Factor price overshooting with trade liberalization: theory and evidence[*]

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Abstract

We develop an intra–industry trade model with human capital and labor as factors of production, endogenous human capital accumulation and firm heterogeneity in factor intensities to examine the effects of trade reforms on factor prices. If exporters are more skill intensive than non–exporters, a decrease in trade barriers increases wage inequality in the short run since demand for skilled workers increases. Over time, however, as agents respond to the change in relative wages by investing in human capital, the relative wage of skilled workers decreases. Evidence from Chilean plant–level data supports the idea of factor price overshooting with trade liberalization.

JEL classification: F12; E22; O41; O54.

Keywords: intra–industry trade; firm heterogeneity in factor intensities; wage inequality; overshooting; short run versus long run; Chile.

1 Introduction

Relatively high levels of wage inequality between skilled and unskilled workers characterize many developing countries, especially those in Latin America (de Ferranti, et al. 2004). According to the Stolper–Samuelson theorem, increased trade with the rest of the world should have decreased wage inequality in these countries, by increasing the wage of unskilled workers (the relatively abundant factor in those countries) relative to the wage of skilled workers (the relatively scarce factor). While some studies find that this prediction holds for some countries (e.g., Gonzaga, et al. 2006), others find that trade liberalization actually increased wage inequality in many countries (Goldberg and Pavcnik, 2004, 2007).[1]

This paper argues that the effect of trade liberalization on relative wages crucially depends on whether the country is able to increase its investments in human capital. We contend that since exporters are more skill intensive than non–exporters (e.g., Alvarez and López, 2005), a decrease in trade barriers around the world should increase the demand for skilled workers in the country, relative to the demand for unskilled labor, thereby increasing the relative wage of skilled labor in the short run. Over time, however, as economic agents respond to this increase in relative wage, investments in human capital take place, which increase the relative supply of skilled labor, resulting in a decrease in the relative wage of skilled workers in the long run. This result arises from introducing firm heterogeneity in factor intensities into a dynamic model of trade with human capital accumulation. This allows us to examine the dynamic effects of decreasing trade barriers on wage inequality and also reconcile the apparently contradictory findings of the existing empirical studies.

The dynamic model in this paper builds upon the intra–industry trade framework in Emami Namini (2009), and we use it to examine the short– and long–run impact of trade liberalization on relative wages. The model modifies the Krugman (1980) setting of intra–industry trade by incorporating (i) human capital and labor as factors of production, (ii) endogenous human capital stocks, (iii) CES production functions, and (iv) exogenously given firm heterogeneity in factor intensities. We use this framework to analyze how trade liberalization affects relative factor prices and firms' factor input choices, and we explicitly distinguish between the short–run and the long–run effects of trade.[2]

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[1] Country–specific studies include Beyer, Rojas and Vergara (1999), Hanson and Harrison (1999), Galiani and Sanguinetti (2003), Attanasio, Goldberg and Pavcnik (2004), and Acosta and Montes–Rojas (2008).

[2] Although our focus is on human capital, the model can also be applied to a setting with labor and physical capital.

We start by analyzing the effects of trade in the short run, a situation in which countries have *fixed* amounts of human capital or skilled labor. The model shows that firms with different factor intensities produce with different levels of marginal costs. Thus, when a country opens up to costly trade, exporters and non–exporters use factors in different intensities. We restrict our analysis to such a constellation of parameters for which exporters are more human capital intensive than non–exporters. The reason for this is twofold: *first*, it is an empirical regularity that exporters are more human capital intensive than non–exporters; and *second*, we can show that exporters can be more human capital intensive than non–exporters regardless of a country's relative factor endowments. The model shows that trade liberalization increases the relative price of human capital in the short run. This induces each firm to produce less human capital intensively.

We then analyze the long–run effects of trade, in which the countries' human capital stocks are *flexible* and determined endogenously in a Ramsey growth setting. Due to the increased competition for human capital in the short run, households increase their investments in human capital in response to the increased price of it. Thus, in the long run, a country's human capital stock increases. This in turn decreases the relative price of human capital, which induces firms to produce more human capital intensively in the long run. Thus, our model identifies an overshooting of the relative price of human capital in the short run after trade liberalization. The reason for this is that the supply of human capital is fixed in the short run, while, in the long run, the supply of human capital reacts to the short–run effects of trade liberalization. Importantly, a Heckscher–Ohlin trade setting would not generate such an overshooting of relative factor prices. Findlay and Kierzkowski (1983), show that Heckscher–Ohlin trade with endogenous skill endowments generates factor price equalization between countries and an adjustment of relative factor endowments, without the overshooting of relative factor prices we observe in our model. Thus, our intra–industry trade setting is necessary for the overshooting of relative factor prices.

Next, we test the theoretical predictions using a panel of Chilean manufacturing plants for the period 1990–1999. Following the empirical literature on trade and wage inequality, we proxy human capital with the amount of skilled labor employed by each plant, and we use the amount of unskilled labor to proxy the labor factor. We find that, in the short run, trade liberalization increases the relative price of skilled labor and decreases the skill intensity of firms. If we look at the long run, we find exactly the opposite: the

2

relative price of skilled labor decreases and the skill intensity of a sector's average firm increases. These empirical results support the channels highlighted in the theoretical part, and suggest that the time dimension plays an important role when evaluating the impact of trade liberalization on wages in the context of firm heterogeneity in factor intensities.

This paper is related to the literature that analyzes the effects of trade liberalization on wage inequality in developing countries. Authors such as Leamer et al. (1999) explain the increased wage inequality in developing countries by arguing that these countries are relatively natural resources abundant rather than relatively unskilled labor abundant. Other researchers emphasize the potential role of skill–biased technological change in increasing wage inequality (Robbins, 1996; Tokarick, 2005; Gallego, 2006). Unlike these papers, our model does not need to introduce natural resources as an additional factor of production, or assume that technological change is biased. Instead, our model generates changes in inequality due to factor reallocations between firms, and due to human capital accumulation by households. Another line of research focuses on the role of exchange rate fluctuations on wage inequality (e.g., Robertson, 2003; Verhoogen, 2008). Since changes in exchange rates may generate effects similar to reducing tariffs abroad, our paper complements this line of research.

This paper is also related to the literature on international trade with firm heterogeneity in total factor productivity (TFP), such as Melitz (2003). Bernard, et al. (2007) extend the Melitz (2003) setup by including two factors of production and two monopolistically competitive sectors that use different capital–labor ratios in production. Within sectors firms are heterogeneous in terms of TFP, but are homogeneous in terms of factor input ratios. Their model provides important insights into the inter–industry factor reallocations due to trade liberalization. By construction their model does not analyze how heterogeneity in capital–labor input ratios *within* a sector and globalization interact to impact wages. The only other papers that we are aware of that consider firm heterogeneity in factor intensities in a similar context are Crozet and Trionfetti (2009), Emami Namini (2009), and Emami Namini et al. (2011). While Crozet and Trionfetti (2009) assume random factor share parameters and analyze how a firm's factor intensity interacts with a country's relative factor endowments to determine the firm's market share, Emami Namini (2009) assumes random factor share parameters and analyzes the growth impact of trade liberalization. Emami Namini et al. (2011), on the other hand, assume that firms can choose their technology and analyze the firm selection due to trade liberalization. In the

3

present paper, and in contrast to the previous ones, we assume that the mass of firms, which are heterogeneous in their factor intensities, is given exogenously.[3] In addition, we distinguish between the short– and long–run impact of trade on wages, and we test our results empirically.

Our paper also belongs to an increasing literature that examines the dynamics of trade liberalization. Ederington and McCalman (2008) construct a dynamic trade model and show that trade liberalization induces firms to adopt an advanced technology earlier. The dynamics in their paper result from an exogenous decline of technology adoption costs over time. Our paper differs from Ederington and McCalman (2008) since in our setting the dynamics result endogenously as trade liberalization increases the relative price of human capital in the short run, which triggers human capital accumulation and, thus, decreases its relative price in the long run. Also related is the work by Atolia (2007). The author constructs a Heckscher–Ohlin setting with 3 factors of production, non–traded and traded goods, and uses calibration techniques to study the dynamic impact of trade liberalization on wage inequality. Atolia (2007) also provides important insights into the role of capital adjustment costs. Our model differs from his since we consider intra–industry trade with firm heterogeneity in factor intensities. This different setting also allows for analytical results, which we test afterwards.

The structure of the paper is as follows. Section 2 describes the setup of the theoretical model. Section 3 analyzes the autarkic steady state. Section 4 analyzes trade liberalization and distinguishes between its short–run and long–run impact on relative wages. Section 5 presents our empirical analysis. Section 6 concludes. All proofs are relegated to the appendix.

2 The model

2.1 Overview

There are two countries, the domestic country D and the foreign country F. Households in each country are characterized by Dixit–Stiglitz preferences (Dixit and Stiglitz, 1977) and consume a continuum of imperfectly substitutable varieties of an aggregate consumption good Q. Firm behavior can therefore be described by large–group monopolistic compe-

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[3]We make this assumption in order to keep the analysis simple. In a previous version of the paper, which is available upon request, we determined the mass of firms endogenously. Since this did not add to our analysis of the impact of trade on wages, we have decided to keep the mass of firms exogenous.

tition, i.e., each firm regards the prices of all other varieties and factor returns as given. The production side of each country consists of this single monopolistically competitive sector.

Firms produce with human capital H and labor L, and use a CES technology to produce a unique variety of the aggregate good Q. Firms are heterogeneous with respect to the factor share parameters of the CES production function. To keep the analysis simple, without affecting our general conclusions, we assume that the mass of firms is given exogenously. Thus, we do not explicitly analyze market entry or exit of firms in this paper.[4] Heterogeneity with respect to factor intensities implies that, if factor prices differ, firms produce with different marginal costs.

Furthermore, we make two additional assumptions in order to keep the analysis simple: (i) labor and human capital are perfectly mobile between firms within a country, but perfectly immobile between countries; (ii) countries D and F are symmetric in every respect.

Finally, we will include a subscript aut or ft, to denote autarkic or free trade variables, respectively, only if otherwise confusion would arise.

2.2 Production

A single firm produces its unique variety of good Q with the following CES function:

$$q(\phi) = \left[\phi^{1-\alpha} \left(A_H h\right)^\alpha + (1-\phi)^{1-\alpha} \left(A_L l\right)^\alpha\right]^{\frac{1}{\alpha}}, \quad 0 \leq \phi \leq 1, \quad 0 < \alpha < 1,$$

where h and l denote the input of human capital and labor, and A_H and A_L are factor specific productivity parameters, which are identical across firms. Thus, $A_H h$ and $A_L l$ stand for the effective human capital and labor input.

The number (or mass) of firms, which is active in the market, is exogenously given and denoted by N. Firms differ with respect to ϕ and we assume that the N firms are distributed over the interval $[0, 1]$ according to an exogenously given density $\mu(\phi)$. Thus, the mass of firms with human capital share parameter ϕ is given by $N\mu(\phi)$.

Furthermore, we assume that firms minimize production costs for a given ϕ. Thus, a

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[4]As mentioned before, allowing the mass of firms to be determined endogenously does not change the main results of our analysis.

firm's marginal production costs are given by:

$$c\left(\phi\right) = \left[\phi\left(\frac{r}{A_H}\right)^{1-\sigma} + (1-\phi)\left(\frac{w}{A_L}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}, \qquad \sigma = \frac{1}{1-\alpha} > 1. \qquad (1)$$

σ stands for the elasticity of substitution between effective factor inputs $A_H h$ and $A_L l$. Furthermore, r and w denote the returns to human capital and labor, respectively. If $\frac{r}{A_H} \neq \frac{w}{A_L}$, the human capital share parameter ϕ influences $c(\phi)$.

2.3 Demand

Households aggregate varieties $q(\phi)$ to give the aggregate consumption good Q:

$$Q = \left[\int_0^1 q\left(\phi\right)^{\frac{\xi-1}{\xi}} \mu(\phi) N d\phi\right]^{\frac{\xi}{\xi-1}}, \qquad \xi > 1. \qquad (2)$$

ξ stands for the elasticity of substitution between the varieties of Q, and N is the mass of firms, which are distributed on $[0,1]$ according to the density $\mu(\phi)$. In order to simplify the algebra, without affecting the results in a qualitative sense, we impose assumption 1 for the remainder of the analysis:

Assumption 1 $\sigma = \xi$. *This implies that, in the following, the parameter σ will denote the elasticity of substitution between human capital and labor in production and the elasticity of substitution between the varieties in consumption.*

Assumption 1 simplifies several proofs since the term $c\left(\phi\right)^{1-\xi}$ becomes linear in ϕ if $\xi = \sigma$.[5]

The price index P, which is dual to the CES function in equation 2, is given by:

$$P = \left[\int_0^1 p\left(\phi\right)^{1-\sigma} \mu(\phi) N d\phi\right]^{\frac{1}{1-\sigma}} = \left[p(\widetilde{\phi})^{1-\sigma} N\right]^{\frac{1}{1-\sigma}}, \qquad (3)$$

with $\widetilde{\phi} = \int_0^1 \phi \mu(\phi) d\phi$. Since P is the price index which is dual to the aggregate consumption good (equation 2), we can state the following definition:

Definition 1 $\widetilde{\phi}$ *is the human capital share parameter of the aggregate good Q.*

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[5]Notice that the results of this paper will depend on (*i*) how ϕ influences $c(\phi)$ and (*ii*) how ϕ and factor prices influence the per unit factor demands by firms. These relationships are not influenced by assumption 1 in a qualitative sense. The proofs for the case of $\sigma \neq \xi$ are available from the authors.

Applying Shephard's Lemma, the demand for a single variety is:

$$q\left(\phi\right) = Y\,P^{\sigma-1}\,p(\phi)^{-\sigma}. \tag{4}$$

Y denotes total factor income, i.e., $Y = r\,H + w\,L = PQ$, with H and L denoting the country's endowments of human capital and labor. Profit maximizing firms charge the price $p(\phi) = \frac{\sigma}{\sigma-1}\,c(\phi)$.

2.4 Profits, the capital share parameter ϕ and factor returns r and w

Labor is chosen as numéraire and only relative returns to human capital $\frac{r}{w} \equiv r$ matter in the following. Later, when we derive the steady state, we will show that the returns to human capital r, which are determined endogenously, can be smaller or larger than $\frac{A_H}{A_L}$ in the steady state, depending on the parameters of the model. Depending on whether $r < \frac{A_H}{A_L}$ or $r > \frac{A_H}{A_L}$, the human capital share parameter ϕ has a positive or a negative influence on a firm's profits $\pi(\phi)$. This is shown by the following equation:

$$\pi\left(\phi\right) = \frac{p(\phi)\,q(\phi)}{\sigma} \;=\; Y\,P^{\sigma-1}\,\frac{\phi\left[r^{1-\sigma} - \left(\frac{A_H}{A_L}\right)^{1-\sigma}\right]A_H^{\sigma-1} + A_L^{\sigma-1}}{\sigma^\sigma\,(\sigma-1)^{1-\sigma}}.$$

Y and P are exogenous for a single firm due to large–group monopolistic competition.

Thus, if $r < \frac{A_H}{A_L}$, a more *human capital* intensive firm has larger profits than a more labor intensive one. If $r > \frac{A_H}{A_L}$, in contrast, a more *labor* intensive firm has larger profits than a more capital intensive one.

2.5 Relative factor returns in the steady state

We assume that households use part of the aggregate consumption good Q for investment purposes. Since it seems reasonable to assume that the investment technology is not characterized by a "love of variety" property, households do not evaluate each unit of investments into the human capital stock with P (see equation 3), but, instead, with $p(\widetilde{\phi}) = P\,N^{\frac{1}{\sigma-1}}$. Households choose their consumption and investment level each period such that lifetime utility V is maximized.[6]

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[6]Notice that, since the distribution of ϕ on the unit interval is exogenously given, the model remains analytically solvable, even if any variety $q(\phi)$ with $\phi \neq \widetilde{\phi}$ were used for investments.

ρ denotes the time discount rate and u the instantaneous utility function. Including the time index t, lifetime utility of the representative household of either country is given by:

$$V = \sum_{t=0}^{\infty} \frac{u(Q_t)}{(1+\rho)^t},$$

(5)

where Q_t is the aggregate consumption good as defined by equation 2.

Each country's labor endowment is assumed to be constant over time. Investments therefore only increase human capital and compensates for the depreciation of it. If δ denotes the human capital depreciation rate, investments into a country's human capital stock in any period t of the steady state are given by:

$$I_t = H_{t+1} - (1-\delta)H_t = \delta H.$$

I_t denotes the amount of the aggregate good Q which is invested in period t, H_t and H_{t+1} denote the country's human capital stocks in t and $t+1$. Investments in the steady state are given by $I_t = \delta H$ since H is constant in the steady state.

Households own the production factors and lend them out to firms for production. Given that households behave perfectly competitively, the steady state of a Ramsey growth setup is characterized by several necessary first order conditions, which determine r in the steady state as a function of the parameters ρ, δ, σ, A_L, A_H and the average capital share parameter $\widetilde{\phi}$ (see also Baxter, 1992). This is summarized by lemma 1.

Lemma 1 *The relative return to human capital in the steady state is given by:*

$$r = \left[\frac{(1-\widetilde{\phi})(\rho+\delta)^{1-\sigma} A_L^{\sigma-1}}{1 - \widetilde{\phi}(\rho+\delta)^{1-\sigma} A_H^{\sigma-1}} \right]^{\frac{1}{1-\sigma}}.$$

(6)

Proof. See appendix A.[7] ∎

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[7]Notice that the more familiar expression for r in the steady state would result if variety $q(\widetilde{\phi})$ were taken as numéraire: $\frac{r}{p(\widetilde{\phi})} = (\rho+\delta)\frac{\sigma-1}{\sigma}$. Equation 6 shows that r is defined for all possible values of σ only if $\widetilde{\phi} < \left(\frac{A_H}{\rho+\delta}\right)^{1-\sigma}$. Since $\widetilde{\phi}$ is exogenous in our present setting, we have to assume that $\widetilde{\phi} < \left(\frac{A_H}{\rho+\delta}\right)^{1-\sigma}$. However, Emami Namini (2009) shows that, in a setting in which $\widetilde{\phi}$ is determined endogenously via a market entry procedure like in Melitz (2003)—firms pay market entry costs, afterwards randomly draw their ϕ and then decide whether to start production or not—, the equilibrium $\widetilde{\phi}$ is necessarily smaller than $\left(\frac{A_H}{\rho+\delta}\right)^{1-\sigma}$.

The time index t has been removed from equation 6 since it denotes a relationship in the steady state. Equation 6 shows that the parameters ρ, δ and A_H determine whether $r < \frac{A_H}{A_L}$ or $r > \frac{A_H}{A_L}$ in the steady state. This leads to lemma 2:

Lemma 2 *If $\rho + \delta < A_H$, then $r < \frac{A_H}{A_L}$ in the steady state. Conversely, if $\rho + \delta > A_H$, then $r > \frac{A_H}{A_L}$ in the steady state.*

Thus, if we compare any two firms i and j with human capital share parameters ϕ_i and ϕ_j, with $\phi_i > \phi_j$, it depends on how $\rho + \delta$ relates to A_H, whether firm i or firm j has larger profits. If, for example, $\rho + \delta < A_H$, then $r < \frac{A_H}{A_L}$, which implies that firm i has larger profits than firm j (see also subsection 2.4).

Furthermore, it is useful for our further analysis to study how the steady state value of r depends on $\widetilde{\phi}$. Remember that $\widetilde{\phi}$ reflects the human capital share parameter of the aggregate good Q and, thus, equals the average human capital share parameter over all varieties that are supplied to the domestic market (see definition 1). Thus, $\widetilde{\phi}$ changes with trade liberalization if not all firms, which supply to the domestic market, export as well. The relationship between $\widetilde{\phi}$ and the steady state value of r is summarized by lemma 3:

Lemma 3 *If $r < \frac{A_H}{A_L}$, an increase in the average human capital share parameter $\widetilde{\phi}$ decreases the steady state value of r. Conversely, if $r > \frac{A_H}{A_L}$, an increase in the average human capital share parameter $\widetilde{\phi}$ increases the steady state value of r.*

Proof. See appendix B. ∎

3   Autarkic steady state

The autarkic steady state for either country is characterized by the following 3 conditions:

(i) output equals demand for each variety at price $p(\phi) = \frac{\sigma}{\sigma - 1} c(\phi)$ (see equation 4);

(ii) $r = \left[\frac{(1-\widetilde{\phi})(\rho+\delta)^{1-\sigma} A_L^{\sigma-1}}{1-\widetilde{\phi}(\rho+\delta)^{1-\sigma} A_H^{\sigma-1}} \right]^{\frac{1}{1-\sigma}}$ since countries are in their steady state (see equation 6);

(iii) the factor market clearing conditions.

Notice that, in the steady state, r is determined by the parameters ρ, δ, σ, A_H, A_L and by the average human capital share parameter $\widetilde{\phi}$, while the human capital stock H is such that human capital demand equals it ssupply at price r. Thus, in subsection 3.1 we

will substitute r from equation 6 into the factor market clearing conditions to determine the steady state human capital stock H. In subsection 3.2 we will substitute the steady state values of H and r into equation 4 to determine $q(\phi)$, $\forall \phi \in [0, 1]$, in the autarkic steady state.

3.1 Factor market clearing conditions

Applying Shephard's Lemma to the marginal cost function (equation 1) leads to the following factor market clearing conditions:

$$\int_0^1 (1 - \phi) A_L^{\sigma-1} c(\phi)^\sigma \frac{Y p(\phi)^{-\sigma}}{P^{1-\sigma}} N \mu(\phi) d\phi + (1 - \widetilde{\phi}) A_L^{\sigma-1} c(\widetilde{\phi})^\sigma \delta H = L \quad (7)$$

$$r^{-\sigma} \int_0^1 \phi A_H^{\sigma-1} c(\phi)^\sigma \frac{Y p(\phi)^{-\sigma}}{P^{1-\sigma}} N \mu(\phi) d\phi + \widetilde{\phi} A_H^{\sigma-1} r^{-\sigma} c(\widetilde{\phi})^\sigma \delta H = H. \quad (8)$$

Notice that δH stands for investments in the steady state, while $(1 - \widetilde{\phi}) A_L^{\sigma-1} c(\widetilde{\phi})^\sigma$ and $\widetilde{\phi} A_H^{\sigma-1} r^{-\sigma} c(\widetilde{\phi})^\sigma$ are the per unit input requirements of labor and human capital, respectively, for the investment good. $\frac{Y p(\phi)^{-\sigma}}{P^{1-\sigma}}$ stands for the demand for variety $q(\phi)$.

Dividing equations 7 and 8 by each other, solving for H and r and, afterwards, considering equation 6 leads to the following autarkic steady state values for r and H:[8]

$$r = \left[\frac{\widetilde{\phi}}{1 - \widetilde{\phi}} \frac{L}{H} \left(\frac{A_H}{A_L} \right)^{\sigma-1} \right]^{\frac{1}{\sigma}} = \left[\frac{(1 - \widetilde{\phi})(\rho + \delta)^{1-\sigma} A_L^{\sigma-1}}{1 - \widetilde{\phi}(\rho + \delta)^{1-\sigma} A_H^{\sigma-1}} \right]^{\frac{1}{1-\sigma}} \quad (9)$$

$$H = L \frac{r^{-\sigma} \widetilde{\phi}}{1 - \widetilde{\phi}} \left(\frac{A_H}{A_L} \right)^{\sigma-1} = L \frac{\left(1 - \widetilde{\phi}\right)^{\frac{1}{\sigma-1}} (\rho + \delta)^{-\sigma} \widetilde{\phi} A_L A_H^{\sigma-1}}{\left[1 - \widetilde{\phi}(\rho + \delta)^{1-\sigma} A_H^{\sigma-1} \right]^{\frac{\sigma}{\sigma-1}}}. \quad (10)$$

3.2 Production and revenue in the autarkic steady state

Substituting the autarkic steady state values for r (equation 9) and H (equation 10) into the demand function for each single variety of the aggregate good Q (equation 4) leads to the following production of a variety $q(\phi)$ in the autarkic steady state:

$$q(\phi) = \frac{L A_L (1 - \widetilde{\phi})^{\frac{\sigma-1}{\sigma}} \Omega(\phi)^{\frac{\sigma}{\sigma-1}}}{N \left[1 - \widetilde{\phi}(\rho + \delta)^{1-\sigma} A_H^{\sigma-1} \right]^{\frac{\sigma}{\sigma-1}}}, \quad \text{with} \quad \Omega(\phi) \equiv (\phi - \widetilde{\phi}) \left(\frac{\rho + \delta}{A_H} \right)^{1-\sigma} + 1 - \phi. \quad (11)$$

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[8]See appendix C for the derivation of equations 9 and 10.

Revenue $q(\phi)p(\phi)$ of a firm which produces with human capital share parameter ϕ results as:

$$q(\phi)p(\phi) = \frac{L(1-\widetilde{\phi})^{-1}\Omega(\phi)}{N\left[1 - \widetilde{\phi}(\rho+\delta)^{1-\sigma}A_H^{\sigma-1}\right]}.$$

The relationship between the term $\Omega(\phi)$ and the human capital share parameter ϕ is reflected by the following partial derivative:

$$\frac{\partial \Omega(\phi)}{\partial \phi} = A_H^{\sigma-1}(\rho+\delta)^{1-\sigma} - 1. \tag{12}$$

Equation 12 implies that a more human capital intensive firms has higher revenues than a more labor intensive one if $\rho + \delta < A_H$. This is because $\rho + \delta < A_H$ implies $r < \frac{A_H}{A_L}$.

3.3 Properties of the autarkic steady state

The autarkic steady state value of r is uniquely determined by equation 6, while equations 10 and 11 uniquely determine the corresponding values for H and $q(\phi)$. Thus, we can formulate lemma 4:

Lemma 4 *A unique and stable autarkic steady state exists.*

Importantly, equations 9 and 10 imply that a country's relative human capital endowment $\frac{H}{L}$ only gives limited information about how r relates to $\frac{A_H}{A_L}$, i.e. about whether a more human capital intensive or a more labor intensive technology leads to higher profits. The reason is that only the parameters ρ, δ and A_H determine whether $r < \frac{A_H}{A_L}$ or $r > \frac{A_H}{A_L}$ in the steady state (see lemma 2). However, the steady state level of $\frac{H}{L}$ also depends on $\widetilde{\phi}$, A_H and A_L. This leads to lemma 5:

Lemma 5 *Regardless of whether the steady state level of r is smaller or larger than $\frac{A_H}{A_L}$, the relative human capital stock $\frac{H}{L}$ can take any value from the interval $[0,\infty)$, depending on the magnitude of $\widetilde{\phi}$, A_H and A_L.*

Proof. See appendix D. ∎

Thus, it is possible in our setting that a country's relative human capital endowment $\frac{H}{L}$ is "large" (for example, $\frac{H}{L} > 1$), while, at the same time, a more human capital intensive firm makes *smaller* profits than a more labor intensive one. Likewise, a country's relative human capital endowment $\frac{H}{L}$ can be smaller than 1, while, at the same time, a more

human capital intensive firm makes *larger* profits than a more labor intensive one. Thus, r being smaller than $\frac{A_H}{A_L}$ is not limited to economies with "large" relative human capital endowments in our setting.

Therefore, if trade is costly so that only firms with sufficiently small marginal costs $c(\phi)$ can afford to export, it is a priori ambiguous in our setting whether exporting firms produce more or less human capital intensively than non–exporting firms. If $r < \frac{A_H}{A_L}$ in the autarkic steady state, exporters are more *human capital* intensive than non–exporters. However, if $r > \frac{A_H}{A_L}$, exporters are more *labor* intensive than non–exporters.

4 Trade liberalization

We assume that import tariffs are initially prohibitively high and that trade liberalization is reflected by a reduction of these tariffs to zero. Following the existing literature, we impose an additional assumption: entering the foreign market leads to sunk costs. For simplicity, we assume that iceberg transport costs are zero and that countries D and F are completely symmetric. Thus, we will derive the equilibrium conditions only for a single country.

Furthermore, since typically not all firms within a sector actually export after trade liberalization, we will assume that the sunk export costs are sufficiently large so that only those firms find it profitable to export, which have sufficiently low marginal costs. We have argued before that, in the autarkic steady state, both $r < \frac{A_H}{A_L}$ and $r > \frac{A_H}{A_L}$ are possible, depending on the parameters ρ, δ and A_H. Thus, in our setting it will depend on the parameters ρ, δ and A_H, whether only the more human capital intensive firms or only the more labor intensive ones export. Since it is an empirical regularity that exporters are more human capital intensive than non–exporters, we make assumption 2 for the analysis of trade liberalization:

Assumption 2 $\rho + \delta < A_H$, *which implies* $r < \frac{A_H}{A_L}$. *Thus, if two firms i and j are characterized by human capital share parameters ϕ_i and ϕ_j, with $\phi_i > \phi_j$, firm i produces with smaller marginal costs than firm j.*

Furthermore, when analyzing trade liberalization, we will distinguish between the short run and the long run.

The short run is characterized by a *fixed* human capital stock H, i.e. the human capital stock will still be at its autarkic level (see equation 10) in the short run after trade

liberalization. Thus, the relative price of human capital r will adjust in the short run after trade liberalization such that factor markets clear. The short run after trade liberalization is characterized by the following 3 conditions:

(i) production equals demand for each variety at price $p(\phi) = \frac{\sigma}{\sigma-1} c(\phi)$—notice that 'demand' is 'worldwide demand' if a firm exports;

(ii) a zero cutoff profit condition for the supply to the foreign market;

(iii) the factor market clearing conditions.

These conditions can be solved for the following variables in the *short run* after trade liberalization: (i) production $q(\phi)$ of each variety, (ii) the relative frequency of exporting firms in the firm distribution and (iii) the relative price of human capital r. Notice that the zero cutoff profit condition for the supply to the foreign market determines a critical ϕ, which defines the dividing line between exporters and non–exporters. Once this dividing line is known, the relative frequency of exporting firms can be determined.

In the *long run* after trade liberalization H becomes *flexible* and adjusts so that factor markets clear. r, instead, is again given by equation 6 in the long run after trade liberalization. Notice, though, that the human capital intensity of the aggregate good Q changes with trade liberalization if not all firms, which supply to the domestic market, export as well. This impacts the steady state level of r (see lemma 3).

We will first discuss the firm's supply decision to the foreign market, and then continue with analyzing the short–run and the long–run (steady state) equilibrium after trade liberalization.

4.1 Supply decision to the foreign market

Foreign demand for a domestic variety is given by $q_X(\phi) = Y P^{\sigma-1} p(\phi)^{-\sigma}$. The subscript X denotes exports. Neither Y nor P have a country index due to symmetry across countries. Since iceberg transport costs are zero, aggregate sales of an exporting firm double with trade liberalization:

$$q(\phi) + q_X(\phi) = 2 Y P^{\sigma-1} p(\phi)^{-\sigma}.$$

Entering the foreign market leads to a sunk input requirement f_{Ex}, which is in terms of a firm's own variety. Thus, the sunk costs for entering the foreign market for a firm

with human capital share parameter ϕ are given by $F_{Ex}(\phi) = c(\phi)f_{Ex}$.[9] The per period equivalent of the sunk entry costs into the foreign market is then given by $c(\phi)f_X$, with $f_X \equiv f_{Ex}\frac{\rho}{1+\rho}$. Notice that a firm with human capital share parameter ϕ is indifferent between paying once $c(\phi)f_{Ex}$ upon entering the foreign market or paying $c(\phi)f_X$ in each period of its remaining life, once it has entered the foreign market.

Furthermore, we make the following assumption concerning the magnitude of f_X:

Assumption 3 *If r_{aut}, H_{aut} and P_{aut}, respectively, denote the autarkic steady state values of the return to human capital, a country's human capital stock and the aggregate price index, f_X is such that the following two conditions hold:*

$$\frac{(L + r_{aut}H_{aut})\left(\frac{\sigma}{\sigma-1}\right)^{-\sigma}A_L^{\sigma}}{\sigma P_{aut}^{1-\sigma}} \quad < \quad f_X \tag{13}$$

$$f_X \quad < \quad \frac{(L + r_{aut}H_{aut})\left(\frac{\sigma}{\sigma-1}\right)^{-\sigma}r_{aut}^{-\sigma}A_H^{\sigma}}{\sigma P_{aut}^{1-\sigma}}. \tag{14}$$

The left hand side of condition 13 denotes supply to the domestic market for a firm which produces with $\phi = 0$. The right hand side of condition 14 denotes supply to the domestic market for a firm which produces with $\phi = 1$.[10] Thus, conditions 13 and 14 ensure that the most labor intensive firms will not serve the foreign market after trade liberalization, while the most human capital intensive ones will.

Thus, we can define a critical human capital share parameter ϕ_X^*, which leads to zero profits from exporting. Since f_X is such that the most human capital intensive firms make strictly positive profits from exporting, while the most labor intensive ones make negative profits, we can conclude that ϕ_X^* is uniquely defined and strictly between 0 and 1 since $\frac{\partial q(\phi)}{\partial \phi} > 0$ due to assumption 2. The critical ϕ solves the following equation:[11]

$$q(\phi_X^*)\left[p(\phi_X^*) - c(\phi_X^*)\right] = c(\phi_X^*)f_X.$$

We are now ready to formulate lemma 6:

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[9]This structure of fixed costs is common in two–factor trade models, e.g., Markusen and Venables (2000). Alternatively, we could assume that firms have to pay for f_{Ex} in terms of labor, i.e. $F_{Ex} = f_{Ex}$ or in terms of human capital, i.e. $F_{Ex} = rf_{Ex}$. Our results are robust to these alternative specifications of F_{Ex}.

[10]Notice that the supply to the *domestic* market in the autarkic steady state is ceteris paribus identical to the supply to the *foreign* market since countries are symmetric.

[11]Strictly speaking, r adjusts with trade liberalization—as we will demonstrate later—and this impacts ϕ_X^*. Still, for our purposes it is sufficient to know that a unique ϕ_X^* exists.

Lemma 6 *If $\rho+\delta < A_H$, where ρ stands for the time discount rate, δ for the human capital depreciation rate and A_H for the capital productivity, and if f_X is such that conditions 13 and 14 hold, only firms with a human capital share parameter equal or larger than ϕ_X^* will export after trade liberalization.*

Thus, the price index in the open economy becomes:

$$P = \left[\int_0^1 p(\phi)^{1-\sigma} N\mu(\phi)d\phi + \int_{\phi_X^*}^1 \frac{p(\phi)^{1-\sigma} s_X N\mu(\phi)}{1-G(\phi_X^*)} d\phi \right]^{\frac{1}{1-\sigma}} = \left[N(1+s_X)p(\widetilde{\widetilde{\phi}})^{1-\sigma} \right]^{\frac{1}{1-\sigma}},$$
(15)

with G denoting the cumulative density function for ϕ on the unit interval, $\widetilde{\widetilde{\phi}} \equiv \frac{\widetilde{\phi}+s_X\widetilde{\phi}_X}{1+s_X}$ and $\widetilde{\phi}_X = \int_{\phi_X^*}^1 \phi \frac{\mu(\phi)}{1-G(\phi_X^*)} d\phi$.

Thus, $\widetilde{\widetilde{\phi}}$ represents the average capital share parameter of the aggregate good Q in the open economy equilibrium. Comparing $\widetilde{\widetilde{\phi}}$ with $\widetilde{\phi}$ leads to lemma 7:

Lemma 7 *Trade liberalization increases the human capital share parameter of the aggregate good Q, i.e. $\widetilde{\widetilde{\phi}} > \widetilde{\phi}$.*

4.2 Impact of trade liberalization — short run

Notice that, in the short run after trade liberalization, each country's human capital stock H is still at its autarkic steady state level (see equation 10). The relative price of human capital is, instead, a variable in the short run and adjusts such that factor markets clear. Adding the additional factor demands by the exporting firms to the closed economy factor market clearing conditions leads to:

$$c(\widetilde{\phi})^{\sigma} q(\widetilde{\phi}) A_L^{\sigma-1} \left[N(1-\widetilde{\phi}) + Ns_X(1-\widetilde{\phi}_X) + \frac{c(\widetilde{\widetilde{\phi}})^{\sigma}(1-\widetilde{\widetilde{\phi}})\delta H}{c(\widetilde{\phi})^{\sigma} q(\widetilde{\phi})} \right] = L - L_{f_X}$$
(16)

$$c(\widetilde{\phi})^{\sigma} q(\widetilde{\phi}) r^{-\sigma} A_H^{\sigma-1} \left[N\widetilde{\phi} + Ns_X\widetilde{\phi}_X + \frac{c(\widetilde{\widetilde{\phi}})^{\sigma}\widetilde{\widetilde{\phi}}\delta H}{c(\widetilde{\phi})^{\sigma} q(\widetilde{\phi})} \right] = H - H_{f_X},$$
(17)

with $L_{f_X} \equiv \frac{Ns_X f_X}{A_L^{1-\sigma}} \int_{\phi_X^*}^1 \frac{(1-\phi)c(\phi)^{\sigma}\mu(\phi)}{1-G(\phi_X^*)} d\phi$ and $H_{f_X} \equiv \frac{Ns_X f_X}{A_H^{1-\sigma}} \int_{\phi_X^*}^1 \frac{\phi r^{-\sigma} c(\phi)^{\sigma}\mu(\phi)}{1-G(\phi_X^*)} d\phi$ denoting the total labor and human capital demand, respectively, for producing the sunk export costs. $s_X \equiv 1 - G(\phi_X^*)$ stands for the share of exporters in the firm distribution. Dividing equations 16 and 17 by each other and solving for r in the short run after trade

liberalization leads to:[12]

$$r = \left[\frac{L - L_{f_X}}{H - H_{f_X}} \left(\frac{A_H}{A_L} \right)^{\sigma-1} \frac{\widetilde{\phi} + s_X \widetilde{\phi}_X}{1 + s_X - \widetilde{\phi} - s_X \widetilde{\phi}_X} \right]^{1/\sigma} . \qquad (18)$$

Comparing equation 18 with equation 9 shows that r increases in the short run after trade liberalization. This follows from: (i) $\frac{L - L_{f_X}}{H - H_{f_X}} > \frac{L}{H}$ and (ii) $\frac{\widetilde{\phi} + s_X \widetilde{\phi}_X}{1 + s_X - \widetilde{\phi} - s_X \widetilde{\phi}_X} > \frac{\widetilde{\phi}}{1 - \widetilde{\phi}}$.[13]

Thus, we can formulate proposition 1:

Proposition 1 *The relative return to capital r increases in the short run after trade liberalization.*

Even though r increases in the short run after trade liberalization, it will never increase to a level equal or even above $\frac{A_H}{A_L}$. This leads us to lemma 8:

Lemma 8 *If $r < \frac{A_H}{A_L}$ in the autarkic steady state, then $r < \frac{A_H}{A_L}$ also in the short run after trade liberalization.*

Proof. See appendix F. ∎

Applying Shephard's lemma to the marginal cost function (equation 1) implies that the human capital–labor input ratio of a firm with human capital share parameter ϕ is given by $\left(\frac{A_H}{A_L} \right)^{\sigma-1} \frac{\phi}{1-\phi} r^{-\sigma}$. Thus, we can formulate proposition 2:

Proposition 2 *The human capital–labor input ratio of each firm decreases in the short run after trade liberalization.*

Proposition 2 follows immediately from the fact that r increases in the short run after trade liberalization.

4.3 Impact of trade liberalization — long–run

Lemma 7 and lemma 3 immediately lead to proposition 3:

Proposition 3 *The relative return to human capital r decreases in the long run after trade liberalization.*

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[12]See appendix E for the derivation of equation 18.

[13]Notice that $\frac{L - L_{f_X}}{H - H_{f_X}} > \frac{L}{H}$ holds if $\frac{L}{H} > \frac{L_{f_X}}{H_{f_X}}$. The latter holds since $\frac{L}{H}$ equals the relative labor demand of aggregate production, while $\frac{L_{f_X}}{H_{f_X}}$ equals relative labor demand for producing sunk export costs. Since exporting firms are less labor intensive than the average firm, it follows that $\frac{L}{H} > \frac{L_{f_X}}{H_{f_X}}$.

Since the human capital–labor input ratio of a firm with human capital share parameter ϕ is given by $\frac{A_H^{\sigma-1}}{A_L^{\sigma-1}}\frac{\phi r^{-\sigma}}{1-\phi}$, proposition 3 implies proposition 4:

Proposition 4 *The human capital–labor input ratio of each firm increases in the long run after trade liberalization.*

Finally, since trade liberalization has increased relative human capital demand, we can state proposition 5:

Proposition 5 *The human capital stock H increases in the long run after trade liberalization.*

Proof. See appendix G. ∎

Figure 1 illustrates the countries' adjustment from the autarkic equilibrium to the short–run trading equilibrium and, finally, to the long–run trading equilibrium.[14]

Figure 1: Adjustment to the trading equilibrium

5 Empirical analysis

This section investigates whether the main predictions identified by the theoretical analysis do indeed get support by the data. The focus is on propositions 1–4, which summarize the core of our findings. Since the dynamics in our setting are triggered by an increase in relative human capital demand due to rising exports, we focus on how a decrease in tariffs *abroad* impacts domestic relative factor prices and factor intensities in production. We proxy the amount of human capital used by a firm by the amount of skilled labor employed. The labor employment is proxied by the amount of unskilled labor employed.

We use a well–known plant–level dataset of the manufacturing sector of Chile, which has been used in several previous studies.[15] The data come from the Annual Survey of Manufacturing Industries, carried out by the National Institute of Statistics of Chile. This dataset covers all manufacturing plants with 10 or more workers and focuses on the

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[14]Notice that chart 2 illustrates the relative human capital input for a firm which produces with a human capital share parameter $\phi \in (0,1)$—those firms that produce with $\phi=0$ or $\phi=1$ use only labor or human capital, respectively, regardless of the magnitude of r. Furthermore, the human capital–labor input ratio will never fall below $\frac{A_L\phi}{A_H(1-\phi)}$ since r will never rise above $\frac{A_H}{A_L}$ in the short run after trade liberalization (see lemma 8).

[15]This dataset has been used, amongst others, by Pavcnik (2002), Pavcnik (2003) and Kasahara and Rodrigue (2008).

period 1990–1999.[16] The Chilean government signed several free trade agreements during this decade that significantly reduced the trade barriers faced by Chilean exporters. This provides an excellent opportunity to test the predictions of the theory.[17]

The dataset has information on almost 4,400 manufacturing plants per year. A little over 22% of the plants are exporters. Exporting plants are more skill intensive than non–exporting plants. As seen in Table 1, column (1), the ratio of skilled labor over unskilled labor is about 59% higher for exporters compared to non–exporters.[18] This difference is statistically significant at the 1% level.[19] Column (2) shows an alternative measure of skill intensity: the share of skilled labor in the total wage bill. In this case, exporters are about 33% more skill intensive than non–exporters, and this difference is statistically significant. Thus, exporters are more skilled labor intensive than non–exporters in the case of Chile.

Table 1: Mean differences in skill intensity between exporters and non–exporters

According to our model, the effects of trade liberalization are transmitted through its impact on exports. Exports, in turn, should increase when foreign tariffs decrease. In order to examine this idea we first estimate the following equation:

$$X_{ijt} = \alpha + \beta \, \tau_{jt} + \lambda \, \Omega_{ijt} + \delta_j + \delta_t + \epsilon_{ijt}, \tag{19}$$

where X_{ijt} corresponds to the ratio exports over sales for firm i operating in industry j at time t, τ_{jt} is the tariff rate applied on Chilean products of sector j by the rest of the world at time t, Ω_{ijt} is a vector of control variables at the plant level, which includes total factor productivity (TFP),[20] size (the natural log of employment), the percentage share of foreign

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[16]All monetary variables are in constant 1985 pesos (annual price deflators are available in the case of Chile at the 4–digit ISIC level).

[17]During the 1990s Chile established free trade agreements with Canada, Central America, Mercosur and Mexico. It also signed partial trade liberalization agreements with Argentina, Bolivia, Colombia, Ecuador and Venezuela.

[18]We use the amount of non–production workers as a measure of skilled labor, while the amount of production workers represents the amount of unskilled labor. According to Slaughter (2000), using measures of production and non–production workers gives comparable results as those using levels of education as measures of skill.

[19]Exporting plants are more skill intensitve than non–exporters even after controlling for year effects, industry affiliation, plant size, and plant fixed effects.

[20]Total factor productivity is the residual of a regression that estimates a Cobb-Douglas production function for each 3-digit industry using the method proposed by Olley and Pakes (1996) and later modified by Levinsohn and Petrin (2003), which corrects the simultaneity bias associated with the fact that productivity is not observed by the econometrician but it may be observed by the firm. In some cases, the production functions were estimated at the 2-digit level due to the small number of observations of some industries at the 3-digit level of disaggregation.

ownership, the ratio of imported intermediate inputs to total inputs, the ratio of foreign technology licenses fees to total sales, and age (in natural log). The variables δ_j and δ_t are 3–digit sector and year dummy variables that attempt to control for unobserved shocks or characteristics at the sector and year level, respectively. We also estimate a variant of equation 19 that includes plant fixed effects to control for all unobserved factors that may affect export activity at the plant level.

The tariff data come from the TRAINS database. We use two different types of tariffs: the simple average tariff and the trade weighted average tariff for the sector. Both are effectively applied tariff rates. An obvious problem of the simple average is that it treats all commodities identically.[21] A problem of the weighted tariff is that low duties are likely to carry more imports than high duties, implying that low duties are given more weight than high duties in the weighted average, which introduces a downward bias. For these reasons we opt for using both tariff rates to see if the results are sensitive to the use of either type of tariff.

The results of estimating the effects of foreign tariffs on exports are presented in Table 2, column (1) for the simple average tariff and column (4) for the weighted average. We can see that younger and larger plants, as well as those with a higher level of foreign ownership, export a higher fraction of their sales. The estimate for the tariff rate is negative, statistically significant, and almost identical with either type of tariff, which suggests that a decrease in foreign tariffs on Chilean products increases the share of sales that is exported by Chilean plants.

<p style="text-align:center;">*Table* 2: Short–run effects of foreign tariffs</p>

We will now examine how these tariffs affect relative factor prices and factor intensities of Chilean firms in the short run and the in long run.

5.1 Short–run impact

The model predicts that, in the short run after trade liberalization, the relative wage of skilled labor should increase, while each single firm should produce less skill intensively (propositions 1 and 2).

We measure the relative wage of skilled labor as the average wage paid to skilled

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[21]The simple average is also sensitive to changes in goods classification in the tariff code (Anderson and Neary, 2005, chapter 1).

workers, relative to the average wage paid to unskilled workers in each plant.[22] We then investigate the short–run impact of declining trade costs abroad by estimating equation 19 with the relative wage as dependent variable. The regressions also include a dummy variable for exporters to control for the fact that exporters are more skill intensive than non–exporters.[23] The results are presented in columns (2) and (5) of Table 2. Plants that are more productive, larger and export tend to pay higher relative wages to skilled workers, on average. The estimate for the tariff rate is negative and statistically significant with either type of tariff, suggesting that a decrease in current foreign tariffs increases the wage of skilled workers relative to the wage unskilled workers at the plant level. This is in line with the model's predictions.

The model also predicts that, in the short run, a reduction in foreign tariffs makes firms less skill intensive in response to the increase in the relative wage of skilled labor. Columns (3) and (6) in Table 2 show the effects of foreign tariffs on skill intensity, measured as the number of skilled workers divided by the number of unskilled workers employed by the plant. As we can see, more productive plants, exporters, and the ones with higher levels of foreign ownership tend to be more skill intensive. The estimates for the tariff variables are positive and statistically significant in both cases, suggesting that firms become less skill intensive following a reduction in foreign tariffs, which is consistent with the model.

We have performed a series of tests to check the robustness of our results. First, we have re–estimated equation 19 including plant fixed effects to control for unobserved heterogeneity at the plant level. The results are presented in Table 3 and are similar to the basic results in Table 2. We again observe that a lower level of foreign tariffs increases the relative wage of skilled labor and reduces the amount of skilled labor relative to unskilled labor used by the plants.

Table 3: Short–run effects of foreign tariffs including plant fixed effects

The second robustness check consisted of estimating equation 19 without plant controls. This is done because many of the plant–level variables are highly collinear with exporting both in the model and in the data. The results, not presented here to save space, are

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[22]The average wage of skilled workers is the ratio of total wages paid to non–production workers, divided by the total number of non–production workers which are employed by a plant. Likewise, the average wage of unskilled workers is the ratio of total wages paid to production workers, divided by the total number of production workers which are employed by a plant.

[23]However, the results are not significantly affected if the dummy for exporters is not included in the regressions.

similar to the results with plant controls. Lower tariffs abroad increase the relative wage of skilled labor and reduce the skill intensity within Chilean plants.

The third and final robustness check consisted of estimating directly the effect of exporting on our two variables of interest, the relative wage and the skill intensity in production. Since exporting is clearly endogenous, we use an IV estimation method that instruments exporting with the foreign tariff rate. The results are presented in the appendix, Table $A1$. Columns (1) and (2) show the results using the simple average tariff rate, while columns (3) and (4) are based on the weighted average tariffs. In both cases, we observe that a higher instrumented exports–to–sales ratio increases the relative wage while it decreases skill intensity, as predicted by the model. The estimates for the tariff rates, in the first stage, are as expected negative and statistically significant in both cases, as shown in the table. Moreover, the F–test of excluded instruments ranges between 15.03 and 22.66, which are higher than the rule of thumb value of 10 (see Staiger and Stock, 1997). This suggests that the instrument does not lack sufficient relevance to explain the endogenous variable.

Summarizing, we find that a decrease in foreign tariffs which are effectively applied on Chilean products increases the relative wage of skilled workers and makes firms less skill intensive. Both effects are in line with the predictions of the theory.

5.2 Long–run impact

The theory predicts that, in the long run after trade liberalization, the relative wage of skilled labor should decrease, while each firm should produce more skill intensively.

An obvious starting point is to examine the effect of tariffs over a longer period using a cross section of plant. This is done by first selecting all the plants that stayed in operation during the entire 10–year period and then examining how the tariff rate, averaged over the first half of the period (1990–1994), affected the variables of interest in the second half of the period (1995–1999), controlling for plant characteristics measured as averages over the initial half. Table 4 shows the results of using this technique. Columns (1) and (3) show that initially more productive and larger plants, exporters and those with foreign ownership have a higher ratio of skilled wages relative to unskilled wages during the second part of the period. The estimate for the foreign tariff variable is positive and significant, consistent with the idea that a reduction of foreign tariffs decreases the relative wage of skilled workers in the long run. Columns (2) and (4) show the impact of foreign tariffs on

the employment of skilled workers relative to the employment of unskilled workers. The estimates for productivity, size and foreign ownership are positive and significant, while the estimates for tariffs are negative and also significant for the case of the unweighted tariff. This is, again, in line with the predictions of the model.

Table 4: Long–run effects of foreign tariffs — cross section results

Although the evidence in Table 4 is consistent with the predictions of the model, there are two concerns. First of all, it is possible that the results are essentially driven by the use of this particular group of plants (the ones that survived during the entire sample period). In order to check this, we have re–estimated equation 19 to test for the short–run impact, but have considered only those plants that we have used in Table 4. If the long–run estimates are due to the use of this specific sample, we should not observe the short–run effects we found earlier with all the plants, when using this reduced sample. The results presented in the appendix (Tables *A*2 and *A*3) show that the short–run estimates are similar to what we obtain with the whole sample. In particular, a lower level of foreign tariffs increases the relative wage of skilled labor while it decreases the amount of skilled labor relative to unskilled labor employed by the plants in the short run. This suggests that the long–run estimates are not the result of using this particular subset of plants.

The second concern with our long–run results is that the estimates in Table 4 may differ from the short–run results in Tables 2 and 3, just because the econometric specification is different (cross section vs. panel estimation). In order to investigate this issue, we estimate three panel regressions that relate tariff rates in the early periods (1990, 1991, and 1992) with the two variables of interest 5 to, at most, 10 years later:

$$Y_{ijt} = \alpha + \sum_{m=1995}^{m=1999} \beta_m \, \tau_{1990} \times \delta_m + \lambda \, \Omega_{ijt} + \delta_j + \delta_t + \epsilon_{ijt} \qquad (20)$$

$$Y_{ijt} = \alpha + \sum_{m=1996}^{m=1999} \beta_m \, \tau_{1991} \times \delta_m + \lambda \, \Omega_{ijt} + \delta_j + \delta_t + \epsilon_{ijt} \qquad (21)$$

$$Y_{ijt} = \alpha + \sum_{m=1997}^{m=1999} \beta_m \, \tau_{1992} \times \delta_m + \lambda \, \Omega_{ijt} + \delta_j + \delta_t + \epsilon_{ijt}, \qquad (22)$$

where Y_{ijt} is the variable of interest (relative wage or skill intensity) in years 1995–1999 (equation 20), 1996–1999 (equation 21) or 1997–1999 (equation 22). τ_{1990}, τ_{1991} and τ_{1992} is the tariff rate for year 1990, 1991 and 1992, respectively. δ_m is a year dummy for year

m, and β_m is the coefficient that measures the effect of tariffs that prevailed in 1990, 1991, or 1992 on the outcomes of interest 5 to, at most, 10 years later. Ω_{ijt} is, again, a vector of control variables at the plant level that we described before. The results are presented in Table 5. In order to save on space, we have omitted presentation of the estimates for the control variables, which are similar to the estimates in Tables 2 and 3.

Table 5: Long–run effects of foreign tariffs — panel results

The top panel of Table 5 is based on the simple average foreign tariff, while the bottom panel uses the trade weighted tariff rate. Columns (1)–(3) show the effects of tariffs in 1990, 1991 and 1992, respectively, on the relative wage 5 to 10 years later. As we can see in both panels, most of the estimates for the interaction terms are positive and statistically significant, suggesting that a decrease in foreign tariffs today decreases the relative wage of skilled labor between 5 and 10 years later. For the case of the relative employment of skilled labor, columns (4)–(6), we observe that a decrease in tariffs today increases the relative employment of skilled labor. Both results are consistent with the predictions of the model and are in line with the cross–section results that we have presented in Table 4. As a robustness check, we also estimated equations 20–22 including plant fixed effects. The results are presented in Table 6, and show that the estimates for tariffs are not significantly affected by the inclusion of plant fixed effects.

Table 6: Long–run effects of foreign tariffs — panel results including plant fixed effects

In summary, we find that a decrease in foreign tariffs today is correlated with a decrease in the relative wage of skilled labor paid by Chilean plants and with an increase in skill intensity of the same plants several years later. These results are robust to the use of a cross section of plants or the whole sample in a panel estimation, and are in line with the predictions of our model for the long run.

6   Conclusions

Previous empirical research has studied the impact of trade liberalization on wage inequality, especially in developing countries. However, while some studies find evidence for a decrease in wage inequality, others find the opposite.

In order to reconcile these empirical findings, we have presented an intra–industry trade model with two crucial properties: (i) households can accumulate human capital

and (ii) firms are heterogeneous in factor intensities. Our theoretical analysis has shown that it is important to distinguish between the short–run and the long–run impact of globalization on wages. If we parameterize the model such that exporters are more human capital intensive than non–exporters—which has been found both for developed and developing countries—, trade liberalization increases relative demand for human capital and, in the short run with fixed factor endowments, the relative returns to human capital. The increase in the relative returns to human capital induces households to raise their investments into human capital. Thus, in the long run after trade liberalization, the country's endowment of human capital increases, which, in turn, decreases the relative return to human capital.

The main result of our theoretical analysis is that the short–run impact of globalization for wage inequality is opposite to the long–run impact: while wage inequality increases in the short run, it decreases in the long run.

Afterwards, we have tested our theoretical predictions with a panel of Chilean manufacturing firms over the period 1990–1999. We have explicitly distinguished between the short–run and the long–run impact of trade liberalization. We have shown that, indeed, trade liberalization appears to increase the relative returns to human capital in the short run after trade liberalization. In the long run, however, the impact of trade liberalization is the opposite: the relative returns to human capital go down. In order to verify these results, we have also tested how Chilean firms correspondingly adjust their factor intensities after trade liberalization.

Thus our paper argues that policy makers should carefully examine the differential impact of trade reforms on wage inequality in the short run versus the long run. As we have shown in the theory and the empirical analysis, although wage inequality may increase in the short run, it is likely to decrease in the long run after trade liberalization, as long as the economy is able to invest into human capital. Although the predictions of the theory are observed in the case of Chile, more research is needed to verify this predictions are also present in other countries.

Appendix

A Proof of lemma 1

Extending the setup of Baxter (1992) by monopolistic competition between firms, the steady state of a Ramsey growth model is characterized by four necessary first order conditions:

$$r_t + (1 - \delta)\, p(\widetilde{\phi}_t) = p_t^H \tag{23}$$

$$r_t = p(\widetilde{\phi}_t)\Big[\widetilde{\phi}_t^{1-\alpha} A_H^\alpha + (1 - \widetilde{\phi}_t)^{1-\alpha} A_L^\alpha \left(\frac{l_t}{h_t}\right)^\alpha\Big]^{(1-\alpha)/\alpha} \widetilde{\phi}_t^{1-\alpha} A_H^\alpha \tag{24}$$

$$w_t = p(\widetilde{\phi}_t)\Big[\widetilde{\phi}_t^{1-\alpha} A_H^\alpha (h_t/l_t)^\alpha + (1 - \widetilde{\phi}_t)^{1-\alpha} A_L^\alpha\Big]^{(1-\alpha)/\alpha} (1 - \widetilde{\phi}_t)^{1-\alpha} A_L^\alpha \tag{25}$$

$$p_{t+1}^H = (1 + \rho)\, p(\widetilde{\phi}_t), \tag{26}$$

where p_t^H is the price per unit human capital in period t, r_t the human capital rate in t and w_t the wage rate in t. $p(\widetilde{\phi}_t)$ is the price of the average variety, which is used for investments.

Equation 23 is a zero profit condition for the households' human capital lending behavior. Households realize zero profits from lending human capital out to firms if p_t^H equals r_t, plus what is left from the unit of human capital in $t + 1$; since one unit of $q(\widetilde{\phi})$ in t leads to one unit of human capital in $t + 1$, the remaining $1 - \delta$ units of capital in $t + 1$ are evaluated with $p(\widetilde{\phi}_t)$. Equations 24 and 25 imply that, in the steady state, factor prices are equal to the value of the marginal product for each factor. Equation 26 denotes the Euler equation.

The time index is removed now for a steady state analysis. Equations 26 and 24 can be substituted into equation 23, which is then rearranged to:

$$\frac{l}{h} = \left\{ \frac{\left[\frac{\rho+\delta}{\widetilde{\phi}^{1-\alpha} A_H^\alpha}\right]^{\alpha/(1-\alpha)} - \widetilde{\phi}^{1-\alpha} A_H^\alpha}{(1 - \widetilde{\phi})^{1-\alpha} A_L^\alpha} \right\}^{1/\alpha}. \tag{27}$$

Substituting equation 27 into equation 25 leads to:

$$\frac{w}{p(\widetilde{\phi})} = \left\{ \frac{(1 - \widetilde{\phi}) A_L^{\alpha/(1-\alpha)} (\rho + \delta)^{\alpha/(1-\alpha)}}{(\rho + \delta)^{\alpha/(1-\alpha)} - \widetilde{\phi} A_H^{\alpha/(1-\alpha)}} \right\}^{(1-\alpha)/\alpha}. \tag{28}$$

Combining equations 23 and 26 gives:

$$\frac{r}{p(\widetilde{\phi})} = (\rho + \delta)\frac{\sigma - 1}{\sigma}. \tag{29}$$

Dividing equations 29 and 28 by each other and considering $\sigma = \frac{1}{1-\alpha}$ leads to equation 6.

B Proof of lemma 3

The partial derivative of r with respect to $\widetilde{\phi}$ is given by:

$$\frac{\partial r}{\partial \widetilde{\phi}} = \frac{1}{1 - \sigma}\, r^\sigma \frac{(\rho + \delta)^{1-\sigma} A_L^{\sigma-1}\left[(\rho + \delta)^{1-\sigma} A_H^{\sigma-1} - 1\right]}{\left[1 - \widetilde{\phi}\,(\rho + \delta)^{1-\sigma} A_H^{\sigma-1}\right]^2}.$$

$\frac{\partial r}{\partial \widetilde{\phi}}$ is negative (positive) if the squared bracket in the numerator is positive (negative), i.e. if $r < \frac{A_H}{A_L}$ $\left(r > \frac{A_H}{A_L}\right)$ in the steady state.

C Derivation of equations 9 and 10

Using $\left[\frac{c(\phi)}{p(\phi)}\right]^{\sigma} = \left(\frac{\sigma-1}{\sigma}\right)^{\sigma} = \left[\frac{c(\widetilde{\phi})}{p(\widetilde{\phi})}\right]^{\sigma}$, equations 7 and 8 can be simplified:

$$c(\widetilde{\phi})^{\sigma} q(\widetilde{\phi})(1-\widetilde{\phi})\, A_L^{\sigma-1} \left[N + \frac{\delta H}{q(\widetilde{\phi})}\right] = L \tag{30}$$

$$c(\widetilde{\phi})^{\sigma} q(\widetilde{\phi}) r^{-\sigma} \widetilde{\phi}\, A_H^{\sigma-1} \left[N + \frac{\delta H}{q(\widetilde{\phi})}\right] = H. \tag{31}$$

Dividing equations 30 and 31 by each other, solving for H and r and, afterwards, considering equation 6 leads to equations 9 and 10.

D Proof of lemma 5

In order to proof lemma 5, we will construct a numerical example with $\sigma = 2$ and $A_L = 1$. A country's relative human capital endowment in the autarkic steady state then becomes $\frac{H}{L} = \frac{(1-\widetilde{\phi})\widetilde{\phi}}{\left(\frac{\rho+\delta}{A_H}-\widetilde{\phi}\right)^2 A_H}$. Notice that $\frac{\rho+\delta}{A_H} - \widetilde{\phi} > 0$ by assumption, while $\frac{\rho+\delta}{A_H}$ can be larger or smaller than 1. If $\widetilde{\phi} \to 0$, then $\frac{H}{L} \to 0$. However, if $\widetilde{\phi} \to \frac{\rho+\delta}{A_H}$, then $\frac{H}{L} \to \infty$. Thus, $\frac{H}{L}$ can reach any value within the interval $[0,\infty)$, regardless of whether $\rho + \delta$ is larger or smaller than A_H.

E Derivation of equation 18

Considering that $\widetilde{\widetilde{\phi}} \equiv \frac{\widetilde{\phi}+s_X \widetilde{\phi}_X}{1+s_X}$, we can simplify equations 16 and 17 to:

$$c(\widetilde{\phi})^{\sigma} q(\widetilde{\phi})(1 + s_X - \widetilde{\phi} - s_X \widetilde{\phi}_X) A_L^{\sigma-1} \left[N + \frac{c(\widetilde{\widetilde{\phi}})^{\sigma} \frac{1}{1+s_X}\delta H}{c(\widetilde{\phi})^{\sigma} q(\widetilde{\phi})}\right] = L - L_{f_X} \tag{32}$$

$$c(\widetilde{\phi})^{\sigma} q(\widetilde{\phi}) r^{-\sigma} (\widetilde{\phi} + s_X \widetilde{\phi}_X) A_H^{\sigma-1} \left[N + \frac{c(\widetilde{\widetilde{\phi}})^{\sigma} \frac{1}{1+s_X}\delta H}{c(\widetilde{\phi})^{\sigma} q(\widetilde{\phi})}\right] = H - H_{f_X}. \tag{33}$$

Dividing equations 32 and 33 by each other and solving for r in the short run after trade liberalization leads equation 18.

F Proof of lemma 8

We can prove lemma 8 by contradiction. First, notice that r being smaller than $\frac{A_H}{A_L}$ is actually necessary for exporters being more human capital intensive than non–exporters. In other words, $r < \frac{A_H}{A_L}$ is actually necessary for r to increase in the short run after trade liberalization. However, if r approaches $\frac{A_H}{A_L}$, then either all firms or no firm would export since, if r approaches $\frac{A_H}{A_L}$, the human capital share parameter does not influence export profits at all. However, if either all firms or if no firm exports after trade liberalization, r would not change at all and remain at its autarkic level since, if all firms export, $s_X = 1$ and $\widetilde{\phi} = \widetilde{\phi}_X$, while $s_X = 0$ if no firm exports. Thus, even though r increases in the short run after trade liberalization, it will never become equal or larger than $\frac{A_H}{A_L}$.

26

G Proof of proposition 5

Solving equation 20 for $\frac{H_{ft}-H_{f_X}}{L-L_{f_X}}$ in the free trade steady state leads to (ft denotes variables in the free trade steady state, while *aut* denotes variables in the autarkic steady state):

$$\frac{H_{ft}-H_{f_X}}{L-L_{f_X}} = \frac{r_{ft}^{-\sigma}(\widetilde{\phi}+s_X\widetilde{\phi}_X)}{1+s_X-\widetilde{\phi}-s_X\widetilde{\phi}_X}\left(\frac{A_H}{A_L}\right)^{\sigma-1}.$$

Relative to the autarkic steady state, relative human capital demand for producing the varieties $q(\phi)$ has increased since $\frac{r_{ft}^{-\sigma}(\widetilde{\phi}+s_X\widetilde{\phi}_X)}{1+s_X-\widetilde{\phi}-s_X\widetilde{\phi}_X} > \frac{r_{aut}^{-\sigma}\widetilde{\phi}}{1-\widetilde{\phi}}$. Thus, relative human capital supply net of sunk export costs, which is given by $\frac{H_{ft}-H_{f_X}}{L-L_{f_X}}$, must be larger than $\frac{H_{aut}}{L}$, i.e. the following holds:

$$\frac{H_{ft}-H_{f_X}}{L-L_{f_X}} > \frac{H_{aut}}{L} \;\Rightarrow\; H_{ft}-H_{aut} > H_{f_X} - \frac{H_{aut}L_{f_X}}{L}.$$

Furthermore, $\frac{H_{f_X}}{L_{f_X}} > \frac{H_{aut}}{L}$, which can be transformed to:

$$H_{f_X} > \frac{H_{aut}L_{f_X}}{L} \;\Rightarrow\; H_{f_X} - \frac{H_{aut}L_{f_X}}{L} > 0.$$

Thus, since $H_{f_X} - \frac{H_{aut}L_{f_X}}{L}$ is larger than zero, we can conclude that $H_{ft}-H_{aut}$ must definitely be larger than zero.

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Figure 1: Adjustment to the trading equilibrium

Chart 1: Relative factor prices and trade liberalization
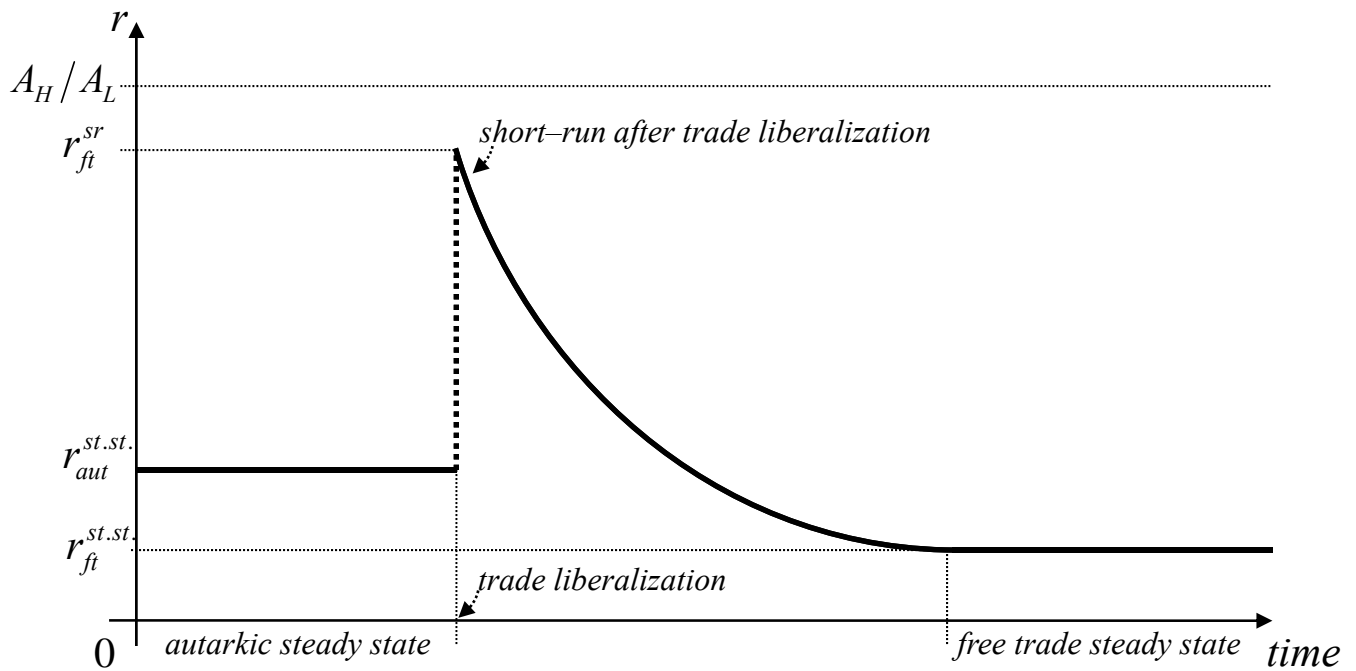
Chart 2: Relative human capital input and trade liberalization
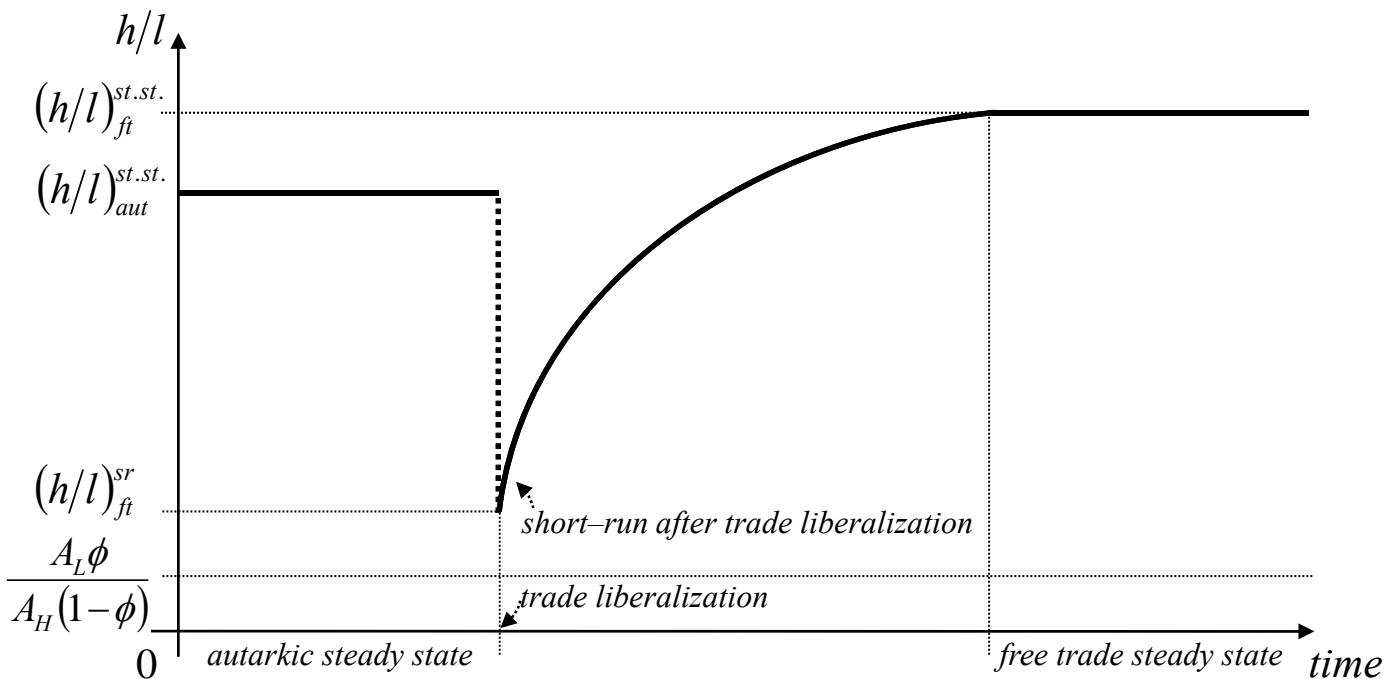
TABLE 1: Mean Differences in Skill Intensity between Exporters and Non–Exporters

	(1)	(2)
	Skilled Labor / Unskilled Labor	Share Skilled Labor in Wage Bill
(1) Exporters	0.9185	0.4635
	(0.053)	(0.002)
(2) Non–Exporters	0.5792	0.3488
	(0.013)	(0.001)
Difference (1)–(2)	0.3393	0.1147
	(0.037)	(0.002)

Standard errors in parentheses. Differences between exporters and non–exporters are all statistically significant at 1%.

TABLE 2: Short–Run Effects of Foreign Tariffs

	(1)	(2)	(3)	(4)	(5)	(6)
	Exports / Sales	Wage Skilled / Wage Unskilled	Skilled Labor / Unskilled Labor	Exports / Sales	Wage Skilled / Wage Unskilled	Skilled Labor / Unskilled Labor
World Tariff: Simple Average	–0.0007**	–0.0061*	0.0052*			
	(0.000)	(0.003)	(0.002)			
World Tariff: Weighted Average				–0.0015**	–0.0223**	0.0161+
				(0.000)	(0.008)	(0.009)
TFP	0.0026	0.2820**	0.2287**	0.0027	0.2825**	0.2283**
	(0.002)	(0.031)	(0.037)	(0.002)	(0.031)	(0.037)
Employment	0.0552**	0.3438**	0.0004	0.0551**	0.3436**	0.0006
	(0.005)	(0.030)	(0.023)	(0.005)	(0.030)	(0.023)
Export Dummy		0.3039**	0.1096*		0.3030**	0.1101*
		(0.054)	(0.045)		(0.054)	(0.045)
Foreign Ownership (%)	0.0006**	0.0019	0.0041**	0.0006**	0.0019	0.0041**
	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)
Imported Inputs / Total Inputs	–0.0019+	–0.0109	–0.0023	–0.0019+	–0.0112	–0.0020
	(0.001)	(0.010)	(0.006)	(0.001)	(0.010)	(0.006)
Age	–0.0293**	–0.0315	–0.0117	–0.0293**	–0.0318	–0.0115
	(0.004)	(0.027)	(0.019)	(0.004)	(0.027)	(0.019)
Foreign Technology Licenses / Sales	0.1016	1.0000	4.8961+	0.1063	1.0828	4.8389+
	(0.185)	(4.067)	(2.700)	(0.185)	(4.064)	(2.703)
Constant	–0.1012**	–0.2372	–0.9721**	–0.1014**	–0.1927	–0.9941**
	(0.021)	(0.222)	(0.280)	(0.020)	(0.227)	(0.287)
Observations	38,359	38,359	38,359	38,359	38,359	38,359
R–squared	0.184	0.059	0.029	0.185	0.059	0.029

Robust standard errors, clustered at the 3–digit sector-year level, in parentheses. * significant at 1%, ** significant at 5%, + significant at 10%. Year and 3–digit sector dummy variables were included but not reported. TFP, Employment, and Age are in logs.

TABLE 3: Short–Run Effects of Foreign Tariffs Including Plant Fixed Effects

	(1) Exports / Sales	(2) Wage Skilled / Wage Unskilled	(3) Skilled Labor / Unskilled Labor	(4) Exports / Sales	(5) Wage Skilled / Wage Unskilled	(6) Skilled Labor / Unskilled Labor
World Tariff: Simple Average	−0.0003*	−0.0028	0.0038*			
	(0.000)	(0.002)	(0.002)			
World Tariff: Weighted Average				−0.0008**	−0.0115*	0.0152+
				(0.000)	(0.005)	(0.009)
TFP	0.0003	0.3437**	0.2186**	0.0004	0.3442**	0.2179**
	(0.001)	(0.036)	(0.043)	(0.001)	(0.036)	(0.043)
Employment	0.0204**	0.0222	0.0063	0.0205**	0.0219	0.0066
	(0.002)	(0.067)	(0.076)	(0.002)	(0.067)	(0.076)
Export Dummy		0.0658	0.2612**		0.0650	0.2622**
		(0.053)	(0.083)		(0.053)	(0.083)
Foreign Ownership (%)	0.0001	0.0014	0.0042*	0.0001	0.0015	0.0041+
	(0.000)	(0.001)	(0.002)	(0.000)	(0.001)	(0.002)
Imported Inputs / Total Inputs	0.0003	0.0048	−0.0113	0.0002	0.0044	−0.0109
	(0.000)	(0.008)	(0.007)	(0.000)	(0.008)	(0.007)
Age	−0.0006	0.0524	−0.1186*	−0.0007	0.0519	−0.1179*
	(0.002)	(0.048)	(0.056)	(0.002)	(0.048)	(0.056)
Foreign Technology Licenses / Sales	0.4893**	5.8330	−2.3119	0.4925**	5.8738	−2.3664
	(0.171)	(4.659)	(2.538)	(0.171)	(4.658)	(2.544)
Constant	−0.0127	−0.8102	−1.2696*	−0.0106	−0.7249	−1.3799*
	(0.069)	(0.697)	(0.553)	(0.069)	(0.712)	(0.549)
Observations	38,359	38,359	38,359	38,359	38,359	38,359
R–squared (within)	0.011	0.018	0.017	0.011	0.018	0.017

Robust standard errors, clustered at the 3–digit sector–year level, in parentheses. * significant at 1%, ** significant at 5%, + significant at 10%. Year and 3–digit sector dummy variables were included but not reported. TFP, Employment, and Age are in logs.

TABLE 4: Long–Run Effects of Foreign Tariffs – Cross Section Results

	(1) Wage Skilled / Wage Unskilled	(2) Skilled Labor / Unskilled Labor	(3) Wage Skilled / Wage Unskilled	(4) Skilled Labor / Unskilled Labor
World Tariff: Simple Average	0.0219*	−0.0327**		
	(0.009)	(0.013)		
World Tariff: Weighted Average			0.0299*	−0.0115
			(0.013)	(0.018)
TFP	0.0903+	0.2430**	0.1146*	0.1931**
	(0.050)	(0.071)	(0.048)	(0.068)
Employment	0.3721**	0.1903*	0.3672**	0.1951**
	(0.053)	(0.075)	(0.053)	(0.075)
Export Dummy	0.3256**	−0.2990+	0.3370**	−0.2974+
	(0.126)	(0.177)	(0.126)	(0.178)
Foreign Ownership (%)	0.0048+	0.0090*	0.0048+	0.0093*
	(0.003)	(0.004)	(0.003)	(0.004)
Imported Inputs / Total Inputs	0.2215	0.1547	0.1218	0.2239
	(0.173)	(0.243)	(0.175)	(0.247)
Age	0.0163	0.0407	0.0258	0.0219
	(0.098)	(0.138)	(0.098)	(0.138)
Foreign Technology Licenses / Sales	6.3531	19.9129	4.7574	21.6569
	(10.688)	(15.057)	(10.685)	(15.073)
Constant	0.3684	−1.2286*	0.2266	−1.1683*
	(0.397)	(0.559)	(0.401)	(0.566)
Observations	2,089	2,089	2,089	2,089
R–squared	0.075	0.021	0.075	0.018

Standard errors in parentheses. * significant at 1%, ** significant at 5%, + significant at 10%. TFP, Employment, and Age are in logs. Dependent variables are averages over the period 1995–1999, while all the independent variables are averages over the period 1990–1994. Only plants that stayed in operation during the entire period 1990–1999 are included. Export Dummy = 1 if plant exported at least 3 years during the period 1990–1994.

TABLE 5: Long–Run Effects of Foreign Tariffs – Panel Results

	(1)	(2)	(3)	(4)	(5)	(6)
	Wage Skilled / Wage Unskilled			Skilled Labor / Unskilled Labor		
	Tariff 1990	Tariff 1991	Tariff 1992	Tariff 1990	Tariff 1991	Tariff 1992
World Tariff: Simple Average						
World Tariff $\times$ Year 1995	–0.0120			–0.0018		
	(0.009)			(0.007)		
World Tariff $\times$ Year 1996	0.0011	0.0086**		0.0019	–0.0037	
	(0.018)	(0.003)		(0.010)	(0.002)	
World Tariff $\times$ Year 1997	–0.0020	0.0076**	0.0038	–0.0140+	–0.0069**	–0.0316+
	(0.014)	(0.002)	(0.028)	(0.007)	(0.001)	(0.017)
World Tariff $\times$ Year 1998	0.0269**	0.0104**	0.0373*	–0.0419**	–0.0073**	–0.0609*
	(0.010)	(0.003)	(0.015)	(0.011)	(0.002)	(0.028)
World Tariff $\times$ Year 1999	0.0423	0.0280**	0.0901+	–0.0413**	–0.0082**	–0.0590*
	(0.028)	(0.002)	(0.048)	(0.010)	(0.002)	(0.029)
Observations	38,359	38,359	38,359	38,359	38,359	38,359
R–squared	0.059	0.060	0.059	0.030	0.029	0.030
World Tariff: Weighted Average						
World Tariff $\times$ Year 1995	0.0009			–0.0012		
	(0.012)			(0.011)		
World Tariff $\times$ Year 1996	0.0159	0.0220+		–0.0246	–0.0148	
	(0.017)	(0.012)		(0.019)	(0.016)	
World Tariff $\times$ Year 1997	0.0444**	0.0168	–0.0023	–0.0284*	–0.0079	0.0004
	(0.016)	(0.013)	(0.017)	(0.012)	(0.011)	(0.009)
World Tariff $\times$ Year 1998	0.0527**	0.0431**	0.0067	–0.0504**	–0.0017	0.0094
	(0.014)	(0.011)	(0.015)	(0.018)	(0.018)	(0.019)
World Tariff $\times$ Year 1999	0.0531+	0.0501+	0.0081	–0.0501**	–0.0224	0.0018
	(0.032)	(0.026)	(0.014)	(0.018)	(0.017)	(0.018)
Observations	38,359	38,359	38,359	38,359	38,359	38,359
R–squared	0.059	0.059	0.059	0.030	0.029	0.029

Robust standard errors, clustered at the 3–digit sector–year level, in parentheses. * significant at 1%, ** significant at 5%, + significant at 10%. Year and 3–digit sector dummy variables were included but not reported. TFP, Employment, and Age are in logs.

TABLE 6: Long–Run Effects of Foreign Tariffs – Panel Results Including Plant Fixed Effects

	(1)	(2)	(3)	(4)	(5)	(6)
	Wage Skilled / Wage Unskilled			Skilled Labor / Unskilled Labor		
	Tariff 1990	Tariff 1991	Tariff 1992	Tariff 1990	Tariff 1991	Tariff 1992
World Tariff: Simple Average						
World Tariff × Year 1995	–0.0164*			–0.0052		
	(0.007)			(0.006)		
World Tariff × Year 1996	–0.0032	0.0085**		–0.0020	–0.0033	
	(0.015)	(0.002)		(0.010)	(0.002)	
World Tariff × Year 1997	–0.0029	0.0080**	0.0167	–0.0151*	–0.0068**	–0.0378*
	(0.013)	(0.002)	(0.018)	(0.007)	(0.001)	(0.016)
World Tariff × Year 1998	0.0239*	0.0093**	0.0288+	–0.0407**	–0.0066**	–0.0657**
	(0.009)	(0.002)	(0.015)	(0.010)	(0.002)	(0.025)
World Tariff × Year 1999	0.0104	0.0047*	0.0136	–0.0421**	–0.0080**	–0.0689*
	(0.008)	(0.002)	(0.013)	(0.011)	(0.002)	(0.031)
Observations	38,359	38,359	38,359	38,359	38,359	38,359
R–squared (within)	0.018	0.018	0.018	0.018	0.017	0.018
World Tariff: Weighted Average						
World Tariff × Year 1995	–0.0005			0.0000		
	(0.012)			(0.012)		
World Tariff × Year 1996	0.0004	0.0216*		–0.0214	–0.0141	
	(0.015)	(0.011)		(0.017)	(0.016)	
World Tariff × Year 1997	0.0315**	0.0239**	0.0070	–0.0319*	–0.0102	–0.0030
	(0.012)	(0.009)	(0.011)	(0.012)	(0.010)	(0.009)
World Tariff × Year 1998	0.0472**	0.0387**	–0.0000	–0.0504**	–0.0104	0.0063
	(0.012)	(0.011)	(0.013)	(0.017)	(0.019)	(0.018)
World Tariff × Year 1999	0.0218*	0.0218*	0.0001	–0.0625**	–0.0266	–0.0017
	(0.010)	(0.010)	(0.009)	(0.020)	(0.019)	(0.019)
Observations	38,359	38,359	38,359	38,359	38,359	38,359
R–squared (within)	0.018	0.018	0.018	0.018	0.017	0.017

Robust standard errors, clustered at the 3–digit sector–year level, in parentheses. * significant at 1%, ** significant at 5%, + significant at 10%. Year and 3–digit sector dummy variables were included but not reported. TFP, Employment, and Age are in logs.

TABLE A1: Short–Run Effects of World Tariffs - IV Estimates

	(1)	(2)	(3)	(4)
	Instrument: Simple Average Tariff		Instrument: Weighted Average Tariff	
	Wage Skilled / Wage Unskilled	Skilled Labor / Unskilled Labor	Wage Skilled / Wage Unskilled	Skilled Labor / Unskilled Labor
Exports / Sales (Instrumented)	9.5060**	–7.6404*	15.5171**	–10.6895+
	(2.893)	(3.071)	(5.179)	(6.482)
TFP	0.2667**	0.2518**	0.2506**	0.2600**
	(0.036)	(0.040)	(0.044)	(0.044)
Employment	–0.1265	0.4413*	–0.4579	0.6094+
	(0.165)	(0.175)	(0.293)	(0.363)
Foreign Ownership (%)	–0.0036	0.0092**	–0.0075*	0.0111*
	(0.002)	(0.002)	(0.004)	(0.005)
Imported Inputs / Total Inputs	0.0106	–0.0152	0.0224	–0.0212
	(0.014)	(0.011)	(0.021)	(0.016)
Age	0.2407**	–0.2378**	0.4168**	–0.3271+
	(0.087)	(0.092)	(0.157)	(0.191)
Foreign Technology Licenses / Sales	0.8552	5.9687+	0.2543	6.2735+
	(4.473)	(3.117)	(5.062)	(3.456)
First Stage Estimates for World Tariff				
World Tariff: Simple Average		–0.0007**		
		(0.000)		
World Tariff: Weighted Average				–0.0015**
				(0.000)
F–test Excluded Instruments		22.66**		15.03**
Observations	38,359	38,359	38,359	38,359

Robust standard errors, clustered at the 3–digit sector–year level, in parentheses. * significant at 1%, ** significant at 5%, + significant at 10%. Year and 3–digit sector dummy variables were included but not reported. TFP, Employment, and Age are in logs.

TABLE A2: Short–Run Effects of Foreign Tariffs – Same Sample as in Table 4

	(1)	(2)	(3)	(4)	(5)	(6)
	Exports / Sales	Wage Skilled / Wage Unskilled	Skilled Labor / Unskilled Labor	Exports / Sales	Wage Skilled / Wage Unskilled	Skilled Labor / Unskilled Labor
World Tariff: Simple Average	–0.0006**	–0.0035	0.0046*			
	(0.000)	(0.003)	(0.002)			
World Tariff: Weighted Average				–0.0011**	–0.0268**	0.0089
				(0.000)	(0.008)	(0.012)
TFP	0.0025	0.3730**	0.3412**	0.0025	0.3733**	0.3407**
	(0.002)	(0.043)	(0.061)	(0.002)	(0.043)	(0.061)
Employment	0.0492**	0.2763**	–0.0500+	0.0491**	0.2764**	–0.0499+
	(0.004)	(0.033)	(0.028)	(0.004)	(0.033)	(0.028)
Export Dummy		0.3125**	0.1686*		0.3122**	0.1682*
		(0.063)	(0.066)		(0.063)	(0.066)
Foreign Ownership (%)	0.0009**	0.0042	0.0059**	0.0009**	0.0042	0.0059**
	(0.000)	(0.003)	(0.002)	(0.000)	(0.003)	(0.002)
Imported Inputs / Total Inputs	–0.0014	0.0018	–0.0257	–0.0015	0.0019	–0.0254
	(0.001)	(0.040)	(0.024)	(0.001)	(0.040)	(0.024)
Age	–0.0587**	–0.0207	0.0564	–0.0588**	–0.0209	0.0568
	(0.007)	(0.056)	(0.044)	(0.007)	(0.056)	(0.044)
Foreign Technology Licenses / Sales	0.1300	–1.7461	2.9536	0.1308	–1.6716	2.9487
	(0.284)	(4.941)	(3.169)	(0.284)	(4.935)	(3.175)
Constant	–0.1074**	–3.0879**	–1.0879*	–0.1068**	–2.9955**	–1.0927*
	(0.026)	(0.462)	(0.518)	(0.026)	(0.452)	(0.521)
Observations	18,914	18,914	18,914	18,914	18,914	18,914
R-squared	0.186	0.063	0.035	0.186	0.063	0.035

Robust standard errors, clustered at the 3–digit sector–year level, in parentheses. * significant at 1%, ** significant at 5%, + significant at 10%. Year and 3–digit sector dummy variables were included but not reported. TFP, Employment, and Age are in logs. Only plants that stayed in operation during the entire period 1990–1999 are included.

TABLE A3: Short–Run Effects of Foreign Tariffs Including Plant Fixed Effects – Same Sample as in Table 4

	(1) Exports / Sales	(2) Wage Skilled / Wage Unskilled	(3) Skilled Labor / Unskilled Labor	(4) Exports / Sales	(5) Wage Skilled / Wage Unskilled	(6) Skilled Labor / Unskilled Labor
World Tariff: Simple Average	–0.0005**	–0.0025	0.0048*			
	(0.000)	(0.003)	(0.002)			
World Tariff: Weighted Average				–0.0011**	–0.0200**	0.0112
				(0.000)	(0.007)	(0.012)
TFP	–0.0000	0.4499**	0.3156**	0.0001	0.4504**	0.3143**
	(0.001)	(0.047)	(0.077)	(0.001)	(0.047)	(0.077)
Employment	0.0226**	0.0713	–0.0675	0.0226**	0.0693	–0.0673
	(0.003)	(0.087)	(0.104)	(0.003)	(0.086)	(0.103)
Export Dummy		0.1747*	0.3072**		0.1739*	0.3064**
		(0.077)	(0.115)		(0.077)	(0.114)
Foreign Ownership (%)	0.0000	0.0014	0.0083*	0.0001	0.0015	0.0083*
	(0.000)	(0.002)	(0.004)	(0.000)	(0.002)	(0.004)
Imported Inputs / Total Inputs	0.0003	0.0115	–0.0265	0.0003	0.0114	–0.0261
	(0.001)	(0.029)	(0.028)	(0.001)	(0.030)	(0.028)
Age	–0.0065	0.1382	–0.1066	–0.0070	0.1385	–0.1028
	(0.006)	(0.105)	(0.168)	(0.006)	(0.105)	(0.168)
Foreign Technology Licenses / Sales	0.4123+	6.1801	–1.9042	0.4150+	6.2711	–1.9322
	(0.243)	(6.132)	(3.098)	(0.243)	(6.130)	(3.105)
Constant	–0.0969	–2.5408*	–1.1857	–0.0992	–2.2685+	–1.2635
	(0.090)	(1.270)	(1.084)	(0.091)	(1.279)	(1.066)
Observations	18,914	18,914	18,914	18,914	18,914	18,914
R–squared (within)	0.016	0.023	0.024	0.016	0.024	0.024

Robust standard errors, clustered at the 3–digit sector–year level, in parentheses. * significant at 1%, ** significant at 5%, + significant at 10%. Year and 3–digit sector dummy variables were included but not reported. TFP, Employment, and Age are in logs. Only plants that stayed in operation during the entire period 1990–1999 are included.