of Exporters

	(1)	**(2)**	**(3)**	**(4)**
	Patent use	Patent use	Investment in new machinery	Investment in new machinery
	Logit model	**Linear probability**	**Logit model**	**Linear probability**
TFP(t-1)	0.263**	0.021**	0.359***	0.045***
	(0.115)	(0.009)	(0.091)	(0.011)
Capital intensity(t-1)	0.133	0.008		
	(0.117)	(0.009)		
Size(t-1)	0.521***	0.046***	0.483***	0.068***
	(0.201)	(0.017)	(0.144)	(0.019)
Credit(t-1)	0.380**	0.037**	0.205	0.026
	(0.157)	(0.015)	(0.137)	(0.017)
FDI(t-1)	-0.448	-0.029*	0.281	0.025
	(0.300)	(0.016)	(0.353)	(0.027)
Year fixed effects	yes	yes	yes	yes
Plant fixed effects	yes	yes	yes	yes
Number of Obs	2171	7465	3906	7465
Adjusted R-Sq.		0.006	0.014	

Note: Huber White Standard errors clustered by firm. The intercept is not reported
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 3: Prediction 2: Changes in skill upgrading by export and technology status. DV: Skilled over unskilled labor (1990-1999).

	(1)	(2)	(3)	(4)	(5)
D.exporter_TECH	0.106**	0.108**	0.103**	0.104**	0.096**
	(0.046)	(0.046)	(0.045)	(0.046)	(0.047)
D.exporter_only	0.032*	0.033*	0.032*	0.032*	0.031
	(0.019)	(0.019)	(0.019)	(0.019)	(0.020)
D.TECH_non_exporter	0.024	0.024	0.023	0.023	0.023
	(0.033)	(0.033)	(0.033)	(0.033)	(0.036)
D.TFP	0.060***	0.070***	0.070***	0.070***	0.088***
	(0.015)	(0.016)	(0.016)	(0.016)	(0.019)
D.capital intensity		0.114***	0.114***	0.114***	0.120***
		(0.015)	(0.015)	(0.015)	(0.018)
D.Credit			0.042**	0.042**	0.034*
			(0.017)	(0.017)	(0.018)
D.FDI				0.038	0.039
				(0.032)	(0.036)
Year fixed effects	yes	yes	yes	yes	yes
Industry isic-3 Ind	yes	yes	yes	yes	no
Plant fixed effects	no	no	no	no	yes
Number of Obs	18247	18247	18247	18247	18247
Adjusted R-Sq.	0.012	0.020	0.020	0.020	0.022

Note: Huber White Standard errors. In column 4-5 errors are clustered by firm.
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 4: Robustness checks: Prediction 2. DV: Skilled over unskilled labor (1990-1999).

	(1)	(2)	(3)	(4)	(5)	(6)
	Full sample	Never exporters	Exporters	Full sample	Never exporters	Exporters
D.Patent Ind	0.042**	0.036*	0.060*	0.043**	0.033	0.068**
	(0.017)	(0.020)	(0.031)	(0.018)	(0.021)	(0.034)
D.TFP	0.070***	0.057***	0.090***	0.087***	0.081***	0.097***
	(0.016)	(0.019)	(0.027)	(0.019)	(0.023)	(0.031)
D.Capital intensity	0.115***	0.090***	0.157***	0.120***	0.099***	0.153***
	(0.015)	(0.018)	(0.026)	(0.018)	(0.022)	(0.030)
D.credit	0.042**	0.040*	0.042	0.033*	0.029	0.038
	(0.017)	(0.021)	(0.028)	(0.018)	(0.023)	(0.030)
D.FDI	0.037	-0.007	0.069	0.038	-0.014	0.081
	(0.032)	(0.041)	(0.046)	(0.036)	(0.045)	(0.053)
Year fixed effects	yes	yes	yes	yes	yes	yes
Industry isic-3 Ind	yes	yes	yes	no	no	no
Plant fixed effects	no	no	no	yes	yes	yes
Number of Obs	18247	12051	6196	18247	12051	6196
Adjusted R-Sq.	0.020	0.015	0.029	0.023	0.019	0.031

Note: Huber White Standard errors. In column 4-5 errors are clustered by firm.
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 5: Robustness checks : Prediction 2. DV: Skilled over unskilled labor (1990-1999).

	(1)	(2)	(3)	(4)	(5)	(6)
	Full sample	Never exporters	Exporters	Full sample	Never exporters	Exporters
D.Investment new machinery	0.007	-0.004	0.036*	0.012	0.002	0.037*
	(0.010)	(0.012)	(0.020)	(0.011)	(0.013)	(0.021)
D.TFP	0.060***	0.049***	0.080***	0.079***	0.073***	0.088***
	(0.015)	(0.018)	(0.027)	(0.018)	(0.023)	(0.031)
D.Credit	0.042**	0.041*	0.041	0.034*	0.030	0.039
	(0.017)	(0.021)	(0.028)	(0.018)	(0.023)	(0.030)
D.FDI	0.037	-0.005	0.066	0.037	-0.010	0.073
	(0.032)	(0.041)	(0.047)	(0.036)	(0.046)	(0.053)
Year fixed effects	yes	yes	yes	yes	yes	yes
Industry isic-3 Ind	yes	yes	yes	no	no	no
Plant fixed effects	no	no	no	yes	yes	yes
Number of Obs	18247	12051	6196	18247	12051	6196
Adjusted R-Sq.	0.013	0.011	0.014	0.015	0.014	0.017

Note: Huber White Standard errors. In column 4-5 errors are clustered by firm.
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 6: Prediction 3: The impact of trade liberalization on technology choice. DV: Technology indicator 0/1

	(1)	(2)	(3)	(4)	(5)
	Full sample	Full sample	Full sample	Full sample	Exporters
change in TX(t-1)	-0.191**	-0.188**	-0.189**	-0.189**	-0.537**
	(0.085)	(0.087)	(0.087)	(0.087)	(0.263)
TFP(t-1)		0.029***	0.029***	0.029***	0.029
		(0.010)	(0.010)	(0.010)	(0.024)
Size(t-1)		0.021	0.022	0.022	-0.024
		(0.018)	(0.019)	(0.019)	(0.043)
FDI(t-1)			-0.016	-0.016	-0.028
			(0.024)	(0.024)	(0.054)
Credit(t-1)				-0.006	0.028
				(0.016)	(0.042)
constant	0.299***	0.198***	0.199***	0.200***	0.769***
	(0.014)	(0.075)	(0.075)	(0.076)	(0.220)
Time Ind	yes	yes	yes	yes	yes
Plant fixed effects	yes	yes	yes	yes	yes
Number of Obs	12281	10461	10461	10461	1755
Adjusted R-Sq.	0.004	0.006	0.006	0.006	0.012

Note: Huber White Standard errors. In column 5 errors are clustered by firm.
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 7: Robustness checks. Prediction 3: The impact of trade liberalization on technology spending. DV: Log of Technology Spending (1990-1999).

	(1)	(2)	(3)	(4)	(5)
TX(t-1)	0.437*	0.341	0.172	0.164	0.155
	(0.233)	(0.242)	(0.221)	(0.221)	(0.219)
Always*TX(t-1)	-0.933***	-0.840***	-0.767***	-0.732***	-0.741***
	(0.252)	(0.282)	(0.276)	(0.278)	(0.270)
Starter*TX(t-1)	-0.205	-0.262	-0.476	-0.477	-0.557*
	(0.288)	(0.332)	(0.316)	(0.315)	(0.303)
Switcher*TX(t-1)	-0.078	-0.257	-0.242	-0.235	-0.184
	(0.255)	(0.273)	(0.256)	(0.255)	(0.255)
Stopper*TX(t-1)	-0.603	-0.724	-0.698*	-0.692*	-0.725*
	(0.406)	(0.463)	(0.401)	(0.404)	(0.408)
Always	3.962***	3.656***	3.122***	3.019***	2.948***
	(0.574)	(0.650)	(0.636)	(0.642)	(0.620)
Starter	1.845***	1.956***	2.233***	2.222***	2.333***
	(0.638)	(0.751)	(0.712)	(0.709)	(0.681)
Switcher	1.119*	1.373**	1.174**	1.149*	0.961
	(0.581)	(0.631)	(0.591)	(0.590)	(0.587)
Stopper	2.727***	2.800**	2.466***	2.444***	2.405**
	(0.947)	(1.091)	(0.933)	(0.941)	(0.952)
Initial TFP		0.629***	0.721***	0.712***	0.693***
		(0.080)	(0.076)	(0.076)	(0.075)
Initial Capital intensity			0.459***	0.451***	0.433***
			(0.050)	(0.050)	(0.051)
FDI(t-1)				0.314**	0.328**
				(0.158)	(0.158)
Credit(t-1)					0.535***
					(0.096)
Constant	8.742***	5.097***	1.949**	2.017**	2.050***
	(0.584)	(0.795)	(0.787)	(0.790)	(0.768)
Year fixed effects	yes	yes	yes	yes	yes
Industry isic-3 Ind	yes	yes	yes	yes	yes
Number of Obs	5811	4370	4370	4370	4370
Adjusted R-Sq.	0.166	0.200	0.264	0.265	0.278

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

Table 8: Prediction 4: The impact of trade liberalization on the relative demand of skilled labor. DV: skilled over unskilled labor (1990-1999).

	(1)	(2)	(3)	(4)	(5)
	Full sample	Full sample	Full sample	Full sample	Exporters high technology
change in TX	-0.642**	-0.662**	-0.668**	-0.658**	-2.479**
	(0.308)	(0.307)	(0.307)	(0.318)	(1.138)
D.TFP(t-1)	0.076***	0.085***	0.085***	0.085***	0.006
	(0.016)	(0.016)	(0.016)	(0.018)	(0.051)
D.Capital intensity		0.125***	0.125***	0.126***	0.129**
		(0.016)	(0.016)	(0.017)	(0.050)
D.FDI			0.060*	0.060	0.061
			(0.035)	(0.038)	(0.073)
D.credit				0.054***	0.034
				(0.019)	(0.045)
constant	0.094**	0.080**	0.080**	0.081**	-0.117
	(0.040)	(0.040)	(0.040)	(0.036)	(0.133)
Year fixed effects	yes	yes	yes	yes	yes
Industry isic-3 Ind	yes	yes	yes	yes	yes
Number of Obs	15421	15421	15421	15421	1440
Adjusted R-Sq.	0.014	0.021	0.022	0.022	0.019

Note: Huber White Standard errors. In columns 3, 4, 5 errors are clustered by firm.
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 9: Robustness checks. Prediction 4: The impact of trade liberalization on on the relative demand of skilled labor. DV: skilled over unskilled labor (1990-1999).

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
TX(t-1)	0.065	0.108**	0.106**	0.108**	0.103**
	(0.046)	(0.051)	(0.051)	(0.050)	(0.050)
Always*TX(t-1)	-0.285***	-0.246***	-0.228**	-0.249***	-0.239***
	(0.081)	(0.094)	(0.094)	(0.093)	(0.091)
Starter*TX(t-1)	-0.157	0.010	0.010	-0.045	-0.067
	(0.105)	(0.106)	(0.105)	(0.102)	(0.101)
Switcher*TX(t-1)	-0.014	-0.119	-0.116	-0.114	-0.103
	(0.079)	(0.087)	(0.087)	(0.086)	(0.086)
Stopper*TX(t-1)	-0.129	-0.150	-0.145	-0.182	-0.188
	(0.144)	(0.158)	(0.157)	(0.155)	(0.154)
Always	0.655***	0.511**	0.455**	0.380*	0.309
	(0.193)	(0.225)	(0.227)	(0.223)	(0.219)
Starter	0.409*	-0.039	-0.044	-0.003	0.006
	(0.238)	(0.239)	(0.237)	(0.231)	(0.231)
Switcher	0.104	0.260	0.249	0.185	0.121
	(0.176)	(0.196)	(0.196)	(0.194)	(0.194)
Stopper	0.271	0.268	0.252	0.250	0.222
	(0.321)	(0.368)	(0.368)	(0.365)	(0.364)
Initial TFP		0.159***	0.157***	0.173***	0.160***
		(0.019)	(0.019)	(0.019)	(0.019)
FDI(t-1)			0.169**	0.117*	0.120*
			(0.069)	(0.067)	(0.066)
Initial Capital Intensity				0.099***	0.089***
				(0.011)	(0.011)
Credit(t-1)					0.214***
					(0.027)
constant	-0.772***	-1.748***	-1.741***	-2.437***	-2.339***
	(0.136)	(0.201)	(0.199)	(0.211)	(0.211)
Year fixed effects	yes	yes	yes	yes	yes
Industry isic-3 Ind	yes	yes	yes	yes	yes
Number of Obs	22900	15724	15724	15724	15724
Adjusted R-Sq.	0.114	0.130	0.131	0.146	0.155

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

Table 10: Variables description

	[Variable]	**[Data]**
Employment	Size	Total labour
Skilled labor	H	Non production workers: employees paid by commissions, administrative stuff, subcontract employees and other non production employees.
Unskilled labor	L	Production workers
Relative skilled labor demand	H/L	Non production over production workers
Wage rate of skilled labor	Wh	Wages paid to non production workers over the number of non production workers hired
Wage rate of unskilled labor	Wl	Wages paid to production workers over the number of production workers hired
Capital intensity	K/L	Capital stock over total workers
Foreign Technology (FTA)	TECH	Dummy variable equals to one if the plant reports expenditures on Foreign Technological Assistance
Patent Indicator	Patent Ind	Dummy variable equals to one if the plant reports patents use and rights
Investment in new machinery	Investment indicator	Dummy variable equals to one if the plant reports expenditures on new machinery
Total factor productivity	TFP	Total factor productivity estimated using Levinsohn and Petrin methodology in Bas and Ledezma (2007)
Financial Indicator	Credit	Dummy variable equals to one if the plant reports having paid a loan tax in year ”‘t”’
Foreign Direct Investment	FDI indicator	Dummy variable equal to one if the firm has more than 50% of foreign capital
Continuing exporters	Always	Dummy variable equal to one if the firm exports during the whole period
New exporters	Starter	Dummy variable equal to one if the firm does not export at the beginning of the period and starts exporting afterwards
Stop exporting	Stopper	Dummy variable equal to one if the firm exports at the beginning of the period and stops exporting afterwards
Switchers	Switcher	Dummy variable equal to one if the firm enters and exits the foreign market more than once
Export barrier	TX	Average import tariffs set by the main trade parterns to Chilean exports at 3 dig industry level.

Table 11: Summary Statistics by Export Status (1990-1999)

	[Exporters]	[Non Exporters]
Number of Firms	31% (1196)	69% (2704)
Always	12%	
Starter	7%	
Stopper	3%	
Switcher	9%	
Size %		
Large (more 150 workers)	40%	6%
Medium (50-149 workers)	36%	20%
Small (10-49 workers)	24%	74%
TFP (Mean)	2740 (176)	1149 (23)
Employment (Mean)	202 (4)	55 (0.61)
Skill intensity (Mean)	0.30 (0.003)	0.25 (0.001)
Capital Intensity (Mean)	7838 (225)	2593 (46)
FTA (%)	14%	2.5%
Patent use (%)	85%	78%
Investment in new machinery (%)	77%	47%
Import share of inputs expenditure (%)	53%	11%
Type of Ownership FDI	11%	1%

Note: Standard errors of means are reported in parentheses.

Table 12: Exporter Premia: TFP by export status. Dependant variable: TFP

	M1	**M2**	**M3**	**M4**	**M5**
Always	0.429***	0.294***	0.293***	0.282***	0.208***
	(0.036)	(0.041)	(0.044)	(0.044)	(0.044)
Starter	0.284***	0.208***	0.190***	0.176***	0.109**
	(0.043)	(0.044)	(0.046)	(0.046)	(0.046)
Switcher	0.258***	0.200***	0.187***	0.173***	0.133***
	(0.033)	(0.034)	(0.035)	(0.035)	(0.034)
Stopper	0.128*	0.043	-0.001	-0.014	-0.049
	(0.068)	(0.070)	(0.074)	(0.074)	(0.071)
Initial employment		0.089***	0.072***	0.057***	0.025*
		(0.013)	(0.014)	(0.014)	(0.014)
FDI(t-1)			0.160***	0.161***	0.140**
			(0.057)	(0.057)	(0.055)
Credit (t-1)				0.112***	0.075***
				(0.021)	(0.021)
TECH Ind					0.313***
					(0.025)
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Industry isic-3 Ind	Yes	Yes	Yes	Yes	Yes
Number of Obs	25990	25990	18588	18588	18588
Adjusted R-Sq.	0.367	0.372	0.397	0.400	0.415

Note: Huber White Standard errors clustered by firm in parentheses
Note: The coefficient of the intercept is not reported
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 13: Decomposition of Relative Demand of Skilled labor (H/L)

	[Total]	**[Between]**	**[Within]**	**[Within/Total]**
		1979-1999		
Industries at 2 digit	0,079	-0,014	0,093	1,182
Industries at 3 digit	0,202	-0,005	0,206	1,023
Firms	0,227	0,068	0,158	0,697
		1979-1986		
Industries at 2 digit	0,377	0,110	0,267	0,708
Industries at 3 digit	0,238	-0,033	0,272	1,140
Firms	0,317	0,173	0,143	0,452
		1990-1999		
Industries at 2 digit	0,056	0,001	0,055	0,983
Industries at 3 digit	0,068	0,002	0,066	0,969
Firms	0,044	-0,083	0,127	2,846

Table 14: Decomposition of Relative Skilled Wage

	[Total]	**[Between]**	**[Within]**	**[Within/Total]**
		1979-1999		
Industries at 2 digit	0,014	-0,008	0,022	1,549
Industries at 3 digit	0,324	0,041	0,283	0,873
Firms	1,518	0,464	1,054	0,694
		1979-1986		
Industries at 2 digit	0,127	0,002	0,124	0,980
Industries at 3 digit	0,518	-0,010	0,528	1,020
Firms	0,752	0,339	0,412	0,548
		1990-1999		
Industries at 2 digit	0,157	-0,038	0,195	1,245
Industries at 3 digit	0,563	-0,295	0,858	1,524
Firms	0,639	0,100	0,539	0,843

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