Random versus conscious selection into export markets — theory and empirical evidence*

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Abstract

Recent theoretical analyses on trade with firm heterogeneity either assume that firms are randomly selected into export markets (Melitz, 2003) or that firms consciously decide whether to become exporters or not (Yeaple, 2005). These two models, however, differ in their structure so that it is not possible to investigate how this difference in firm behavior influences the gains from trade. This paper, in contrast, presents a dynamic general equilibrium model, which unifies the approaches of Melitz (2003) and Yeaple (2005): in the first version of the model, firms are randomly selected into export markets. In the second version, firms consciously decide whether to export or not. It is shown that a negative growth effect of trade liberalization results in the first version if less than half of a country's firms export. However, a positive growth effect of trade liberalization always results in the second version. Since empirical analyses document a positive growth effect of trade liberalization, a conscious selection into export markets is closer to reality. This hypothesis is tested with the help of plant–level data from the manufacturing sector of Chile between 1990 and 1999. The analysis shows that when firms decide to export, they consciously adopt more human capital intensive technologies. Therefore, exporting is not just a random process but rather a conscious decision. This evidence strongly supports the theory.

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1 Introduction

Very recently, new trade theory has been extended by the 'new new' trade theory.[1] The 'new new' trade theory extends Krugman's (1980) intra–industry trade model by introducing firm heterogeneity with respect to total factor productivity and is formalized by, among others, Melitz (2003), Baldwin/Forslid (2004), Falvey et al. (2004) and Bernard et al. (2006). Two assumptions are central to these 'new new' trade models. First, fixed market entry costs, fixed production costs and fixed export costs exist. Second, productivity levels are completely randomly allocated to firms after market entry. Combining these two assumptions, exposure to trade leads to the following firm selection mechanism:

Since fixed export costs exist, only the more productive firms export and produce more in the open economy. Competition for scarce resources accordingly increases with exposure to trade and forces the least productive firms to exit the market. Exposure to trade therefore increases a country's average total factor productivity.

'New new' trade models can explain certain empirical regularities: first, firms producing identical or similar products, exhibit a large degree of heterogeneity with respect to their size and productivity. Second, exporters are more productive and larger than non–exporters.[2]

The assumption of a random allocation of the technology parameter to firms, which is central to the above–cited 'new new' trade models, is not present in Yeaple (2005). Firms are ex ante homogeneous and heterogeneity results since firms consciously decide whether to become high–tech exporters or low–tech non–exporters. Furthermore, firms choose their labor input from a pool of workers, which are differentiated by an exogenous distribution of skill levels. Yeaple (2005) then analyzes how exposure to trade effects the workers' skill premia.

Obviously, the previous 'new new' trade literature can be divided into two subgroups: first, Melitz (2003), Baldwin/Forslid (2004), Falvey et al. (2004) and Bernard et al. (2006) assume complete uncertainty of firms with respect to their technologies, i. e., a random selection into export markets. Second, Yeaple (2005) assumes complete certainty of firms with respect to their technologies, i. e., a conscious selection into export markets. On the one hand, the resulting difference in the model structures — *complete* uncertainty versus *complete* certainty with respect to the technologies — prevents a direct investigation of how the random versus the conscious selection into export mar-

[1] Cf. Baldwin/Forslid (2004) for this labeling.

[2] Cf., e. g., Bernard/Jensen (1999), Aw et al. (2000) and Girma et al. (2003).

kets influences the gains from trade. On the other hand, the assumption of complete certainty of firms with respect to their technologies in Yeaple (2005) certainly does not reflect reality properly as well. Several empirical studies document that firms are faced with, at least, some degree of uncertainty about their technologies.[3] This paper therefore presents a novel theoretical model, which extends the previous models in four dimensions:

First of all, the present model unifies the approaches of Melitz (2003) and Yeaple (2005): in a first version of the model, technologies are completely randomly allocated to firms, i. e., firms are randomly selected into export markets.[4] In a second version, the firms' uncertainty about their technologies is reduced such that firms consciously decide whether their technology is randomly drawn from a pool of high–tech technologies or from a pool of low–tech technologies. If only the high–tech firms export in the open economy, firms consciously select into export markets in the second version.

Second, the present model highlights the idea that heterogeneity with respect to total factor productivity can always be explained with the help of an *additional* factor of production, which is employed in differing intensities at given relative factor prices. The present model introduces human capital as a second factor of production besides labor. Consistent with reality, the present model assumes heterogeneity across firms with respect to the factor intensities in production at given relative factor prices.[5]

Third, the present model is extended by a dynamic optimizing behavior of households: the human capital endowment in the current period is determined by investments in the previous period and the periodical depreciation rate. This dynamic setup establishes a relationship between the country's average factor intensity in production and the gains from trade in the sense of positive/negative growth effects of exposure to trade. If the time discount rate and the depreciation rate are chosen such that the relative price of labor exceeds unity and if fixed export costs exist, only the more human capital intensive or high–tech firms can afford to become exporters in the open economy.

Fourth, unlike most papers in this area, the present paper confronts the theory with the data, using plant–level data from Chile.

The present model still retains important properties of the previous 'new new' trade models: first, three different types of fixed costs exist: fixed market entry costs, fixed

[3]Cf., e. g., Dunne et al. (1988, 1989) and López (2006); these authors show that plant failure declines with the plant's age. This evidence supports the idea of, at least, some degree of uncertainty of firms with respect to their technologies.

[4]The first version of the model draws on Emami Namini (2006).

[5]Cf., e. g., Bernard/Jensen (1999); these authors show that firms which produce identical or similar goods exhibit substantial heterogeneity with respect to the factor intensities in production.

production costs, and fixed export costs. Second, firms are heterogeneous with respect to their production technologies while workers are heterogeneous with respect to their human capital endowments or skill levels.

The theoretical results show the following: if firms are randomly selected into export markets, exposure to trade leads to a negative growth effect if less than half of a country's firms export. However, if firms consciously decide whether to export or not, exposure to trade always leads to a positive growth effect. Since previous empirical work consistently documents a positive growth effect of exposure to trade, a conscious selection into export markets is closer to reality. This hypothesis is tested with the help of plant–level data from the manufacturing sector of Chile between 1990 and 1999. The empirical results confirm the hypothesis of a conscious selection into export markets.

This paper is organized as follows: section 2 outlines the setup of the basic model. Section 3 characterizes the equilibrium in the closed economy. Section 4 characterizes the equilibrium in the open economy and discusses the growth effect of exposure to trade. Section 5 presents the empirical analysis, which tests whether the data support a random or a conscious selection of firms into export markets. Section 6 concludes.

2 Basic model

The steady states of two symmetric countries, the home country H and the foreign country F, are analyzed. Both countries are endowed with labor L and human capital S, which are used to produce one differentiated good. The labor endowment is constant over time. Since countries H and F are completely identical, the country index is initially omitted. Furthermore, since only the steady state is analyzed, the time index is also omitted for the time being. The market for the differentiated good is characterized by large–group Dixit–Stiglitz monopolistic competition.

2.1 Production

A single firm i produces a unique variety of the differentiated good with the following modified *CES* production function:

$$q(\phi_i) = \left(\phi_i^\alpha \cdot L_i^\alpha + (1-\phi_i)^\alpha \cdot S_i^\alpha\right)^{1/\alpha}, \tag{1}$$

where L_i and S_i denote the labor and human capital inputs of firm i. This modified *CES* production function leads to the calibrated share form of the per unit cost function if all absolute prices are equal to unity. The calibrated share form of the cost function is taken from applied general equilibrium theory and simplifies further calculations since only the firms' cost functions will be used. The parameter ϕ_i indicates different factor intensities across firms. The cost function of firm i results as:

$$c(\phi_i) \;=\; \Big(\phi_i \cdot w^{1-\sigma} + (1-\phi_i) \cdot s^{1-\sigma}\Big)^{1/(1-\sigma)}, \quad \sigma = \frac{1}{1-\alpha}, \tag{2}$$

with w denoting the price for labor and s the human capital rental rate, respectively. The parameter σ represents the elasticity of substitution in production. Furthermore, serving the domestic market leads to fixed per period costs $f_i \cdot c(\phi_i)$ which are produced with the same technology as the good itself. Given Dixit–Stiglitz preferences for the representative household, the profit maximizing price of firm i is given by $p(\phi_i) \cdot (1 - 1/\sigma) = c(\phi_i)$, where σ stands for the elasticity of substitution in the representative household's utility function. In order to avoid analytical complexities, the firms' production function and the household's utility function share an identical value for σ. Furthermore, subsection 2.6 shows that the relative price of labor in the steady state exceeds unity if the time discount rate and the depreciation rate for human capital are chosen properly. The per unit costs therefore decline in the present model if the human capital intensity increases. Finally, the number of firms is assumed to reach infinity.

2.2 Demand

Intratemporal preferences of the representative household are described by a *CES* love of variety utility function over the varieties of the differentiated good. This utility function leads to the following revenue function for firm i:

$$R(\phi_i) \;=\; q(\phi_i) \cdot p(\phi_i) \;=\; P \cdot Q \cdot \Big(p(\phi_i)/P\Big)^{1-\sigma}, \tag{3}$$

where $P = \Big(\int_i p(\phi_i)^{1-\sigma} d\phi_i + \int_j \left(p(\phi_j) \cdot \tau\right)^{1-\sigma} d\phi_j\Big)^{1/(1-\sigma)}$ denotes the aggregate price index and $Q = \Big(\int_i q(\phi_i)^{\alpha} d\phi_i + \int_j \left(q(\phi_j)/\tau\right)^{\alpha} d\phi_j\Big)^{1/\alpha}$ the aggregate consumption good. The index j stands for foreign varieties supplied to the home market and τ, $\tau \geq 1$, denotes iceberg transport costs.

2.3 Firm entry and exit

The monopolistically competitive sector is populated by an unbounded mass of potential entrants into the market. Entering the market in t instantaneously requires an irreversible investment of $f_X \cdot c(\phi_i)$, which is included in the model as a fixed one–time market entry cost. Concerning the allocation of technologies to firms, two different versions of the model will be analyzed:

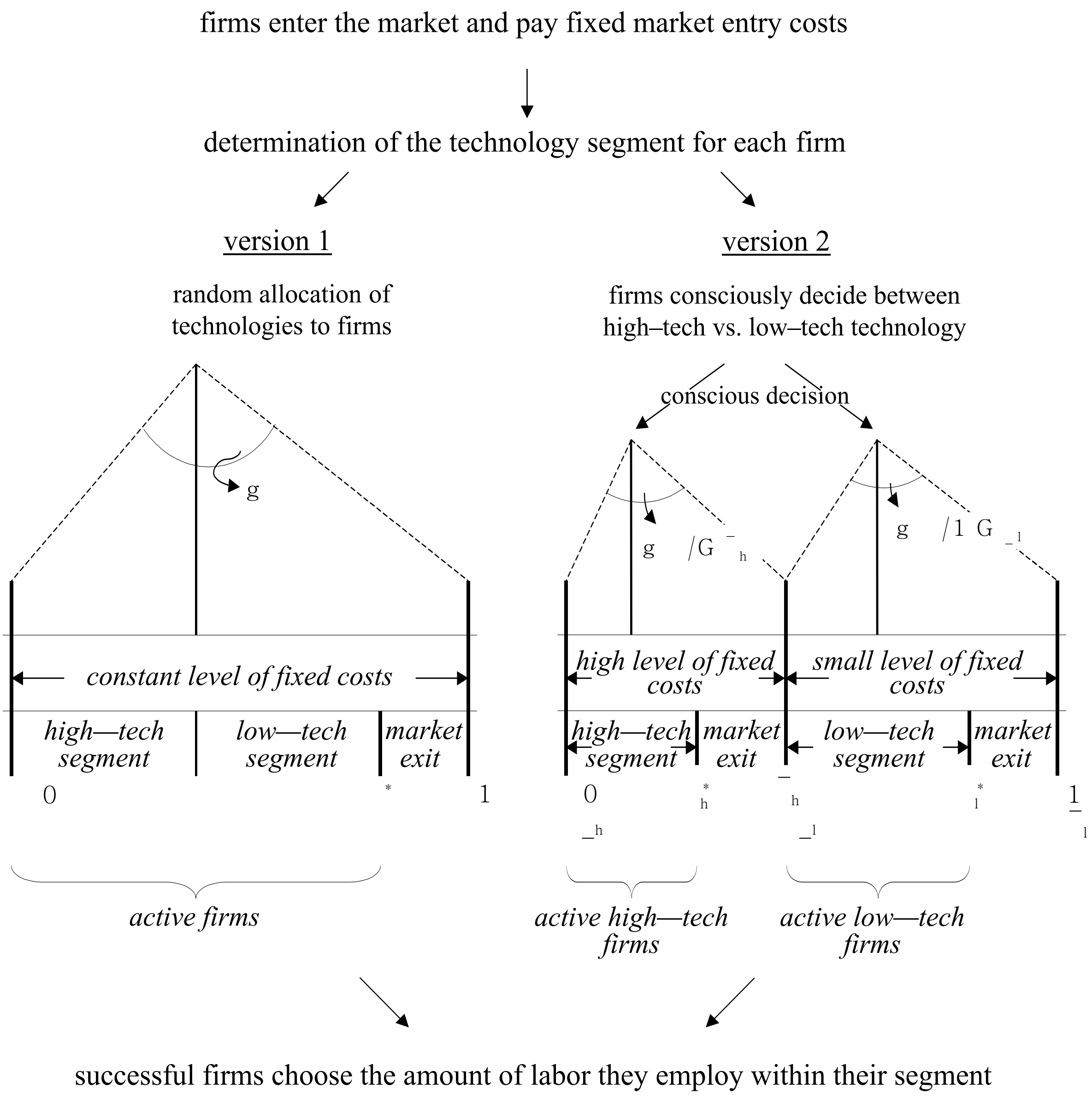
First version: Random allocation of technologies to firms
The fixed costs parameter f_i is assumed to be constant across firms, $f_i = f \; \forall i$. After the firm enters the market, it has to draw in t its factor share parameter ϕ_i from an exogenous cumulative distribution, which is given by G and has positive support over the interval $[0;1]$. Since fixed per period costs exist, the firm starts producing in $t+1$ only if its labor intensity is equal to or smaller than a threshold value ϕ^*. Due to a relative price of labor larger than unity, total per period profits are positive only for a 'sufficiently' small labor intensity $\phi_i \leq \phi^*$. In every period, each firm may be hit by a negative technology shock with probability θ, $0 < \theta < 1$. If a firm is hit by such a shock, it immediately exits the market.[6]

Second version: Firms decide between high–tech vs. low–tech technology
Uncertainty of firms with respect to their technologies is now reduced to a subinterval of the unit interval: if, after market entry, a firm decides to be a high–tech firm, it has to draw in t its labor intensity ϕ_i from an exogenous conditional distribution, which is given by $g(\phi)/G(\overline{\phi}_h)$ and has positive support over the interval $[0; \overline{\phi}_h]$. g denotes the density function for ϕ, the index h stands for 'high–tech' and $\overline{\phi}_h > 0$ ($\underline{\phi}_h = 0$)denotes the maximum (minimum) value for ϕ, which high–tech firms can draw. If, after market entry, a firm decides to be a low–tech firm, it has to draw in t its labor intensity ϕ_i from an exogenous conditional distribution, which is given by $g(\phi)/(1-G(\underline{\phi}_l))$ and has positive support over the interval $[\underline{\phi}_l; 1]$. The index l stands for 'low–tech' and $\overline{\phi}_l = 1$ ($\underline{\phi}_l < 1$)denotes the maximum (minimum) value for ϕ, which low–tech firms can draw. In order to avoid an overlap of the high–tech and the low–tech segment, $\overline{\phi}_h \leq \underline{\phi}_l$.
Since fixed per period costs exist, a high–tech (low–tech) firm starts producing in $t+1$ only if its labor intensity is equal to or smaller than a threshold value ϕ_h^* (ϕ_l^*). As high–tech workers require more sophisticated technologies than low–tech workers, $f_h > f_l$ is assumed.[7] $\phi_h^* < \phi_l^*$ follows immediately due to a relative price of labor larger than unity. In every period, each firm may be hit by a negative technology shock with probability θ, $0 < \theta < 1$. If a firm is hit by such a shock, it has to exit the market.
The dynamic entry and exit process for both versions is illustrated in figure 1.

[6] The negative shock guarantees that in every period a constant amount of fixed market entry costs arises in the steady state. This sequence of the market entry and exit decision is adopted from Hopenhayn (1992) and Melitz (2003).

[7] If f_i did not differ between technologies, all firms would choose the high–tech technology.

Figure 1: Market entry and exit of firms



2.4 Aggregation

In order to keep the model still tractable, the mass of heterogeneous firms, whose factor share parameter ϕ is within the subinterval $[\underline{\phi};\overline{\phi}]$ of the unit interval, is aggregated to a mass of average firms.[8] In the first version with a random allocation of technologies to firms $\underline{\phi} = 0$ and $\overline{\phi} = \phi^*$, i. e., both high–tech and low–tech firms are aggregated to average firms. In the second version with a conscious decision between the high–tech versus the low–tech technology, all high–tech (low–tech) firms are *separately* aggregated to average high–tech (low–tech) firms, i. e., $\underline{\phi} = 0$ and $\overline{\phi} = \phi_h^*$ ($\underline{\phi} = \underline{\phi}_l$ and $\overline{\phi} = \phi_l^*$). Aggregation proceeds in two steps. First, the production side is analyzed. It can be shown that both the disaggregated and the aggregated model lead to identical absolute factor prices and total factor income:

disaggregated model

A mass N of heterogeneous firms, whose ϕ_i is within the subinterval $[\underline{\phi};\overline{\phi}]$ of the unit interval, produces with the following per unit cost function:

$$c(\phi_i) \;=\; \left(\phi_i \cdot w^{1-\sigma} + (1-\phi_i)\cdot s^{1-\sigma}\right)^{1/(1-\sigma)}, \;\text{ with }\; \phi_i \in [\underline{\phi};\overline{\phi}],$$

while the demand for each single variety is given by $q(\phi_i) = P^\sigma \cdot Q \cdot p(\phi_i)^{-\sigma}$.

aggregated model

A mass $\widetilde{N}$ of average firms produces with the following per unit cost function:

$$c(\widetilde{\phi}) \;=\; \left(\widetilde{\phi} \cdot w^{1-\sigma} + (1-\widetilde{\phi})\cdot s^{1-\sigma}\right)^{1/(1-\sigma)}, \;\text{ with }\; \int_{\underline{\phi}}^{\overline{\phi}} \phi \cdot g(\phi) d\phi \;=\; \widetilde{\phi},$$

where g is the density function for ϕ. Each average firm's demand is given by $q(\widetilde{\phi}) = M_C/(\widetilde{N} \cdot c(\widetilde{\phi}) \cdot \sigma/(\sigma-1))$. M_C denotes total factor income which is available for consumption and equals $P \cdot Q$ in the disaggregated model.

The share parameters $\widetilde{\phi}$ and $1-\widetilde{\phi}$ will be labelled in the following as average labor intensity and average human capital intensity of the subinterval $[\underline{\phi};\overline{\phi}]$, respectively. Second, if both versions of the model lead to identical general equilibrium factor prices and total factor income, the aggregated model has to be extended by a Dixit–Stiglitz demand side. The equilibrium mass of average firms $\widetilde{N}$ on the subinterval $[\underline{\phi};\overline{\phi}]$ is determined by a free entry/exit condition of the average firm, which is derived in section 3 for the closed economy and in section 4 for the open economy.

[8] Cf. Appendix A for details on aggregation.

2.5 Labor market

In each country, there exists a continuum of workers with mass $\overline{L}$. Each household consists of one worker, workers are differentiated by their human capital endowment and are indexed by i. While each worker has an identical labor endowment of L_i, the human capital endowment S_i differs across workers. Since the human capital endowment per worker has to equal the firms' relative demand for both factors in the steady state equilibrium, the human capital endowment of a worker i, which is employed by firm i, is given by $S_i = L_i \cdot (\partial c(\phi_i)/\partial s) \big/ (\partial c(\phi_i)/\partial w)$. A firm, which is characterized by $\phi_i \to 0$ $\big(\phi_i \to 1\big)$, therefore employs workers which are characterized by $S_i \to \infty$ $\big(S_i \to 0\big)$.

For simplicity, it is assumed that ϕ is uniformly distributed over $[0; 1]$. If, in addition, it is assumed that workers adjust their human capital endowment so that they are employed in the steady state equilibrium, workers are also uniformly distributed over that range of the unit interval, which is populated by active firms. Furthermore, the aggregate labor input in each country is therefore constant and equal to $L = \overline{L}$ in the steady state equilibrium. The structure of the labor market is illustrated in figure 2.[9]

2.6 Dynamic structure

This paper endogenizes each country's long run human capital endowment by means of the Ramsey growth model. In the short run, each country's human capital endowment is fixed. Both countries' labor endowment is fixed in the short and the long run.

Let the parameter t denote any single time period. Each household has an infinite time horizon. The representative household in each country maximizes its lifetime utility

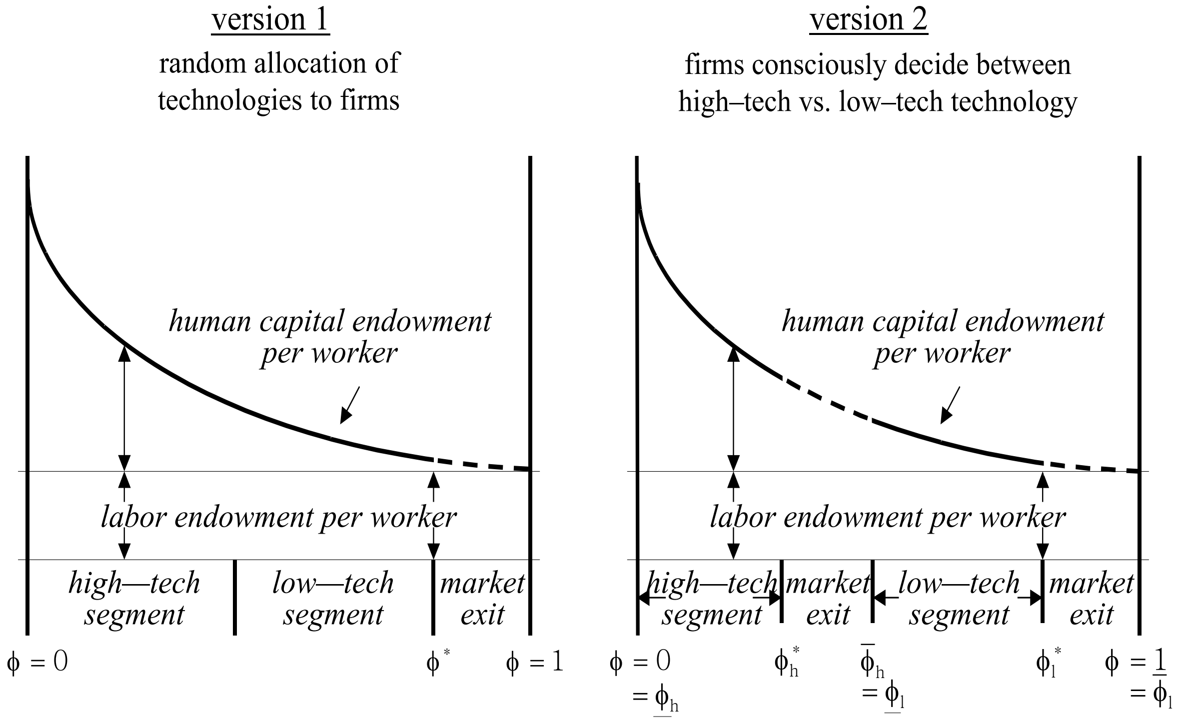
$$U \;=\; \sum_{t=0}^{\infty} \frac{1}{(1+\rho)^t} \cdot u(Q_t), \tag{4}$$

subject to the production technologies and the factor endowments in each period. The parameter ρ denotes the time discount rate and u the intratemporal utility function. Q_t denotes the aggregate consumption good for period t as described before.

The human capital endowment in both the high–tech and the low–tech market segment in period t, S_{kt}, $k = h, l$, depends on the human capital endowment in segment k in $t-1$, $S_{k(t-1)}$, investment into human capital of segment k in $t-1$, $I_{k(t-1)}$, and the

[9] Figure 2 reveals that the average labor intensity may differ between both versions since the subinterval $[\phi_h^*; \underline{\phi_l}]$ of the unit interval is not populated by firms in version 2. Furthermore, ϕ^* in version 1 equals ϕ_l^* in version 2 only if f in version 1 equals f_l in version 2.

Figure 2: Labor market



per period depreciation rate for human capital, δ: $S_{kt} = (1-\delta)\cdot S_{k(t-1)} + I_{k(t-1)}$. The average firm's good is used for investment in the human capital stock of both market segments. It follows immediately that the price per unit human capital has to be identical across both market segments. The human capital rental rate s_t is therefore written without the index k. Furthermore, the investment technology assumes that the varieties of the differentiated good are perfect substitutes. Since workers are mobile across market segments, the price per unit labor has to be identical across all segments as well. The price w_t is likewise written without the index k.

When the dual to this restricted maximization problem is formulated, the dynamic general equilibrium for the economy is defined by several zero profit and market clearing conditions. Most importantly, the zero profit condition for investment, the zero profit condition for the average good and the zero profit condition for the human capital rental activity by households, which is the Euler equation, already determine relative factor prices in the steady state:[10]

$$Z.P.C.\text{ for investment: } p(\widetilde{\phi}_t) = \frac{1}{1+\rho}\cdot p_t^S \quad\text{and}\quad p(\widetilde{\phi}_t) = p_{t+1}^S \quad (5)$$

[10]The result that w_t/s_t in the steady state is independent of the factor market equilibrium conditions is originally due to Baxter (1992), pp. 737–739, but also follows from Lau et al. (2002), pp. 595–596. Concentrating on the steady state therefore simplifies the analysis considerably.

Z.P.C. for human capital rental activity: $p_t^S = s_t + (1-\delta)\cdot p_{t+1}^S$ (6)

Z.P.C. for average/investment good: $p(\widetilde{\phi}_t) = \left(\widetilde{\phi}\cdot w_t^{1-\sigma} + (1-\widetilde{\phi})\cdot s_t^{1-\sigma}\right)^{1/(1-\sigma)}$, (7)

where $p(\widetilde{\phi}_t)$ denotes the price of the average/investment good and p_t^S and p_{t+1}^S the price per unit human capital in t and $t+1$. $\widetilde{\phi}_t$ denotes the average labor intensity over all active firms in t. Solving equations (5)–(7) for the relative price of labor in the steady state gives

$$\frac{w_t}{s_t} = \left(\frac{(\rho+\delta)^{\sigma-1} - 1 + \widetilde{\phi}_t}{\widetilde{\phi}_t}\right)^{1/(1-\sigma)}. \tag{8}$$

In order to simplify further calculations without changing the general results, the following assumption is made:

(A1): The elasticity of substitution is set equal to $\sigma = 2$.

The relative wage rate and the human capital rental rate in the steady state then simplify to

$$\frac{w_t}{s_t} = \frac{\widetilde{\phi}_t}{\rho+\delta-1+\widetilde{\phi}_t} \qquad \text{and} \qquad s_t = w_t\cdot\frac{\rho+\delta-1+\widetilde{\phi}_t}{\widetilde{\phi}_t}. \tag{9}$$

In order to guarantee that the relative price of labor is positive and, at the same time, larger than unity, two further assumptions are made:

(A2): $\rho+\delta > 1-\widetilde{\phi}_t$ and (A3): $1 > \rho+\delta$.

(A3) implies that per unit production costs decline if the human capital intensity increases.[11] As only steady states will be analyzed and the labor endowment is assumed to be constant over time, the index t can henceforth be dropped. Since the factor price ratio in the steady state only depends on the model parameters and on the average labor intensity $\widetilde{\phi}$, the factor input ratio of the average firm only depends on the model parameters and on the average labor intensity $\widetilde{\phi}$ as well. Therefore, a country's human capital stock in the steady state, S, can be derived as:

$$S = \frac{\partial c(\widetilde{\phi})/\partial s}{\partial c(\widetilde{\phi})/\partial w}\cdot\overline{L} = \frac{1-\widetilde{\phi}}{\widetilde{\phi}}\cdot\left(\frac{w}{s}\right)^{\sigma}\cdot\overline{L} = \frac{(1-\widetilde{\phi})\cdot\widetilde{\phi}\cdot\overline{L}}{(\rho+\delta-1+\widetilde{\phi})^2} \text{ since } \sigma = 2 \text{ by (A1).} \tag{10}$$

From this follows that all other aggregate variables for both countries only depend on the model parameters and on the average labor intensity $\widetilde{\phi}$. Furthermore, it can be shown that $\partial S/\partial\widetilde{\phi} < 0$ if $1 > \rho+\delta$, i. e., a positive growth effect results from an increase in the average human capital intensity $1-\widetilde{\phi}$.

[11](A3) is critical for the results of the present model: in the second version with a conscious decision of firms between the high–tech or the low–tech technology, no firm would choose the high–tech technology if $w_t/s_t < 1$ since $f_h > f_l$.

3 Closed economy

3.1 First version — random allocation of technologies to firms

The steady state equilibrium of the closed economy is identical to the one in a Ramsey growth model with given technologies. The present model therefore has to be extended by further equations which determine the average labor intensity $\widetilde{\phi}$. First, the zero profit condition defines the threshold labor intensity ϕ^*:

$$R(\phi^*) - q(\phi^*) \cdot c(\phi^*) \;=\; \frac{R(\phi^*)}{\sigma} \;=\; f \cdot c(\phi^*). \tag{11}$$

Equation (11) states that the variable per period profits of a firm with the threshold labor intensity, $R(\phi^*)/\sigma$, have to equal the per period fixed costs of this firm, $f \cdot c(\phi^*)$. Second, firms with $\phi_i < \phi^*$ are characterized by $R(\phi_i)/\sigma > f \cdot c(\phi_i)$. The resulting positive total per period profits are used to cover the per period equivalent of the one–time fixed market entry costs. However, if market entry and exit are unrestricted, the average firm's expected total per period profits have to equal the per period equivalent of the one–time fixed market entry costs. This free entry/exit condition is given by:

$$G(\phi^*) \cdot \left(\frac{R(\widetilde{\phi})}{\sigma} - f \cdot c(\widetilde{\phi}) \right) \;=\; f_M \cdot c(\widetilde{\phi}). \tag{12}$$

f_M denotes the per period equivalent of the one–time fixed market entry costs and is defined by $f_X = f_M/(\rho + \mu + \rho \cdot \mu)$, $\mu = \theta/(1-\theta)$, since the firm has an infinite lifetime as well.[12] $G(\phi^*)$ equals the probability that ϕ is equal or smaller than ϕ^* and that the firm starts producing, i. e., that variable profits and per period fixed costs occur.

Third, the aggregate production function links the equilibrium mass of average firms $\widetilde{N}$ with the production per average firm $q(\widetilde{\phi})$:

$$\widetilde{N} \cdot q(\widetilde{\phi}) \;=\; (1 - 1/\sigma) \cdot \left(\widetilde{\phi}^{\alpha} \cdot \overline{L} + (1 - \widetilde{\phi})^{\alpha} \cdot S^{\alpha} \right)^{1/\alpha} \;=\; \overline{L} \cdot \frac{(1 - 1/\sigma) \cdot \widetilde{\phi} \cdot (\rho + \delta)^2}{(\rho + \delta - 1 + \widetilde{\phi})^2}, \tag{13}$$

where the fraction $1/\sigma$ of aggregate production is used to produce fixed costs.

Equations (11)–(13) determine the equilibrium values for $q(\widetilde{\phi})$, ϕ^* and $\widetilde{N}$ in autarky. However, both the zero profit condition and the free entry/exit condition can be simplified: the relationship between the amount produced by the marginal firm, $q(\phi^*)$,

[12] The negative shock, which occurs with probability θ, forces the firm to exit the market immediately. Therefore, the firm reaches period T with probability $(1-\theta)^{T-1}$. The discounted value of the per period equivalent of the fixed market entry costs in period t, $1/(1+\rho)^t \cdot f_M$, accordingly only occurs with probability $(1-\theta)^t$. Defining $\mu = \theta/(1-\theta)$ gives $f_X = f_M/(\rho+\mu+\rho\cdot\mu)$ from the formula of an infinite geometric series. f_M obviously increases with the probability of a negative shock.

and the amount produced by the average firm, $q(\widetilde{\phi})$, is given by:

$$\frac{q(\phi^*)}{q(\widetilde{\phi})} \;=\; \frac{p(\phi^*)^{-\sigma}\cdot P^{\sigma-1}\cdot M_C}{p(\widetilde{\phi})^{-\sigma}\cdot P^{\sigma-1}\cdot M_C} \;=\; \left(\frac{p(\widetilde{\phi})}{p(\phi^*)}\right)^2 \quad \text{due to } \sigma = 2 \text{ by (A1).} \qquad (14)$$

Inserting the respective equilibrium prices gives:[13]

$$\frac{q(\phi^*)}{q(\widetilde{\phi})} \;=\; \left(\frac{w\cdot(\rho+\delta-1+\widetilde{\phi})/(\widetilde{\phi}\cdot(\rho+\delta))}{w\cdot(\rho+\delta-1+\widetilde{\phi})/(2\cdot\widetilde{\phi}\cdot(\rho+\delta)-\widetilde{\phi})}\right)^2 \;=\; \left(\frac{2\cdot(\rho+\delta)-1}{\rho+\delta}\right)^2. \qquad (15)$$

Substituting $R(\phi^*) = \sigma/(\sigma-1)\cdot c(\phi^*)\cdot q(\phi^*)$ into equation (11) and considering equation (15) and $\sigma = 2$ from (A1) gives the following simplified zero profit condition:

$$q(\widetilde{\phi})\cdot\left(\frac{2\cdot(\rho+\delta)-1}{\rho+\delta}\right)^2 \;=\; f. \qquad (16)$$

Furthermore, considering $G(\phi^*) = \phi^* = 2\cdot\widetilde{\phi}$ due to the uniform distribution of ϕ and inserting $R(\widetilde{\phi}) = \sigma/(\sigma-1)\cdot c(\widetilde{\phi})\cdot q(\widetilde{\phi})$ and $\sigma = 2$ into equation (12) gives the following simplified free entry/exit condition:

$$q(\widetilde{\phi}) - f \;=\; \frac{f_M}{2\cdot\widetilde{\phi}}\;. \qquad (17)$$

The autarky equilibrium is alternatively described by equations (13), (16) and (17).

3.2 Second version — firms decide between high–tech vs. low–tech technology

The number of equations doubles in comparison to the first version since both versions of the model only differ with respect to the degree of aggregation: in the second version, the mass of heterogeneous firms is aggregated to a mass $\widetilde{N}_h$ of average high–tech firms and a mass $\widetilde{N}_l$ of average low–tech firms. Furthermore, since $f_h > f_l$ and $\partial R/\partial\phi < 0$ due to $w/s > 1$, the following zero profit conditions lead to $\phi_h^* < \phi_l^*$ for the threshold values of the labor intensity:

$$R(\phi_k^*) - q(\phi_k^*)\cdot c(\phi_k^*) \;=\; \frac{R(\phi_k^*)}{\sigma} \;=\; f_k\cdot c(\phi_k^*), \quad k \;=\; h,\, l. \qquad (18)$$

[13] The prices $p(\widetilde{\phi})$ and $p(\phi^*)$ in the steady state result from substituting s as defined by equation (9) into the cost function (2) and from $\phi^* = 2\cdot\widetilde{\phi}$ since ϕ is assumed to be uniformly distributed over $[0;1]$. The expression for $p(\phi^*)$ shows that an additional restriction for $\rho+\delta$ has to be fulfilled if $p(\phi^*) > 0$. The price $p(\phi^*)$ is positive if $\rho+\delta > 0.5$. In general, it can be shown that the price $p(\phi_i)$, with $\phi_i = \lambda\cdot\widetilde{\phi}$, is positive if $\rho+\delta > (\lambda-1)/\lambda$.

Since firms consciously decide whether to enter the high–tech or the low–tech segment, the free entry/exit condition is formulated for both market segments separately:

$$\frac{G(\phi_k^*) - G(\underline{\phi}_k)}{G(\overline{\phi}_k) - G(\underline{\phi}_k)} \cdot \left(\frac{R(\widetilde{\phi}_k)}{\sigma} - f_k \cdot c(\widetilde{\phi}_k) \right) \;=\; f_M \cdot c(\widetilde{\phi}_k), \quad k = h,\, l. \tag{19}$$

$(G(\phi_k^*) - G(\underline{\phi}_k))/(G(\overline{\phi}_k) - G(\underline{\phi}_k))$ stands for the conditional probability that ϕ falls below ϕ_k^*, given that the firm entered segment k, and $\underline{\phi}_k$ ($\overline{\phi}_k$) stands for the lower (upper) bound of ϕ in segment k, $k = h, l$. The relationship between the equilibrium mass of average high–tech (low–tech) firms, $\widetilde{N}_h$ ($\widetilde{N}_l$), and the production per average high–tech (low–tech) firm, $q(\widetilde{\phi}_h)$ $\left(q(\widetilde{\phi}_l)\right)$, is given by the aggregate production functions:[14]

$$\widetilde{N}_k \cdot q(\widetilde{\phi}_k) \;=\; \overline{L}_k \cdot \frac{(1 - 1/\sigma) \cdot \widetilde{\phi}_k \cdot (\rho + \delta)^2}{(\rho + \delta - 1 + \widetilde{\phi}_k)^2}, \;\; k \;=\; h,\, l. \tag{20}$$

Equations (18)–(20) determine the equilibrium values for $q(\widetilde{\phi}_k)$, ϕ_k^* and $\widetilde{N}_k$ for segment k, $k = h,\, l$, in autarky. Equations (18) and (19) can again be simplified to:

$$q(\widetilde{\phi}_k) \cdot \left(\frac{2 \cdot (\rho + \delta) - 1}{\rho + \delta} \right)^2 \;=\; f_k, \quad k \;=\; h,\, l \tag{21}$$

$$q(\widetilde{\phi}_k) - f_k \;=\; \frac{f_M}{\phi_k^* - \underline{\phi}_k} \cdot (\overline{\phi}_k - \underline{\phi}_k), \quad k \;=\; h,\, l. \tag{22}$$

4 Open economy

Since both countries are symmetric, only the home country H will be analyzed in detail. Country H can trade the differentiated good with the foreign country F. International trade leads to two types of extra costs. First, iceberg transport costs $\tau \geq 1$ may exist. Second, exporters have to pay additional fixed per period costs $f_{Ex} \cdot c(\phi_i)$ for serving the foreign market. If $\tau > 1$ and/or $f_{Ex} > f$, not all active firms find it profitable to export. Since $w/s > 1$, firms will export only if their labor intensity does not exceed a second and lower threshold value ϕ_{Ex}^*. It is assumed that τ and f_{Ex} are such that

[14] The steady state division of a country's total labor endowment between both segments is fixed, i. e., $\overline{L}_h$ and $\overline{L}_l$ are constant across steady states: first, the sector–specific human capital stocks can be derived the same way as the country–wide human capital stock in equation (10), i. e., $S_k = (\partial c(\widetilde{\phi}_k)/\partial s)/(\partial c(\widetilde{\phi}_k)/\partial w) \cdot \overline{L}_k$, $k = h,\, l$. Second, substituting S_k and $\overline{L}_k$, $k = h,\, l$, into the average production function of either segment, equation (1) with $\widetilde{\phi}_h$ or $\widetilde{\phi}_l$, respectively, gives the steady state supply of either segment. It can be shown that the ratio of steady state supply to the marshallian demand is always equal to unity for both segments and independent of $\overline{L}_k$ and ϕ_k, $k = h,\, l$.

$\phi_h^* = \phi_{Ex}^* < \underline{\phi}_l$, i. e., all high–tech firms export but no low–tech firm exports.[15]
Due to Dixit–Stiglitz monopolistic competition, the exporting firms produce more in the open economy. Since resources are fixed in the short–run, exposure to trade therefore increases the competition for scarce resources and leads to a firm selection process. However, since firms are heterogeneous, they react differently to the increased competition for scarce resources and the composition of the average established firm changes with exposure to trade. The selection process with exposure to trade accordingly has to be split up into a first and a second selection process if firms are heterogeneous since the inactive firms *first* observe how exposure to trade influences the average established firm and *afterwards* decide whether to enter the market or not.
The first selection process analyzes, how the increased competition for scarce resources influences the established firms, i. e., how the increased competition for scarce resources changes the composition of the average established firm. The first selection process with exposure to trade is obviously identical for both versions of the model since the first selection process starts from an equilibrium allocation of technologies to firms in the closed economy.
The second selection process differs between both versions of the model. In the first version, the second selection process refers to the whole market, while it refers to the high–tech (low–tech) segment separately in the second version. The second selection process results from the following entry decision of the inactive firms: the mass of new entrants will be larger (smaller) than the mass of shock–induced firm exits if the average established firm would otherwise realize positive (negative) lifetime profits after the first selection process. The resulting increase (decrease) in competition leads to a further firm selection (market entry).
In order to avoid the inclusion of a discount factor into the free entry/exit condition in the open economy, it is assumed that both the first and the second selection process are completed within a single time period. The first selection process is described in subsection 4.1. The second selection process is described in subsection 4.2.

[15]The assumption $\phi_h^* = \phi_{Ex}^*$ is important for the second version of the model, in which firms can decide between the high–tech vs. the low–tech technology. The discussion in subsection 4.2.1 reveals that the second version would lead to identical qualitative results if $\phi_h^*/2 < \phi_{Ex}^* \leq \phi_h^*$, i. e., if at least more than 50% of the high–tech firms export in the open economy. However, the empirical evidence in section 5 shows that reality supports the idea that the cost parameters are such that $\phi_h^* \approx \phi_{Ex}^*$.

4.1 First selection process with exposure to trade

Opening the country up to international markets is equivalent to an increase in the fixed costs of the high–tech exporting firms. The high–tech firms also face an additional demand from abroad. However, if each high–tech firm produces a larger amount than in autarky, some firms have to exit the market due to fixed resources in the short run: if the high–tech firms produce more in the open economy, both absolute factor prices and the relative price of human capital increase with exposure to trade. While the resulting increase in total factor income ceteris paribus benefits all active firms, the increase in the relative price of human capital hurts the high–tech firms. More specifically, it can be shown that the unique equilibrium on goods and factor markets can be regained only if the mass of the high–tech firms decreases such that their total production finally remains constant.[16]

The remaining high–tech exporting firms unambiguously gain with the first selection process since the decision to export results from profit maximizing behavior. The established low–tech non–exporting firms remain unaffected by the first selection process since the price index P does not change with the first selection process.

However, it is a priori ambiguous whether the average over *all* established firms, i. e., the average over the remaining high–tech firms and the established low–tech firms, gains or loses with the first selection process: the first selection process ceteris paribus benefits the average established firm since the average over the remaining high–tech firms gains from serving the foreign market. However, the first selection process ceteris paribus harms the average established firm since the average human capital intensity for serving the domestic market decreases — the domestic supply of each single high–tech firm remains constant, but their mass decreases with the first selection process.

[16]Due to symmetry across countries, total demand for an average high–tech exporting firm's good rises with exposure to trade from $q(\widetilde{\phi}_h) = M_C \cdot P^{\sigma-1} \cdot \big(p(\widetilde{\phi}_h)\big)^{-\sigma}$ to $q(\widetilde{\phi}_h) = M_C \cdot P^{\sigma-1} \cdot \big(p(\widetilde{\phi}_h)\big)^{-\sigma} \cdot \big(1+\tau^{1-\sigma}\big)$, where M_C stands for the disposable factor income. The price index P therefore rises from

$$\begin{aligned} P &= \Big(\widetilde{N}_l \cdot \big(p(\widetilde{\phi}_l)\big)^{1-\sigma} + \widetilde{N}_h \cdot \big(p(\widetilde{\phi}_h)\big)^{1-\sigma}\Big)^{1/(1-\sigma)} \quad \text{to} \\ P &= \Big(\widetilde{N}_l \cdot \big(p(\widetilde{\phi}_l)\big)^{1-\sigma} + \widetilde{N}_h \cdot \big(1+\tau^{1-\sigma}\big) \cdot \big(p(\widetilde{\phi}_h)\big)^{1-\sigma}\Big)^{1/(1-\sigma)} \quad \text{with exposure to trade.} \end{aligned}$$

The price index P accordingly does not change if $\widetilde{N}_h$ decreases by the factor $1/\big(1+\tau^{1-\sigma}\big)$ with exposure to trade. Factor market equilibrium conditions hold again at initial absolute factor prices and the new *unique* equilibrium on goods and factor markets results. Only the free entry/exit condition is not necessarily fulfilled after the first selection process. Note that this first selection process against the high–tech exporting firms is supported by reality: Pavcnik (2002), pp. 256–257, reports that the *short run* firm selection with exposure to trade mainly hurts the exporting firms.

4.2 Second selection process with exposure to trade

The second selection process with exposure to trade differs between both versions of the model:

In the first version with a random allocation of technologies to firms, all active firms, i. e., both the remaining high–tech firms and the established low–tech firms, are aggregated to average firms. The second selection process therefore refers to the whole market in the first version. Furthermore, the second selection process can be derived only if it is previously determined under which conditions a single average firm gains or loses with the first selection process.

In the second version, in which firms choose between the high–tech versus the low–tech technology, the high–tech and the low–tech firms are separately aggregated to average high–tech and average low–tech firms, respectively. The second selection process therefore refers to both market segments separately in the second version. It will be shown that the incentives for a market entry into either of both market segments follow immediately after the first selection process.

The properties of the second selection process follow from the equilibrium in the open economy. Therefore, the equilibrium in the open economy for the first version is described in subsection 4.2.1. The equilibrium in the open economy for the second version is described in subsection 4.2.2.

4.2.1 First version — random allocation of technologies to firms

The additional threshold value ϕ^*_{ExH} determines whether an active home firm, which already serves the domestic market, also exports. First of all, the zero profit condition for exports therefore adds to the zero profit condition for production:[17]

$$\text{zero profit condition for production:} \quad \frac{R_H(\phi^*_H)}{\sigma} = f \cdot c(\phi^*_H), \tag{23}$$

$$\text{zero profit condition for exports:} \quad \frac{R_F(\phi^*_{ExH})}{\sigma} = f_{Ex} \cdot c(\phi^*_{ExH}). \tag{24}$$

Equation (24) states that the variable per period export profits of a firm with the threshold labor intensity ϕ^*_{ExH} have to equal that firm's fixed per period costs for serving the foreign market. Dividing both zero profit conditions by each other gives

$$\frac{R_H(\phi^*_H)}{R_F(\phi^*_{ExH})} = \frac{M_{CH} \cdot P_H^{\sigma-1} \cdot p(\phi^*_H)^{1-\sigma}}{M_{CF} \cdot P_F^{\sigma-1} \cdot \tau^{1-\sigma} \cdot p(\phi^*_{ExH})^{1-\sigma}} = \frac{f \cdot c(\phi^*_H)}{f_{Ex} \cdot c(\phi^*_{ExH})}, \tag{25}$$

[17]The subscript H denotes variables of home firms and the subscript F denotes foreign activities of home firms and foreign variables.

$$\text{which is equal to} \quad \left(\frac{p(\phi^*_{ExH})}{p(\phi^*_H)}\right)^{-\sigma} \quad = \quad \tau^{\sigma-1} \cdot \frac{f_{Ex}}{f} \tag{26}$$

since countries are symmetric and $p(\phi) \cdot (1 - 1/\sigma) = c(\phi)$. The ratio of the prices of both marginal firms, $p(\phi^*_{ExH})/p(\phi^*_H)$, can be derived as

$$\frac{p(\phi^*_{ExH})}{p(\phi^*_H)} = \frac{\left(\phi^*_{ExH} \cdot w^{1-\sigma} + (1-\phi^*_{ExH}) \cdot s^{1-\sigma}\right)^{\frac{1}{1-\sigma}}}{\left(\phi^*_H \cdot w^{1-\sigma} + (1-\phi^*_H) \cdot s^{1-\sigma}\right)^{\frac{1}{1-\sigma}}} = \frac{\phi^*_H + (1-\phi^*_H) \cdot \frac{\widetilde{\phi}_H}{\rho+\delta-1+\widetilde{\phi}_H}}{\phi^*_{ExH} + (1-\phi^*_{ExH}) \cdot \frac{\widetilde{\phi}_H}{\rho+\delta-1+\widetilde{\phi}_H}}, \tag{27}$$

where the second equality follows from the steady state value of w/s as derived in subsection 2.6 and from $\sigma = 2$ by (A1). Further simplification results in

$$\frac{p(\phi^*_{ExH})}{p(\phi^*_H)} = \frac{\phi^*_H \cdot (\rho+\delta) - \phi^*_H + \widetilde{\phi}_H}{\phi^*_{ExH} \cdot (\rho+\delta) - \phi^*_{ExH} + \widetilde{\phi}_H} = \frac{\rho+\delta-0.5}{\phi^*_{ExH}/\phi^*_H \cdot (\rho+\delta-1) + 0.5}, \tag{28}$$

where the second equality uses $\phi^*_H = 2 \cdot \widetilde{\phi}_H$ due to the uniform distribution of ϕ. Equation (28) can be substituted into equation (26), which can be solved for the ratio ϕ^*_{ExH}/ϕ^*_H, which equals the probability that the average active firm exports:

$$\frac{\phi^*_{ExH}}{\phi^*_H} \quad = \quad \frac{(\rho+\delta-0.5) \cdot \tau^{0.5} \cdot (f_{Ex}/f)^{0.5} - 0.5}{\rho+\delta-1}. \tag{29}$$

The zero profit condition for exports will henceforth be dropped and equation (29) will be taken instead. Most importantly, equation (29) shows that the ratio ϕ^*_{ExH}/ϕ^*_H does not depend on the equilibrium $\widetilde{\phi}_H$. Furthermore, $\phi^*_{ExH}/\phi^*_H < 1$, i. e., $\tau > f/f_{Ex}$ leads to partitioning of firms with respect to the export status.

Since ϕ is uniformly distributed over the interval $[0; 1]$ and since ϕ^*_{ExH}/ϕ^*_H does not depend on $\widetilde{\phi}_H$, the share of high–tech firms in autarky results as $\widetilde{N}_{hH}/(\widetilde{N}_{hH} + \widetilde{N}_{lH}) = \phi^*_{ExH}/\phi^*_H$ for any given $\widetilde{\phi}_H$. The corresponding share of low–tech firms in autarky results as $\widetilde{N}_{lH}/(\widetilde{N}_{hH} + \widetilde{N}_{lH}) = 1 - \phi^*_{ExH}/\phi^*_H$. Since the mass of high–tech exporting firms decreases by the factor $1/(1+\tau^{1-\sigma})$ with the first selection process with exposure to trade, the share of high–tech firms in the open economy results as $\widetilde{N}_{hH}/(1+\tau^{1-\sigma})\Big/\Big(\widetilde{N}_{hH}/(1+\tau^{1-\sigma}) + \widetilde{N}_{lH}\Big)$ for the same $\widetilde{\phi}_H$ as in autarky. The corresponding share of low–tech firms in the open economy results as $\widetilde{N}_{lH}\Big/\Big(\widetilde{N}_{hH}/(1+\tau^{1-\sigma}) + \widetilde{N}_{lH}\Big)$.

Second, the free entry/exit condition has to be extended by the expected variable export profits and the expected fixed export costs. If variable per period profits, fixed per period costs and fixed market entry costs are displayed separately for high–tech and low–tech firms, the free entry/exit condition in the open economy results as follows:

$$
\begin{aligned}
&G(\phi_H^*)\cdot\left(\frac{R_H(\widetilde{\phi}_{hH})+R_H(\widetilde{\phi}_{hH})\cdot\tau^{1-\sigma}}{\sigma}\cdot\frac{\widetilde{N}_{hH}/(1+\tau^{1-\sigma})}{\frac{\widetilde{N}_{hH}}{1+\tau^{1-\sigma}}+\widetilde{N}_{lH}}+\frac{R_H(\widetilde{\phi}_{lH})}{\sigma}\cdot\frac{\widetilde{N}_{lH}}{\frac{\widetilde{N}_{hH}}{1+\tau^{1-\sigma}}+\widetilde{N}_{lH}}\right)\\
&\quad-\ G(\phi_H^*)\cdot(f+f_{Ex})\cdot c(\widetilde{\phi}_{hH})\cdot\frac{\widetilde{N}_{hH}/(1+\tau^{1-\sigma})}{\frac{\widetilde{N}_{hH}}{1+\tau^{1-\sigma}}+\widetilde{N}_{lH}}-G(\phi_H^*)\cdot f\cdot c(\widetilde{\phi}_{lH})\cdot\frac{\widetilde{N}_{lH}}{\frac{\widetilde{N}_{hH}}{1+\tau^{1-\sigma}}+\widetilde{N}_{lH}}\\
&\quad=f_M\cdot\left(c(\widetilde{\phi}_{hH})\cdot\frac{\widetilde{N}_{hH}/(1+\tau^{1-\sigma})}{\frac{\widetilde{N}_{hH}}{1+\tau^{1-\sigma}}+\widetilde{N}_{lH}}+c(\widetilde{\phi}_{lH})\cdot\frac{\widetilde{N}_{lH}}{\frac{\widetilde{N}_{hH}}{1+\tau^{1-\sigma}}+\widetilde{N}_{lH}}\right). \qquad (30)
\end{aligned}
$$

$\widetilde{\phi}_{kH}$, $k=h,l$, stands for the average labor intensity of the domestic high–tech and low–tech firms and $\widetilde{N}_{kH}$, $k=h,l$, stands for the mass of average domestic high–tech and low–tech firms, respectively. $R_H(\widetilde{\phi}_{hH})\cdot\tau^{1-\sigma}=R_F(\widetilde{\phi}_{hH})$ denotes revenues of an average domestic high–tech firm from serving the foreign market due to symmetry across countries. The weighting factors $\widetilde{N}_{hH}/(1+\tau^{1-\sigma})\Big/(\widetilde{N}_{hH}/(1+\tau^{1-\sigma})+\widetilde{N}_{lH})$ and $\widetilde{N}_{lH}\Big/(\widetilde{N}_{hH}/(1+\tau^{1-\sigma})+\widetilde{N}_{lH})$ denote the relative importance of average domestic high–tech and low–tech firms in the open economy, respectively, for a given $\widetilde{\phi}_H$.
Finally, the aggregate production function specifies the relationship between the equilibrium mass of average home firms $\widetilde{N}_H$ and the amount produced by a single average home firm. $\widetilde{N}_H$ stands for the average over both exporting and non–exporting firms:

$$
\begin{aligned}
&\widetilde{N}_H\cdot\left(\left(q_{HH}(\widetilde{\phi}_{hH})+q_{HH}(\widetilde{\phi}_{hH})\cdot\tau^{1-\sigma}\right)\cdot\frac{\widetilde{N}_{hH}/(1+\tau^{1-\sigma})}{\frac{\widetilde{N}_{hH}}{1+\tau^{1-\sigma}}+\widetilde{N}_{lH}}+q_{HH}(\widetilde{\phi}_{lH})\cdot\frac{\widetilde{N}_{lH}}{\frac{\widetilde{N}_{hH}}{1+\tau^{1-\sigma}}+\widetilde{N}_{lH}}\right)\\
&\quad=\ \overline{L}_H\cdot\frac{(1-1/\sigma)\cdot\widetilde{\phi}_H\cdot(\rho+\delta)^2}{(\rho+\delta-1+\widetilde{\phi}_H)^2}. \qquad (31)
\end{aligned}
$$

$q_{HH}(\phi_{iH})$ denotes domestic supply of a home firm with labor intensity ϕ_{iH} and $q_{HH}(\phi_{iH})\cdot\tau^{1-\sigma}$ denotes exports of the same firm due to symmetry across countries.
Equations (23), (30) and (31) can be further simplified: first, since the relationship between $q_{HH}(\phi_H^*)/q_{HH}(\widetilde{\phi}_H)$ is still given by equation (15), the zero profit condition for production can be simplified to:

$$
q_{HH}(\widetilde{\phi}_H)\cdot\left(\frac{2\cdot(\rho+\delta)-1}{\rho+\delta}\right)^2 \ = \ f. \qquad (32)
$$

Second, due to the assumption of a uniform distribution of ϕ, the free entry/exit condition can be simplified to:[18]

$$
q_{HH}(\widetilde{\phi}_H)-f-\frac{\phi_{ExH}^*}{\phi_H^*}\cdot\frac{c(\widetilde{\phi}_{hH})}{c(\widetilde{\phi}_H)}\cdot\left(\frac{-\tau^{1-\sigma}}{1+\tau^{1-\sigma}}\cdot\left(\frac{f_M}{2\cdot\widetilde{\phi}_H}+f\right)+\frac{f_{Ex}}{1+\tau^{1-\sigma}}\right) \ = \ \frac{f_M}{2\cdot\widetilde{\phi}_H}. \qquad (33)
$$

[18]Cf. Appendix B for the equivalence between equations (30) and (33).

Third, $q_{HH}(\widetilde{\phi}_H) = q_{HH}(\widetilde{\phi}_{hH}) \cdot \widetilde{N}_{hH}/(\widetilde{N}_{hH}+\widetilde{N}_{lH}) + q_{HH}(\widetilde{\phi}_{lH}) \cdot \widetilde{N}_{lH}/(\widetilde{N}_{hH}+\widetilde{N}_{lH})$ due to the aggregation procedure described in Appendix A. Therefore, the aggregate production function can be simplified to:

$$\widetilde{N}_H \cdot q_{HH}(\widetilde{\phi}_H) \cdot \frac{\widetilde{N}_{hH} + \widetilde{N}_{lH}}{\widetilde{N}_{hH}/(1+\tau^{1-\sigma}) + \widetilde{N}_{lH}} \quad = \quad \overline{L}_H \cdot \frac{(1-1/\sigma) \cdot \widetilde{\phi}_H \cdot (\rho+\delta)^2}{(\rho+\delta-1+\widetilde{\phi}_H)^2}. \qquad (34)$$

The equilibrium in the open economy is therefore alternatively described by equations (29), (32), (33) and (34).

How does the second selection process, which leads to these equilibrium conditions, look like? First of all, the zero profit condition for production, equation (32), shows that the domestic supply of the average firm does not change with exposure to trade. Second, the aggregate production function, equation (34), shows that, for a given $\widetilde{\phi}_H$, the mass of average domestic firms decreases with exposure to trade since the ratio on the left hand side of equation (34) exceeds unity. Third, the free entry/exit condition, equation (33), reveals that the expected per period profits change with exposure to trade due to an additional term in the open economy: $\phi^*_{ExH}/\phi^*_H \cdot c(\widetilde{\phi}_{hH})/c(\widetilde{\phi}_H) \cdot \Big(-\tau^{1-\sigma} \cdot \big(f_M/(2\cdot\widetilde{\phi}_H) + f\big) + f_{Ex}\Big)\Big/(1+\tau^{1-\sigma})$. The average established firm gains (loses) with the first selection process if this additional term is negative (positive).[19]

If the average established firm gains with the first selection process, the free entry/exit condition, equation (33), implies that the mass of new entrants exceeds the mass of shock–induced firm exits. The mass of active average firms $\widetilde{N}_H$ accordingly increases. The zero profit condition of the marginal firm can now be used to determine how this increase in $\widetilde{N}_H$ influences the threshold labor intensity ϕ^*_H. From equations (15) and (32) and from $\sigma = 2$, the zero profit condition of the marginal firm follows as $q_{HH}(\phi^*_H) = M_{CH}/\big(\widetilde{N}_H \cdot p(\phi^*_H)\big) = f$. This condition shows that an increase in $\widetilde{N}_H$ leads to a decrease in ϕ^*_H: a decrease in ϕ^*_H reduces $p(\phi^*_H)$, which offsets the increase in $\widetilde{N}_H$. Therefore, due to more competition with the increase in $\widetilde{N}_H$, only firms with a labor intensity strictly below the initial ϕ^*_H successfully enter the market. The decrease in $\phi^*_H = 2\cdot\widetilde{\phi}_H$ equalizes both sides of the free entry/exit condition again. The average human capital intensity $1-\phi^*_H$ therefore increases, i. e., a positive growth effect results during the second selection process if the average established firm gains with the first selection process.

However, if the average established firm loses with the first selection process, the previ-

[19]Note that this additional term does not depend on the equilibrium $\widetilde{\phi}_H$: equation (29) shows that ϕ^*_{ExH}/ϕ^*_H does not depend on $\widetilde{\phi}_H$; equations (28) and (29) show that $c(\widetilde{\phi}_{hH})/c(\widetilde{\phi}_H)$ does not depend on $\widetilde{\phi}_H$; equations (16) and (17) finally show that $f_M/2\cdot\widetilde{\phi}_H + f = f\cdot(\rho+\delta)^2/(2\cdot(\rho+\delta)-1)^2$.

ous line of argument turns around, i. e., the average human capital intensity decreases during the second selection process. Therefore, a negative growth effect results if the average established firm loses with the first selection process.
Inserting $f_M/(2 \cdot \widetilde{\phi}) + f = f \cdot (\rho+\delta)^2/(2\cdot(\rho+\delta)-1)^2$ from equations (16) and (17) into the additional term of the free entry/exit condition in the open economy, equation (33), leads to the following assessment of exposure to trade:

$$\begin{aligned}\text{positive growth effect:} \qquad \tau &< \frac{(\rho+\delta)^2}{(2\cdot(\rho+\delta)-1)^2}\cdot\frac{f}{f_{Ex}}\\ \text{no growth effect:} \qquad \tau &= \frac{(\rho+\delta)^2}{(2\cdot(\rho+\delta)-1)^2}\cdot\frac{f}{f_{Ex}}\\ \text{negative growth effect:} \qquad \tau &> \frac{(\rho+\delta)^2}{(2\cdot(\rho+\delta)-1)^2}\cdot\frac{f}{f_{Ex}}.\end{aligned}$$

These conditions can be divided by f/f_{Ex}. If the resulting conditions for $\tau \cdot f_{Ex}/f$ are substituted into equation (29), the growth effect of exposure to trade can alternatively be expressed in terms of the share of exporting firms:

$$\begin{aligned}\text{positive growth effect:} \quad \frac{\phi^*_{ExH}}{\phi^*_H} > 0.5, \text{ i. e., share of exporting firms} &> 50\%\\ \text{no growth effect:} \quad \frac{\phi^*_{ExH}}{\phi^*_H} = 0.5, \text{ i. e., share of exporting firms} &= 50\%\\ \text{negative growth effect:} \quad \frac{\phi^*_{ExH}}{\phi^*_H} < 0.5, \text{ i. e., share of exporting firms} &< 50\%.\end{aligned}$$

Chart a) of figure 3 visualizes the results for the first version. The countries suffer a negative growth effect with exposure to trade if τ and/or f_{Ex} exceed a threshold value.

4.2.2 Second version — firms decide between high–tech vs. low–tech technology

Since the low–tech non–exporting firms are unaffected by the first selection process, only the equations for the high–tech exporting firms are analyzed in this subsection.
The equilibrium in the low–tech segment is still described by equations (20)–(22). The equilibrium conditions for the high–tech segment in the open economy follow from equations (23), (24), (30) and (31) with $\widetilde{N}_{lH} = 0$ and a probability for exports equal to unity since each high–tech firm exports in the open economy. Those simplifications which generated equations (32)–(34) in the previous subsection finally lead to the following equilibrium conditions for the high–tech segment in the open economy:

$$q_{HH}(\widetilde{\phi}_{hH}) \cdot \left(\frac{2 \cdot (\rho+\delta) - 1}{\rho+\delta}\right)^2 = f_h \tag{35}$$

$$q_{HH}(\widetilde{\phi}_{hH}) - f - \left(f_{Ex} - q_{HH}(\widetilde{\phi}_{hH}) \cdot \tau^{1-\sigma}\right) = \frac{f_M}{2 \cdot \widetilde{\phi}_{hH}} \cdot (\overline{\phi}_{hH} - \underbrace{\underline{\phi}_{hH}}_{=0}) \tag{36}$$

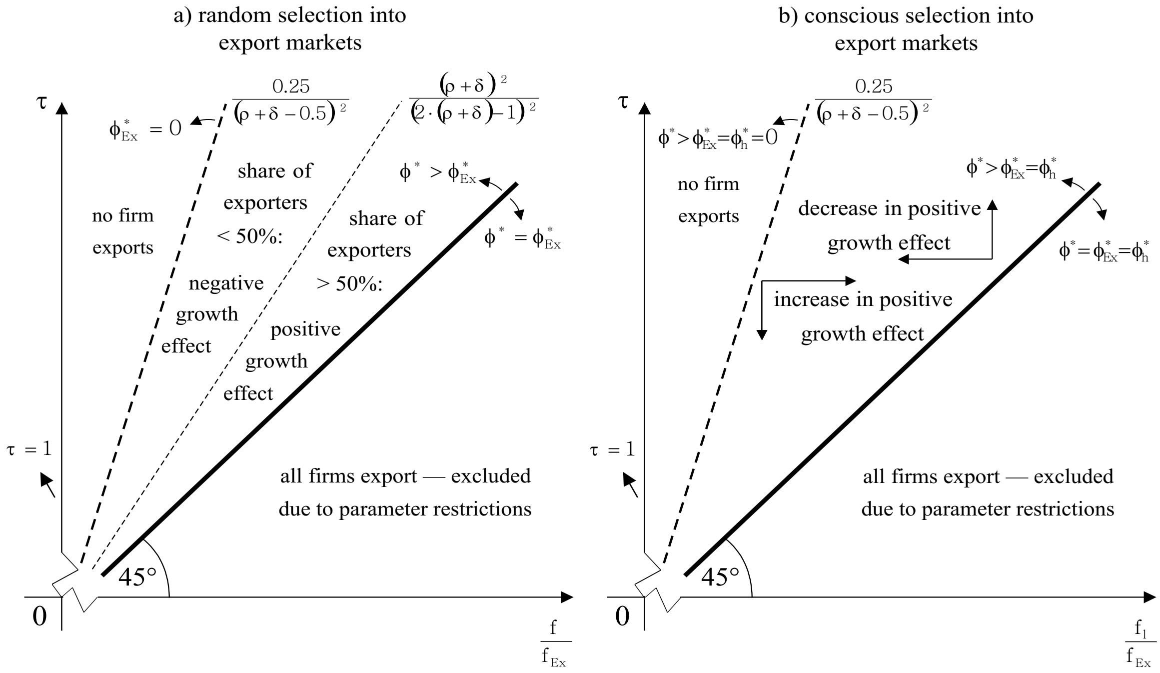
$$\widetilde{N}_{hH} \cdot q_{HH}(\widetilde{\phi}_{hH}) \cdot (1 + \tau^{1-\sigma}) = \overline{L}_{hH} \cdot \frac{(1 - 1/\sigma) \cdot \widetilde{\phi}_{hH} \cdot (\rho+\delta)^2}{(\rho+\delta-1+\widetilde{\phi}_{hH})^2}. \tag{37}$$

Comparing the free entry/exit conditions for autarky and free trade, equations (22) and (36), respectively, reveals that the expected per period profits for the high–tech segment increase with the first selection process: the additional term with free trade, $f_{Ex} - q_{HH}(\widetilde{\phi}_{hH}) \cdot \tau^{1-\sigma}$, is negative due to equation (24): using $R(\phi^*_{ExH}) = p(\phi^*_{ExH}) \cdot q(\phi^*_{ExH}) = \sigma/(\sigma-1) \cdot c(\phi^*_{ExH}) \cdot q(\phi^*_{ExH})$, $\sigma = 2$ from (A1) and $q_{HF}(\phi) = q_{HH}(\phi) \cdot \tau^{1-\sigma}$, equation (24) can be transformed to $q_{HH}(\phi^*_{ExH}) \cdot \tau^{1-\sigma} = f_{Ex}$. Furthermore, $\widetilde{\phi}_{hH} = \phi^*_{hH}/2$, $\phi^*_{hH} = \phi^*_{ExH}$ and $w/s > 1$ finally lead to $q_{HH}(\widetilde{\phi}_{hH}) \cdot \tau^{1-\sigma} > f_{Ex}$. The mass of new entrants into the high–tech segment is accordingly larger than the mass of shock–induced exits from the high–tech segment. The mass of active average high–tech firms $\widetilde{N}_{hH}$ accordingly increases. Completely analogous to the discussion of the second selection process in subsection 4.2.1, the resulting increase in competition within the high–tech segment implies that firms can successfully enter the high–tech segment only if their labor intensity is strictly below the initial threshold value ϕ^*_{hH}. The decrease in $\phi^*_{hH} = 2 \cdot \widetilde{\phi}_{hH}$ equalizes both sides of the free entry/exit condition of the high–tech segment again. Exposure to trade therefore unambiguously increases the average human capital intensity within the high–tech segment, $1 - \widetilde{\phi}_{hH}$. The countrywide average human capital intensity therefore increases as well. According to this analysis, exposure to trade always leads to a positive growth effect in the second version of the model with a conscious selection into export markets.[20]

Chart b) of figure 3 visualizes the results for the second version of the model. The positive growth effect of exposure to trade increases (decreases) in the south–east (north–west) direction: equation (24), which can be transformed to $q(\phi^*_{ExH}) \cdot \tau^{1-\sigma} = f_{Ex}$, shows that ϕ^*_{ExH} increases (decreases) with a fall (rise) in τ or f_{Ex}. An increase (decrease) in ϕ^*_{ExH} augments (reduces) the weight of the high–tech segment in the country.

[20] The results in the second version did not change in a qualitative sense if not *each single* high–tech firm exports in the open economy. Indeed, the conditions for the growth effect of exposure to trade in subsection 4.2.1 show that the qualitative results of the second version do not change if $\phi^*_{hH}/2 < \phi^*_{ExH} \leq \phi^*_{hH}$ is fulfilled, i. e., if at least more than 50% of the high–tech firms export. However, the empirical analysis in section 5 shows that indeed $\phi^*_{hH} \approx \phi^*_{ExH}$.

Figure 3: Growth effect of exposure to trade



5 Empirical Evidence

The theoretical part shows that the growth effect of exposure to trade is negative in the case of a random selection into export markets if less than half of a country's firms export. However, the growth effect of exposure to trade is always positive in the case of a conscious selection into export markets. Since, first, in general less than half of a country's firms export in reality and, second, empirical studies consistently document a positive growth effect of exposure to trade (cf., e.g., Frankel/Romer, 1999),[21] the following hypothesis will be tested: do firms consciously make different decisions about their technologies when they decide to become exporters?

5.1 Data

The empirical analysis is based on plant level data from the Annual National Industrial Survey (*ENIA*) carried out by the National Institute of Statistics of Chile (*INE*) for the years 1990 to 1999. This survey covers the universe of Chilean manufacturing plants with 10 or more workers. A plant is not necessarily a firm; however, a signifi-

[21]Furthermore, figure 4 shows for Chile, that the period 1985–2005 was characterized by a growth in exports and a simultaneous growth in GDP. This evidence is in line with a positive growth effect of exposure to trade.

cant percentage of firms in the survey are single–plant firms (Pavcnik, 2002). The *INE* updates the survey annually by incorporating plants that started operating during the year and excluding those plants that stopped operating for any reason.

For each plant and year, the *ENIA* collects data on production, value added, sales, employment and wages (production and non–production), exports, investment, depreciation, energy usage, foreign licenses, and other plant characteristics. In addition, plants are classified according to the International Standard Industrial Classification (*ISIC*) rev. 2. Using 4–digit industry level price deflators, all monetary variables were converted to constant pesos of 1985. Plants do not report information on capital stock, thus it was necessary to construct this variable using the perpetual inventory method for each plant.

The share of plants with export activity in the total number of plants is smaller than 50%, but has been growing during the 1990s. As seen in table 1, on average, 22.4% of plants are exporters, and their share increased from 17.5% in 1991 to almost 25% in 1997–1998, although declined slightly in 1999 due to the effects of the Asian crisis. Exporters are larger in size than non–exporters and many of them have foreign ownership. Table 2 shows that a large fraction of non–exporters (74.2%) are classified as small plants (10–49 employees) while only 6.4% of them are considered large plants (150 or more employees). In contrast, 24.5% of exporters are small, while 37.3% are large. In terms of foreign ownership, almost 15% of exporters have some foreign participation while this number is only 3.4% for non–exporters.

5.2 Econometric analysis

The theoretical model in this paper suggests that plants that export are relatively skill intensive or more human capital intensive. Unfortunately, plant–level datasets do not have, in general, information about the quality (e. g., education, experience, etc.) of the workers. The Chilean data is not an exception. Thus, different measures of skill intensity have to be considered. One possibility is to use the fraction of non–production workers on the total number of workers. In principle, it is expected that exporters use relatively more non–production workers than non–exporters. But this measure does not reveal the workers' level of human capital. An alternative is to assume that labor markets are perfect and that wages reflect the marginal product of labor. In this context, firms that pay higher wages are assumed to employ more skilled labor. Thus, the average wage paid by the plant is used as an additional measure of skill intensity. The average wage paid to non–production workers and the wage

paid to production workers are also considered in order to check whether exporters use better non–production or production workers. Another measure of skill intensity is value added per worker (average labor productivity). Productivity differentials between exporters and non–exporters are also analyzed. Using the recent technique proposed by Levinsohn and Petrin (2003a),[22] total factor productivity (*TFP*) is estimated for each plant and year. Since the quality of labor is not observed, plants that employ high–quality workers will have high measured *TFP*. This section also investigates the difference in the (physical) capital–labor ratio between these two groups of firms.
In order to measure these differences, the following equation is estimated:

$$\log y_{ijrt} = \alpha + \beta X_{ijrt} + \delta_j + \delta_r + \delta_t + \epsilon_{ijrt},$$

y_{ijrt} is a measure of skill intensity, or productivity, of plant i belonging to sector j operating in region r at time t; X_{ijrt} is a dummy variable equal to one if plant i exports at time t and 0 otherwise; δ_j, and δ_r, are 3–digit level industry, and region dummy variables that attempt to control for unobserved industry and region characteristics that can make exporters more productive and skill intensive, while δ_t are year dummy variables that control for macroeconomic shocks, common to all plants, which may make exporters relatively more productive. The parameter of interest is β, which reflects the skill intensity or productivity differential in favor of exporters; β is expected to be positive and statistically significant. The results are given in column (1) of table 3. As can be seen, all estimated βs are positive and statistically significant, confirming that exporters use more non–production workers, pay higher wages, are more productive, and more capital intensive than non–exporters. But since exporters tend to be larger in size and more likely to have foreign ownership than non–exporters, the advantage of exporters may be just reflecting these other factors and not exporting itself. Thus, it is necessary to add a vector of control variables (Z_{ijrt}), which includes dummy variables for medium and large plants, and a dummy for foreign affiliates:

$$\log y_{ijrt} = \alpha + \beta X_{ijrt} + \pi' Z_{ijrt} + \delta_j + \delta_r + \delta_t + \epsilon_{ijrt}.$$

Column (2) of table 3 shows the results. As expected, all estimates are lower in magnitude compared to the case without controls, confirming that larger and foreign owned plants are more human capital intensive. But the coefficients are still positive and statistically significant in all cases, which indicates that exporters are more skill intensive than non–exporters even after controlling for size and foreign ownership.

[22]See Appendix C for details.

Finally, it is possible that unobserved plant characteristics (e. g., managerial ability) may be responsible for the higher productivity of exporters. If these characteristics are time–invariant, one can decompose the error term in the above equation into two parts: $\epsilon_{ijrt} = c_i + u_{ijrt}$, where c_i is the time–invariant unobserved plant effect, and u_{ijrt} is an error term. Column (3) of table 3 shows the results of including these plant–fixed effects. The estimates are lower in magnitude but they are still all positive and statistically significant, confirming that exporters are indeed more skill intensive and more productive than non–exporters.

The previous analysis only shows a positive correlation between exporting and skill intensity and productivity, and it may not be interpreted as proving a causal relationship. But the model developed in this paper, however, predicts that exporters are plants that choose high–tech technologies which makes them more skill or human capital intensive. In reality, plants might even make conscious decisions to increase their skill levels and productivity with the purpose of becoming exporters. Put it in another way, the entry decision might not be completely random: firms determine whether they will be exporters or not in the future by their technology choice today. Although there is considerable anecdotal evidence suggesting that this is very common at least in developing countries (López, 2005), it is very difficult to study empirically this idea: the evolution of productivity and skills generated by a random process is observationally equivalent to the one generated by a conscious decision.

This paper follows the methodology proposed by Hallward–Driemeier, Iarossi and Sokoloff (2002), adapted here to the context of skill intensities. Hallward–Driemeier, Iarossi and Sokoloff (2002) compare plants that started exporting during the first year of operation with plants that became exporters after the first year of operation. They argue that the behavior of the firm during the first year of operation is exogenous with respect to productivity. Thus, if firms that were established as exporters are more productive than those that became exporters then there would be strong support for the idea that firms make different decisions about technologies when they aim export markets. In the context of this paper, if firms choose the skill intensive technology with the purpose of exporting, then plants that started operations as exporters should be more skill intensive and more productive than those that became exporters.

Table 4 shows the differences in skill intensity between plants that were established as exporters and those plants that became exporters. Since foreign affiliates are likely to be more skill intensive and productive than domestic plants we compare domestic exporters only. As can be seen in columns (1) and (2), and the one–sided test in column

(3), plants that were established as exporters pay higher wages, are more productive and more capital intensive than those that became exporters. Although the fraction of non–production workers they use is not statistically different between the two groups, the first group of plants seems to use better quality workers. This evidence strongly supports the idea that self–selection into export markets is a conscious process and not just the result of random shocks.

It is possible, however, that unobserved plant–characteristics may be explaining these differentials. In the business literature for example, it is commonly found that managers that speak more than one language or with higher levels of education are more likely to internationalize their firms (Reid, 1981). To address this issue, columns (4) and (5) show the estimates with plant–fixed effects. Most of the results hold, although now there does not seem to be a significant differential in the capital–labor ratio (column (6)).

An implication of the previous analysis is that plants that use better non–production workers are more likely to start exporting. The next exercise considers only plants that became exporters in a given year and asks how plant characteristics in the previous year affected the probability of becoming an exporter:[23]

$$\Pr(X_{ijr,t} = 1 | X_{ijr,t-1} = 0) = F(\beta' \Omega_{ijr,t-1} + \delta_j + \delta_r + \delta_t + \epsilon_{ijrt}),$$

where $X_{ijr,t}$ is a dummy variable equal to one if plant i exported at time t. $\Omega_{i,t-1}$ is a vector of plant characteristics at $t-1$ that previous literature suggests may affect the probability of exporting; these variables are *TFP*, plant size, foreign ownership, a dummy equal to one if the firm spends on foreign licences, and plant age. Plant size is included as two dummy variables for medium and large plants. The dummy for foreign licenses, which refers to expenditures on foreign technical assistance and licenses, is used as a proxy for technological innovation. Finally age is the number of years the plant has been present in the survey since 1979 (the first year the survey is available).[24] β is the vector of parameters that reflect the impact of changes in Ω on X. To investigate whether more skill intensive plants are more likely to enter foreign markets, the share of non–production to total workers, and the average wage are also included.

One econometric issue that needs to be addressed is the influence of unobserved plant–characteristics. A probit or a logit model with random effects is a possibility but the

[23]See Alvarez and López (2005).

[24]Although the survey is available since 1979, data on exports is collected only from 1990.

assumption that the random effects are uncorrelated with the explanatory variables is likely violated in this case. A logit with fixed effects is not recommended in this context since most plants are non–starters (their export status does not change from $t-1$ to t).[25] Based on these problems, the analysis is based on a linear probability model with and without plant–fixed effects.

Another potential issue is the possibility that policy changes are making some plants more likely to enter export markets and to adopt better technologies. Although this is possible, in the case of Chile is very unlikely. Chile has followed a neutral incentive system since the mid 1970s. Tariffs, for example, are uniform while export promotion policies and incentives to technology adoption have not been as important as in other countries. Moreover, they do not discriminate across firms. Thus, the set of sector, region and year dummies should be able to control for any unaccounted change in policy.

Tables 5 shows the results. As seen in column (1), more productive and larger plants are more likely to begin to export. Plants with foreign ownership and those that purchase foreign licenses are also more likely to enter export markets. Age and age squared do not appear to be significant. Column (2) shows the results including measures of skill intensity, the fraction of non–production workers and the average wage. As can be seen, both variables enter positively and significantly into the equation, confirming that skill intensive plants are more likely to become exporters. Column (3) distinguishes between wages paid to non–production and production workers. Both estimates are positive and statistically significant, although the estimate for the production wage is only significant at 10%. This suggests that plants that use better non–production workers are more likely to enter international markets, which is consistent with the theory.

Columns (4)–(6) present the results including the plant–fixed effects. All variables, except *TFP*, remain statistically significant. Age is now positive and significant, while age squared is negative and significant. The ratio of non–production workers to total workers is still positive and significant. The average wage is not significant, although plants that pay higher wages to non–production workers are more likely to begin to export.

As a robustness check, the probability of beginning to export is also estimated using a probit model with and without random effects. The results, not reported here, show that plants that use a higher share of non–production workers and plants that pay

[25] See, for example, Cameron/Trivedi (2005), chapter 23.

higher wages, especially to non–production workers, are more likely to start exporting. These results are thus consistent with the estimates from the linear probability model, and confirm that skill intensity is positively correlated with entry to export markets.

6 Conclusions

Previous models within the 'new new' trade theory either assume that firms are completely randomly selected into export markets or that firms consciously decide whether to become high–tech exporters or low–tech non–exporters. None of these previous models analyzes how this difference in firm behavior affects the gains from trade. This paper tries to fill this gap with the help of a novel theoretical setup. Most importantly, two different versions of the model are analyzed: firms are randomly selected into export markets in the first version, while firms consciously decide whether to become high–tech exporters or not in the second version. Second, this paper introduces the idea that heterogeneity across firms with respect to the total factor productivity can always be explained with the help of an additional factor of production, which is employed in different intensities at given relative factor prices. This paper therefore introduces human capital as the second factor of production besides labor and assumes that firms differ with respect to the factor intensities in production at given relative factor prices. Third, this paper assumes that a country's human capital stock is determined by the dynamic optimizing behavior of households. This assumption links the average firm's factor intensity in production with the gains from trade. Fourth, this paper test the theoretical predictions with the help of plant–level data from Chile.

It is shown that a negative growth effect results with exposure to trade if firms are randomly selected into export markets and if the export cost parameters are such that less than half of a country's firms export. However, the growth effect of exposure to trade is always positive if firms consciously decide whether to become exporters or not. Since in reality less than half of a country's firms export and since in reality exposure to trade fosters economic growth, the version with a conscious selection into export markets properly reflects reality.

The empirical analysis tests the hypothesis whether reality indeed supports the idea of a conscious selection into export markets. Using plant–level data from the Chilean manufacturing sector, the empirical analysis shows that, first, only the more human capital intensive firms export, and second, that human capital is an important determinant of the decision to start exporting. Thus, there is self–selection into international markets. But the empirical analysis also shows that firms that target export markets from the beginning are more skill intensive than firms that became exporters. This result strongly supports the idea that when firms decide to export they consciously adopt better technologies. Thus, exporting is not just a random process, but rather the result of a conscious decision.

Appendix

A Aggregation

This Appendix shows that any general equilibrium model with $N_X + N_Y = N$ heterogeneous firms can be aggregated to a model with $\widetilde{N}$ average firms. The aggregation procedure is split into two steps. First, it is assumed that the equilibrium number of firms is given exogenously. The N heterogeneous firms are then aggregated to a single average firm. Second, it is explained how the single average firm is split into $\widetilde{N}$ average firms, where $\widetilde{N}$ is determined endogenously by a free entry/exit condition.
Type–X firms may represent the human capital intensive firms and type–Y firms may represent the labor intensive firms. Each firm produces a single variety of a differentiated good. In principle, N could go to infinity. However, since no love of variety effect exists on the production side, it is immaterial for the general equilibrium factor prices w and s whether N_X firms each produce the amount x_i of their variety of the differentiated good or whether one single type–X firm produces the amount $X = N_X \cdot x_i$. The same equivalence holds with respect to type–Y firms. Furthermore, ϕ is assumed to be uniformly distributed over $[0;1]$. Therefore, the aggregation procedure is explained with $N_X = N_Y = 1$ and $N = 2$ in order to keep the exposition easily tractable. Finally, it is assumed that the aggregate goods X and Y are aggregated via a *CES* technology to give total welfare W.
First of all, the general equilibrium factor prices w and s and total factor income are determined:

$$N_X \cdot x_i = X = \left(\phi_X^\alpha \cdot L_X^\alpha + (1-\phi_X)^\alpha \cdot S_X^\alpha\right)^{1/\alpha} \tag{38}$$

$$N_Y \cdot y_i = Y = \left(\phi_Y^\alpha \cdot L_Y^\alpha + (1-\phi_Y)^\alpha \cdot S_Y^\alpha\right)^{1/\alpha} \tag{39}$$

$$W = \left(X^\alpha + Y^\alpha\right)^{1/\alpha}, \tag{40}$$

where L_X, S_X, L_Y and S_Y represent the total input of labor and human capital in the production of the aggregate goods X and Y, respectively. These factor inputs exclude those resources that are needed to produce fixed costs. Assuming large group monopolistic competition, the corresponding prices $p(\phi_X)$, $p(\phi_Y)$ and $p_W \equiv P$ result as follows:

$$p\big(\phi_X\big) \cdot (1 - 1/\sigma) = \underbrace{\left(\phi_X \cdot w^{1-\sigma} + (1-\phi_X) \cdot s^{1-\sigma}\right)^{1/(1-\sigma)}}_{\equiv c(\phi_X)} \tag{41}$$

$$p\big(\phi_Y\big) \cdot (1 - 1/\sigma) = \underbrace{\left(\phi_Y \cdot w^{1-\sigma} + (1-\phi_Y) \cdot s^{1-\sigma}\right)^{1/(1-\sigma)}}_{\equiv c(\phi_Y)} \tag{42}$$

$$p_W \equiv P = \left((1/N) \cdot p\big(\phi_X\big)^{1-\sigma} + (1/N) \cdot p\big(\phi_Y\big)^{1-\sigma}\right)^{1/(1-\sigma)} \cdot N^{1/(1-\sigma)}. \tag{43}$$

The prices $p\big(\phi_X\big)$ and $p\big(\phi_Y\big)$ include a monopolistic markup over marginal costs. Obviously, $N = 2$ in the present case. The demand functions are given by

$$Q_X = p\big(\phi_X\big)^{-\sigma} \cdot P^{\sigma-1} \cdot M, \qquad Q_Y = p\big(\phi_Y\big)^{-\sigma} \cdot P^{\sigma-1} \cdot M, \qquad W = M/P, \tag{44}$$

where M denotes total factor income. Finally, the factor market equilibrium conditions are given by

$$\left(\phi_X \cdot w^{1-\sigma} + (1-\phi_X) \cdot s^{1-\sigma}\right)^{\sigma/(1-\sigma)} \cdot \phi_X \cdot w^{-\sigma}$$
$$\cdot \left(\underbrace{p\big(\phi_X\big)^{-\sigma} \cdot \left((1/N) \cdot p\big(\phi_X\big)^{1-\sigma} + (1/N) \cdot p\big(\phi_Y\big)^{1-\sigma}\right)^{\sigma/(1-\sigma)} \cdot N^{\sigma/(1-\sigma)} \cdot W}_{=p(\phi_X)^{-\sigma} \cdot P^\sigma \cdot M/P = N_X \cdot x_i = Q_X} + N_X \cdot f_X \right)$$

$$+\Big(\phi_Y \cdot w^{1-\sigma} + (1-\phi_Y)\cdot s^{1-\sigma}\Big)^{\sigma/(1-\sigma)} \cdot \phi_Y \cdot w^{-\sigma}$$

$$\cdot\Bigg(\underbrace{p(\phi_Y)^{-\sigma}\cdot \Big((1/N)\cdot p(\phi_X)^{1-\sigma} + (1/N)\cdot p(\phi_Y)^{1-\sigma}\Big)^{\sigma/(1-\sigma)} \cdot N^{\sigma/(1-\sigma)} \cdot W}_{=p(\phi_Y)^{-\sigma}\cdot P^{\sigma}\cdot M/P = N_Y \cdot y_i = Q_Y} + N_Y \cdot f_Y\Bigg) = \overline{L}, \tag{45}$$

$$\Big(\phi_X \cdot w^{1-\sigma} + (1-\phi_X)\cdot s^{1-\sigma}\Big)^{\sigma/(1-\sigma)} \cdot (1-\phi_X)\cdot s^{-\sigma}$$

$$\cdot\Bigg(\underbrace{p(\phi_X)^{-\sigma}\cdot \Big((1/N)\cdot p(\phi_X)^{1-\sigma} + (1/N)\cdot p(\phi_Y)^{1-\sigma}\Big)^{\sigma/(1-\sigma)} \cdot N^{\sigma/(1-\sigma)} \cdot W}_{=p(\phi_X)^{-\sigma}\cdot P^{\sigma}\cdot M/P = N_X \cdot x_i = Q_X} + N_X \cdot f_X\Bigg)$$

$$+\Big(\phi_Y \cdot w^{1-\sigma} + (1-\phi_Y)\cdot s^{1-\sigma}\Big)^{\sigma/(1-\sigma)} \cdot (1-\phi_Y)\cdot s^{-\sigma}$$

$$\cdot\Bigg(\underbrace{p(\phi_Y)^{-\sigma}\cdot \Big((1/N)\cdot p(\phi_X)^{1-\sigma} + (1/N)\cdot p(\phi_Y)^{1-\sigma}\Big)^{\sigma/(1-\sigma)} \cdot N^{\sigma/(1-\sigma)} \cdot W}_{=p(\phi_Y)^{-\sigma}\cdot P^{\sigma}\cdot M/P = N_Y \cdot y_i = Q_Y} + N_Y \cdot f_Y\Bigg) = \overline{S}, \tag{46}$$

where the demand for labor and human capital by sectors X and Y is derived by Shephard's Lemma. The terms $N_X \cdot f_X$ and $N_Y \cdot f_Y$ denote total fixed costs which are produced by type–X firms and type–Y firms, respectively. Since the free entry/exit condition is fulfilled for both types of firms in general equilibrium, $Q_X = f_X \cdot (\sigma - 1)$ and $Q_Y = f_Y \cdot (\sigma - 1)$ holds. Inserting these expressions for Q_X and Q_Y into the factor market equilibrium conditions and considering that

$$\begin{aligned} P &= \Big(\frac{1}{N}\cdot p(\phi_X)^{1-\sigma} + \frac{1}{N}\cdot p(\phi_Y)^{1-\sigma}\Big)^{1/(1-\sigma)} \cdot N^{1/(1-\sigma)} \\ &= \Big(\frac{1}{N}\cdot c(\phi_X)^{1-\sigma} + \frac{1}{N}\cdot c(\phi_Y)^{1-\sigma}\Big)^{1/(1-\sigma)} \cdot \frac{\sigma}{\sigma-1} \cdot N^{1/(1-\sigma)}, \end{aligned} \tag{47}$$

with $p(\phi_k) = \sigma/(\sigma-1)\cdot c(\phi_k)$, $k = X, Y$, results in:

$$\begin{aligned} &\Big(\phi_X \cdot w^{1-\sigma} + (1-\phi_X)\cdot s^{1-\sigma}\Big)^{\sigma/(1-\sigma)} \cdot \phi_X \cdot w^{-\sigma} \\ &\cdot c(\phi_X)^{-\sigma} \cdot \Big((1/N)\cdot c(\phi_X)^{1-\sigma} + (1/N)\cdot c(\phi_Y)^{1-\sigma}\Big)^{\sigma/(1-\sigma)} \cdot N^{\sigma/(1-\sigma)} \cdot W \cdot \frac{\sigma}{\sigma-1} \\ &+\Big(\phi_Y \cdot w^{1-\sigma} + (1-\phi_Y)\cdot s^{1-\sigma}\Big)^{\sigma/(1-\sigma)} \cdot \phi_Y \cdot w^{-\sigma} \\ &\cdot c(\phi_Y)^{-\sigma} \cdot \Big((1/N)\cdot c(\phi_X)^{1-\sigma} + (1/N)\cdot c(\phi_Y)^{1-\sigma}\Big)^{\sigma/(1-\sigma)} \cdot N^{\sigma/(1-\sigma)} \cdot W \cdot \frac{\sigma}{\sigma-1} = \overline{L}, \end{aligned} \tag{48}$$

$$\begin{aligned} &\Big(\phi_X \cdot w^{1-\sigma} + (1-\phi_X)\cdot s^{1-\sigma}\Big)^{\sigma/(1-\sigma)} \cdot (1-\phi_X)\cdot s^{-\sigma} \\ &\cdot c(\phi_X)^{-\sigma} \cdot \Big((1/N)\cdot c(\phi_X)^{1-\sigma} + (1/N)\cdot c(\phi_Y)^{1-\sigma}\Big)^{\sigma/(1-\sigma)} \cdot N^{\sigma/(1-\sigma)} \cdot W \cdot \frac{\sigma}{\sigma-1} \\ &+\Big(\phi_Y \cdot w^{1-\sigma} + (1-\phi_Y)\cdot s^{1-\sigma}\Big)^{\sigma/(1-\sigma)} \cdot (1-\phi_Y)\cdot s^{-\sigma} \\ &\cdot c(\phi_Y)^{-\sigma} \cdot \Big((1/N)\cdot c(\phi_X)^{1-\sigma} + (1/N)\cdot c(\phi_Y)^{1-\sigma}\Big)^{\sigma/(1-\sigma)} \cdot N^{\sigma/(1-\sigma)} \cdot W \cdot \frac{\sigma}{\sigma-1} = \overline{S}, \end{aligned} \tag{49}$$

However, if it is considered that

$$\Big(\phi_X \cdot w^{1-\sigma} + (1-\phi_X)\cdot s^{1-\sigma}\Big)^{\sigma/(1-\sigma)} = c(\phi_X)^{\sigma} \tag{50}$$

$$\Big(\phi_Y \cdot w^{1-\sigma} + (1-\phi_Y)\cdot s^{1-\sigma}\Big)^{\sigma/(1-\sigma)} = c(\phi_Y)^{\sigma}, \tag{51}$$

the factor market equilibrium conditions can be simplified further to

$$\phi_X \cdot w^{-\sigma} \cdot \left(\frac{1}{N} \cdot c\big(\phi_X\big)^{1-\sigma} + \frac{1}{N} \cdot c\big(\phi_Y\big)^{1-\sigma}\right)^{\sigma/(1-\sigma)} \cdot N^{\sigma/(1-\sigma)} \cdot W \cdot \frac{\sigma}{\sigma-1}$$
$$+\phi_Y \cdot w^{-\sigma} \cdot \left(\frac{1}{N} \cdot c\big(\phi_X\big)^{1-\sigma} + \frac{1}{N} \cdot c\big(\phi_Y\big)^{1-\sigma}\right)^{\sigma/(1-\sigma)} \cdot N^{\sigma/(1-\sigma)} \cdot W \cdot \frac{\sigma}{\sigma-1} = \overline{L} \quad (52)$$

and

$$(1-\phi_X) \cdot s^{-\sigma} \cdot \left(\frac{1}{N} \cdot c\big(\phi_X\big)^{1-\sigma} + \frac{1}{N} \cdot c\big(\phi_Y\big)^{1-\sigma}\right)^{\sigma/(1-\sigma)} \cdot N^{\sigma/(1-\sigma)} \cdot W \cdot \frac{\sigma}{\sigma-1}$$
$$+(1-\phi_Y) \cdot s^{-\sigma} \cdot \left(\frac{1}{N} \cdot c\big(\phi_X\big)^{1-\sigma} + \frac{1}{N} \cdot c\big(\phi_Y\big)^{1-\sigma}\right)^{\sigma/(1-\sigma)} \cdot N^{\sigma/(1-\sigma)} \cdot W \cdot \frac{\sigma}{\sigma-1} = \overline{S}. \quad (53)$$

Furthermore, the expression $\big((1/N) \cdot c\big(\phi_X\big)^{1-\sigma} + (1/N) \cdot c\big(\phi_Y\big)^{1-\sigma}\big)^{\sigma/(1-\sigma)} \cdot N^{\sigma/(1-\sigma)} \cdot W$ in the factor market equilibrium conditions can be simplified as well: inserting the expressions for $c\big(\phi_X\big)$ and $c\big(\phi_Y\big)$ into equation (47) gives

$$P = \left(\frac{1}{N} \cdot \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} \cdot \left(\phi_X \cdot w^{1-\sigma} + (1-\phi_X) \cdot s^{1-\sigma}\right) + \frac{1}{N} \cdot \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} \cdot \left(\phi_Y \cdot w^{1-\sigma} + (1-\phi_Y) \cdot s^{1-\sigma}\right)\right)^{1/(1-\sigma)} \cdot N^{1/(1-\sigma)}, \quad (54)$$

which leads to

$$P = \frac{\sigma}{\sigma-1} \cdot \left(\widetilde{\phi} \cdot w^{1-\sigma} + (1-\widetilde{\phi}) \cdot s^{1-\sigma}\right)^{1/(1-\sigma)} \cdot N^{1/(1-\sigma)} = \left(N \cdot p(\widetilde{\phi})^{1-\sigma}\right)^{1/(1-\sigma)} \quad (55)$$

if $\widetilde{\phi} \equiv \Big((1/N) \cdot \phi_X + (1/N) \cdot \phi_Y\Big)$ and $1-\widetilde{\phi} \equiv \Big((1/N) \cdot (1-\phi_X) + (1/N) \cdot (1-\phi_Y)\Big)$. Therefore,

$$\big((1/N) \cdot c\big(\phi_X\big)^{1-\sigma} + (1/N) \cdot c\big(\phi_Y\big)^{1-\sigma}\big)^{\sigma/(1-\sigma)} \cdot N^{\sigma/(1-\sigma)} \cdot W = \left(\widetilde{\phi} \cdot w^{1-\sigma} + (1-\widetilde{\phi}) \cdot s^{1-\sigma}\right)^{\sigma/(1-\sigma)} \cdot \frac{M}{P} \cdot N^{\sigma/(1-\sigma)}. \quad (56)$$

Inserting the expression for P, which is derived in equation (55), gives

$$\left(\widetilde{\phi} \cdot w^{1-\sigma} + (1-\widetilde{\phi}) \cdot s^{1-\sigma}\right)^{\sigma/(1-\sigma)} \cdot \frac{M}{P} \cdot N^{\sigma/(1-\sigma)} = \frac{\left(\widetilde{\phi} \cdot w^{1-\sigma} + (1-\widetilde{\phi}) \cdot s^{1-\sigma}\right)^{\sigma/(1-\sigma)} \cdot M \cdot N^{\sigma/(1-\sigma)}}{\frac{\sigma}{\sigma-1} \cdot \left(\widetilde{\phi} \cdot w^{1-\sigma} + (1-\widetilde{\phi}) \cdot s^{1-\sigma}\right)^{1/(1-\sigma)} \cdot N^{1/(1-\sigma)}} = \frac{\frac{\sigma-1}{\sigma} \cdot M \cdot 1/N}{\widetilde{\phi} \cdot w^{1-\sigma} + (1-\widetilde{\phi}) \cdot s^{1-\sigma}}. \quad (57)$$

If $c(\widetilde{\phi})$ denotes the marginal costs of the average firm, the following equation holds:

$$c(\widetilde{\phi})^{\sigma-1} = \left(\widetilde{\phi} \cdot w^{1-\sigma} + (1-\widetilde{\phi}) \cdot s^{1-\sigma}\right)^{-1}. \quad (58)$$

The factor market equilibrium conditions can therefore be simplified to

$$c(\widetilde{\phi})^{\sigma-1} \cdot M \cdot \left(\phi_X \cdot w^{-\sigma} \cdot \frac{1}{N} + \phi_Y \cdot w^{-\sigma} \cdot \frac{1}{N}\right) = \overline{L} \quad (59)$$

and $$c(\widetilde{\phi})^{\sigma-1} \cdot M \cdot \left(\big(1-\phi_X\big) \cdot s^{-\sigma} \cdot \frac{1}{N} + \big(1-\phi_Y\big) \cdot s^{-\sigma} \cdot \frac{1}{N}\right) = \overline{S}. \quad (60)$$

However, as $\widetilde{\phi} = (\phi_X + \phi_Y)/N$, these factor market equilibrium conditions result in

$$\widetilde{\phi} \cdot w^{-\sigma} \cdot c(\widetilde{\phi})^{\sigma-1} \cdot M = \overline{L} \tag{61}$$

$$\text{and} \quad \big(1-\widetilde{\phi}\big) \cdot s^{-\sigma} \cdot c(\widetilde{\phi})^{\sigma-1} \cdot M = \overline{S}. \tag{62}$$

Obviously, with respect to the production side, the monopolistic competition model with $N_X + N_Y = N$ heterogeneous firms is identical to a model with a single perfectly competitive average firm. The average firm faces a demand of $Q(\widetilde{\phi}) = M/c(\widetilde{\phi})$. Both models therefore lead to identical factor prices and an identical total factor income.

However, in order to return to a model with monopolistic competition, the single average firm has to be split into $\widetilde{N}$ monopolistic competitive average firms. The equilibrium mass of average firms can be determined with the help of the free entry/exit condition of the average firm.

Total per period profits of a single firm i in the original disaggregated model with heterogeneous firms are given by $\pi_i = R(\phi_i)/\sigma - f \cdot c(\phi_i)$. The economy is in an equilibrium, i. e., no additional firms enter the market whenever the expected total profits of a potential entrant are equal to zero, i. e., if $\int_0^{\phi^*} 1/\phi^* \cdot \big(R(\phi_i)/\sigma - f \cdot c(\phi_i)\big) d\phi = 0$. It can be shown that the expected total profits of a potential entrant reduce to the total profits of a firm with the average labor intensity $\widetilde{\phi}$, $\pi\big(\widetilde{\phi}\big) = R\big(\widetilde{\phi}\big)/\sigma - f \cdot c\big(\widetilde{\phi}\big)$, since the number of firms goes to infinity. First of all, it is straightforward to show that

$$\frac{R\big(\widetilde{\phi}\big)}{\sigma} = \int_0^{\phi^*} \frac{1}{\phi^*} \cdot \frac{R(\phi_i)}{\sigma} d\phi, \tag{63}$$

with $\widetilde{\phi} = \phi^*/2$ as ϕ is assumed to be uniformly distributed over the interval $[0, \phi^*]$. Since this equality also holds for a finite number of firms, it will be explained for the case of two firms for simplicity of exposition. Firm 1 is assumed to produce with $\phi_1 = 0$ and firm 2 is assumed to produce with $\phi_2 = \phi^*$. $\widetilde{\phi}$ is equal to $\phi^*/2 = (0 + \phi^*)/2$. Using $R(\phi_i)/\sigma = 1/\sigma \cdot P^{\sigma-1} \cdot M \cdot \big(p(\phi_i)\big)^{1-\sigma}$, it can be shown that

$$\begin{aligned} \frac{R\big(\widetilde{\phi}\big)}{\sigma} &= \frac{1}{\sigma} \cdot P^{\sigma-1} \cdot M \cdot \big(p(\widetilde{\phi})\big)^{1-\sigma} \\ &= \frac{1}{\sigma} \cdot P^{\sigma-1} \cdot M \cdot \Big(0.5 \cdot p(\phi_1 = 0)^{1-\sigma} + 0.5 \cdot p(\phi_2 = \phi^*)^{1-\sigma}\Big), \end{aligned} \tag{64}$$

where the second equality is the critical one. Since the price only includes a constant markup over the per unit costs, the second equality is fulfilled if

$$c\big(\widetilde{\phi}\big)^{1-\sigma} = 0.5 \cdot \Big(c(\phi_1 = 0)^{1-\sigma} + c(\phi_2 = \phi^*)^{1-\sigma}\Big). \tag{65}$$

Equation (65) holds since

$$c\big(\widetilde{\phi}\big)^{1-\sigma} = \widetilde{\phi} \cdot w^{1-\sigma} + \big(1-\widetilde{\phi}\big) \cdot s^{1-\sigma} \quad \text{and} \tag{66}$$

$$\begin{aligned} 0.5 \cdot \Big(c(\phi_1)^{1-\sigma} + c(\phi_2)^{1-\sigma}\Big) &= 0.5 \cdot \Big(\phi_1 \cdot w^{1-\sigma} + (1-\phi_1) \cdot s^{1-\sigma}\Big) \\ &\quad + 0.5 \cdot \Big(\phi_2 \cdot w^{1-\sigma} + (1-\phi_2) \cdot s^{1-\sigma}\Big) \\ &= 0.5 \cdot (\phi_1 + \phi_2) \cdot w^{1-\sigma} + 0.5 \cdot (2 - \phi_1 - \phi_2) \cdot s^{1-\sigma} \\ &= \widetilde{\phi} \cdot w^{1-\sigma} + \big(1-\widetilde{\phi}\big) \cdot s^{1-\sigma}, \end{aligned} \tag{67}$$

with $\widetilde{\phi} = \phi^*/2 = (0 + \phi^*)/2$. Second, it has to be shown that

$$f \cdot c\big(\widetilde{\phi}\big) = f \cdot \int_0^{\phi^*} \frac{1}{\phi^*} \cdot c(\phi_i) d\phi \equiv f \cdot \widetilde{c}(\phi). \tag{68}$$

Equation (68) only holds approximately for a finite number of firms, but it holds exactly if the number of firms approaches infinity. Therefore, it has to be shown that

$$c\big(\widetilde{\phi}\big) \cdot \Upsilon \;=\; \lim_{N\to\infty} \frac{1}{N} \cdot \sum_{i=1}^{N} c\big(\phi_i\big) \;=\; \int_0^{\phi^*} \frac{1}{\phi^*} \cdot c(\phi_i) d\phi \;=\; \widetilde{c}(\phi), \tag{69}$$

where the second equality is due to the definition of a Riemann integral and Υ is a constant. First of all, since $\sigma = 2$ and $w = 1$, the cost function of firm i results as

$$c\big(\phi_i\big) \;=\; \Big(\phi_i + \big(1-\phi_i\big) \cdot s^{1-\sigma}\Big)^{1/(1-\sigma)} \;=\; \Big(\phi_i \cdot \big(1 - 1/s\big) + 1/s\Big)^{-1}. \tag{70}$$

Therefore,

$$\begin{aligned}
\frac{1}{\phi^*} \cdot \int_0^{\phi^*} c(\phi_i) d\phi \;&=\; \frac{1}{\phi^*} \cdot \int_0^{\phi^*} \Big(\phi_i \cdot \big(1 - 1/s\big) + 1/s\Big)^{-1} d\phi \\
&=\; \frac{1}{\phi^*} \cdot \frac{1}{1-1/s} \cdot \Big[\ln\big(\phi_i \cdot (1-1/s) + 1/s\big)\Big]_0^{\phi^*} \\
&=\; \frac{1}{\phi^*} \cdot \frac{1}{1-1/s} \cdot \Big(\ln\big(\phi^* \cdot (1-1/s) + 1/s\big) - \ln(1/s)\Big).
\end{aligned} \tag{71}$$

Furthermore, subsection 2.6 shows that the human capital rental rate in the steady state is given by

$$s \;=\; \frac{\rho + \delta - 1 + \phi^*/2}{\phi^*/2} \;=\; \frac{2 \cdot a + \phi^*}{\phi^*} \quad \text{if} \quad a \equiv \rho + \delta - 1. \tag{72}$$

It follows that

$$1 - \frac{1}{s} \;=\; 1 - \frac{1}{(2 \cdot a + \phi^*)/\phi^*} \;=\; \frac{2 \cdot a}{2 \cdot a + \phi^*}. \tag{73}$$

Therefore, equation (71) can be transformed to give

$$\begin{aligned}
\widetilde{c}(\phi) \;&=\; \frac{1}{\phi^*} \cdot \frac{2 \cdot a + \phi^*}{2 \cdot a} \cdot \left(\ln\left(\phi^* \cdot \frac{2 \cdot a}{2 \cdot a + \phi^*} + \frac{\phi^*}{2 \cdot a + \phi^*}\right) - \ln\frac{\phi^*}{2 \cdot a + \phi^*}\right) \\
&=\; \frac{2 \cdot a + \phi^*}{2 \cdot a \cdot \phi^*} \cdot \left(\ln\frac{\phi^* \cdot (2 \cdot a + 1)}{2 \cdot a + \phi^*} - \ln\frac{\phi^*}{2 \cdot a + \phi^*}\right) \\
&=\; \frac{2 \cdot a + \phi^*}{2 \cdot a \cdot \phi^*} \cdot \ln\frac{\phi^* \cdot (2 \cdot a + 1)}{\phi^*}.
\end{aligned} \tag{74}$$

The ratio $\widetilde{c}(\phi)/c\big(\widetilde{\phi}\big)$ therefore results as

$$\begin{aligned}
\frac{\widetilde{c}(\phi)}{c\big(\widetilde{\phi}\big)} \;&=\; \frac{\big(2 \cdot a + 2 \cdot \widetilde{\phi}\big)/\big(2 \cdot a \cdot 2 \cdot \widetilde{\phi}\big) \cdot \ln(2 \cdot a + 1)}{\big(2 \cdot a + 2 \cdot \widetilde{\phi}\big)/\big(2 \cdot \widetilde{\phi} \cdot (a+1)\big)} \\
&=\; \frac{\rho + \delta}{2 \cdot (\rho + \delta - 1)} \cdot \ln\big(2 \cdot \rho + 2 \cdot \delta - 1\big) \;=\; \Upsilon.
\end{aligned} \tag{75}$$

Most importantly, the constant Υ does not depend on ϕ^*. Υ therefore can be omitted from the analysis without changing the comparative steady state results.

B The equivalence between equations (30) and (33)

First of all, given that a firm has drawn a labor intensity $\phi \leq \phi^*$, the *expected* variable profits of this firm in the open economy equal the *average* variable profits over all active firms in the open economy.

The average variable profits over all active firms in the open economy result from total variable profits, $R_H(\widetilde{\phi}_{hH})\cdot(1+\tau^{1-\sigma})/\sigma\cdot\widetilde{N}_{hH}/(1+\tau^{1-\sigma})+R_H(\widetilde{\phi}_{lH})/\sigma\cdot\widetilde{N}_{lH}$, divided by the total mass of active firms in the open economy, $\widetilde{N}_{hH}/(1+\tau^{1-\sigma})+\widetilde{N}_{lH}$. Average variable profits in the open economy therefore result as:[26]

$$\left(\frac{R_H(\widetilde{\phi}_{hH})}{\sigma}\cdot\frac{\widetilde{N}_{hH}}{\widetilde{N}_{hH}+\widetilde{N}_{lH}}+\frac{R_H(\widetilde{\phi}_{lH})}{\sigma}\cdot\frac{\widetilde{N}_{hH}}{\widetilde{N}_{hH}+\widetilde{N}_{lH}}\right)\cdot\frac{\widetilde{N}_{hH}+\widetilde{N}_{lH}}{\frac{\widetilde{N}_{hH}}{1+\tau^{1-\sigma}}+\widetilde{N}_{lH}}. \tag{76}$$

The bracket in expression (76) is equal to $R_H(\widetilde{\phi}_H)/\sigma$, with $\widetilde{\phi}_H=\widetilde{\phi}_{hH}\cdot\phi^*_{hH}/\phi^*_H+\widetilde{\phi}_{lH}\cdot(1-\phi^*_{hH}/\phi^*_H)$, due to the aggregation procedure as described in Appendix A. Exposure to trade therefore increases the variable profits of the average active firm by the factor $\left(\widetilde{N}_{hH}+\widetilde{N}_{lH}\right)\Big/\left(\widetilde{N}_{hH}/(1+\tau^{1-\sigma})+\widetilde{N}_{lH}\right)$. Second, given that a firm has drawn a labor intensity $\phi<\phi^*$, total *expected* fixed costs of this firm in the open economy equal total *average* fixed costs over all active firms in the open economy. Again, total average fixed costs in the open economy result from total fixed costs in the open economy, $(f_M/(2\cdot\widetilde{\phi}_H)+f)\cdot\left(c(\widetilde{\phi}_{hH})\cdot\widetilde{N}_{hH}/(1+\tau^{1-\sigma})+c(\widetilde{\phi}_{lH})\cdot\widetilde{N}_{lH}\right)+f_{Ex}\cdot c(\widetilde{\phi}_{hH})\cdot\widetilde{N}_{hH}/(1+\tau^{1-\sigma})$, divided by the total mass of active firms in the open economy, $\widetilde{N}_{hH}/(1+\tau^{1-\sigma})+\widetilde{N}_{lH}$. Total average fixed costs in the open economy therefore result as:

$$\begin{aligned}&\left(\frac{f_M}{2\cdot\widetilde{\phi}_H}+f\right)\cdot\left(c\big(\widetilde{\phi}_{hH}\big)\cdot\frac{\widetilde{N}_{hH}}{\widetilde{N}_{hH}+\widetilde{N}_{lH}}+c\big(\widetilde{\phi}_{lH}\big)\cdot\frac{\widetilde{N}_{lH}}{\widetilde{N}_{hH}+\widetilde{N}_{lH}}\right)\cdot\frac{\widetilde{N}_{hH}+\widetilde{N}_{lH}}{\frac{\widetilde{N}_{hH}}{1+\tau^{1-\sigma}}+\widetilde{N}_{lH}}\\&\quad+\left(\frac{f_M}{2\cdot\widetilde{\phi}_H}+f\right)\cdot\left(c\big(\widetilde{\phi}_{hH}\big)\cdot\frac{\widetilde{N}_{hH}/(1+\tau^{1-\sigma})}{\frac{\widetilde{N}_{hH}}{1+\tau^{1-\sigma}}+\widetilde{N}_{lH}}-c\big(\widetilde{\phi}_{hH}\big)\cdot\frac{\widetilde{N}_{hH}}{\frac{\widetilde{N}_{hH}}{1+\tau^{1-\sigma}}+\widetilde{N}_{lH}}\right)\\&\quad+f_{Ex}\cdot c\big(\widetilde{\phi}_{hH}\big)\cdot\frac{\widetilde{N}_{hH}/(1+\tau^{1-\sigma})}{\frac{\widetilde{N}_{hH}}{1+\tau^{1-\sigma}}+\widetilde{N}_{lH}}.\end{aligned} \tag{77}$$

Due to the aggregation procedure as described in Appendix A, both brackets in the first line of expression (77) can be simplified to $\left(f_M/(2\cdot\widetilde{\phi}_H)+f\right)\cdot c(\widetilde{\phi}_H)$. Furthermore, the second and the third line in expression (77) can be simplified to

$$c(\widetilde{\phi}_{hH})\cdot\frac{\widetilde{N}_{hH}}{\frac{\widetilde{N}_{hH}}{1+\tau^{1-\sigma}}+\widetilde{N}_{lH}}\cdot\left(\frac{-\tau^{1-\sigma}}{1+\tau^{1-\sigma}}\cdot\left(\frac{f_M}{2\cdot\widetilde{\phi}_H}+f\right)+\frac{f_{Ex}}{1+\tau^{1-\sigma}}\right).$$

Equation (30) therefore can alternatively be written as

$$\begin{aligned}\frac{R_H\big(\widetilde{\phi}_H\big)}{\sigma}\cdot\frac{\widetilde{N}_{hH}+\widetilde{N}_{lH}}{\frac{\widetilde{N}_{hH}}{1+\tau^{1-\sigma}}+\widetilde{N}_{lH}}&=\left(\frac{f_M}{2\cdot\widetilde{\phi}_H}+f\right)\cdot c\big(\widetilde{\phi}_H\big)\cdot\frac{\widetilde{N}_{hH}+\widetilde{N}_{lH}}{\frac{\widetilde{N}_{hH}}{1+\tau^{1-\sigma}}+\widetilde{N}_{lH}}\\&\quad+c\big(\widetilde{\phi}_{hH}\big)\cdot\frac{\widetilde{N}_{hH}}{\frac{\widetilde{N}_{hH}}{1+\tau^{1-\sigma}}+\widetilde{N}_{lH}}\cdot\left(\frac{-\tau^{1-\sigma}}{1+\tau^{1-\sigma}}\cdot\left(\frac{f_M}{2\cdot\widetilde{\phi}_H}+f\right)+\frac{f_{Ex}}{1+\tau^{1-\sigma}}\right).\end{aligned} \tag{78}$$

Using $\sigma=2$ from assumption (A1), $R_H\big(\widetilde{\phi}_H\big)=\sigma/(\sigma-1)\cdot c\big(\widetilde{\phi}_H\big)\cdot q_{HH}\big(\widetilde{\phi}_H\big)$ and the fact that $\phi^*_{hH}/\phi^*_H=\phi^*_{ExH}/\phi^*_H=\widetilde{N}_{hH}/(\widetilde{N}_{hH}+\widetilde{N}_{lH})$ for any given ϕ^*_H, equation (78) can be transformed to equation (79), which equals equation (33):

$$q_{HH}\big(\widetilde{\phi}_H\big)-f-\frac{\phi^*_{ExH}}{\phi^*_H}\cdot\frac{c\big(\widetilde{\phi}_{hH}\big)}{c\big(\widetilde{\phi}_H\big)}\cdot\left(\frac{-\tau^{1-\sigma}}{1+\tau^{1-\sigma}}\cdot\left(\frac{f_M}{2\cdot\widetilde{\phi}_H}+f\right)+\frac{f_{Ex}}{1+\tau^{1-\sigma}}\right)\quad=\quad\frac{f_M}{2\cdot\widetilde{\phi}_H}. \tag{79}$$

[26]Note that the probability $G(\phi^*)$ is omitted since equation (76) displays the expected variable profits conditional on a successful market entry.

C *TFP* estimation

To measure *TFP* we estimate a Cobb–Douglas production function separately for each industry. Specifically, for each 3–digit sector, we estimate the following equation:

$$y_{it} = \beta_0 + \beta_1 \cdot k_{it} + \beta_2 \cdot l_{it}^{NP} + \beta_3 \cdot l_{it}^{P} + \epsilon_{it}, \tag{80}$$

where y_{it} is the log of value added of plant i at time t; k_{it} is the log of plant's capital stock, while l_{it}^{NP} and l_{it}^{P} are the logs of non–production and production labor respectively. *TFP* is defined as:

$$TFP = \exp\Big(y_{it} + \beta_1 \cdot k_{it} - \beta_2 \cdot l_{it}^{NP} - \beta_3 \cdot l_{it}^{P}\Big).$$

If ϵ_{it} is uncorrelated with the right–hand side variables in equation (80), then the production function could be estimated using *OLS*. However, although productivity is not observed by the econometrician it may be observed by the firm, thus ϵ_{it} is likely to be correlated with the regressors. Following Olley and Pakes (1996), and Levinsohn and Petrin (2003a and 2003b) we explicitly consider this endogeneity problem by writing $\epsilon_{it} = \omega_{it} + \eta_{it}$, where ω_{it} is the transmitted productivity component and η_{it} is an error term that is uncorrelated with input choices, and assuming that $m_{it} = m_{it}\big(k_{it}, \omega_{it}\big)$, where m_{it} is the intermediate input. Levinsohn and Petrin (2003a) show that this relationship is monotonically increasing in ω_{it}, so the intermediate input function can be inverted to obtain: $\omega_{it} = \omega_{it}\big(k_{it}, m_{it}\big)$. Then, equation (80) becomes:

$$y_{it} = \beta_2 \cdot l_{it}^{NP} + \beta_3 \cdot l_{it}^{P} + \phi\big(k_{it}, m_{it}\big) + \eta_{it}, \tag{81}$$

where $\phi\big(k_{it}, m_{it}\big) = \beta_0 + \beta_1 \cdot k_{it} + \omega_{it}\big(k_{it}, m_{it}\big)$. Equation (81) can be estimated using the procedures discussed in Petrin, Poi, and Levinsohn (2004). As in Levinsohn and Petrin (2003a) we use consumption of electricity as the intermediate input that allows the identification of the elasticity of capital.

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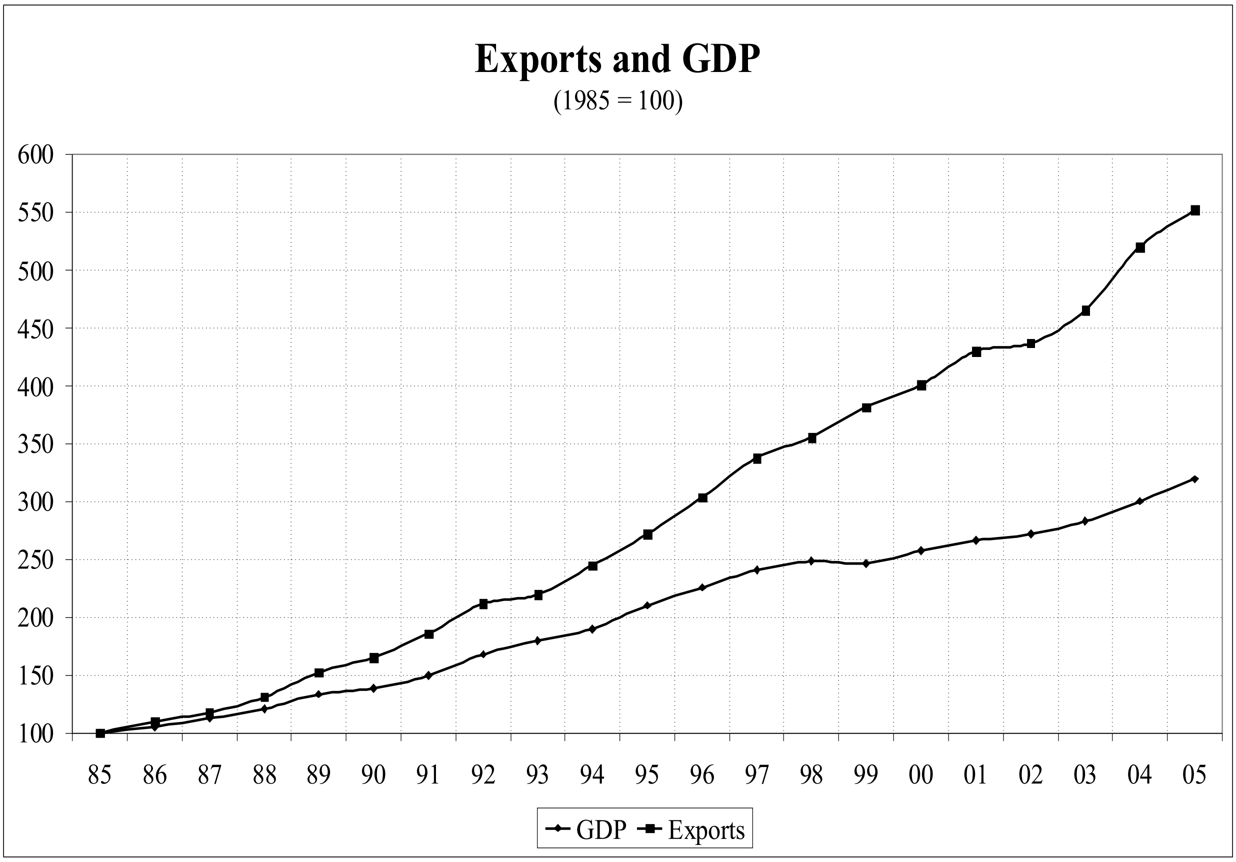
Figure 4: Chilean export growth and GDP growth



Source: Central Bank of Chile.

Table 1: Number and percentage of exporters

	number of non–exporters	number of exporters	total number of plants	percentage of non–exporters in total	percentage of exporters in total
1990	3,528	748	4,276	82.5	17.5
1991	3,570	902	4,472	79.8	20.2
1992	3,652	964	4,589	79.0	21.0
1993	3,647	1,042	4,689	77.8	22.2
1994	3,637	1,096	4,733	76.8	23.2
1995	3,631	1,113	4,744	76.5	23.5
1996	3,603	1,111	4,714	76.4	23.6
1997	3,096	1,025	4,121	75.1	24.9
1998	2,940	963	3,903	75.3	24.7
1999	2,712	826	3,538	76.7	23.3
average 1990–99	3,398.9	979.0	4,377.9	77.6	22.4

Source: *ENIA*.

Table 2: Descriptive statistics — average 1990–99

	number	percentage in category
1. *ownership*		
all plants	4,377.9	100.0
domestic	4,117.2	94.0
foreign ownership	260.7	6.0
non–exporters	3,398.9	100.0
domestic	3,281.9	96.6
foreign ownership	117.0	3.4
exporters	979.9	100.0
domestic	835.3	85.3
foreign ownership	143.7	14.7
2. *size*		
all plants	4,377.9	100.0
small	2,760.8	63.1
medium	1,034.5	23.6
large	582.6	13.3
non–exporters	3,398.9	100.0
small	2,520.6	74.2
medium	661.1	19.5
large	217.2	6.4
exporters	979.9	100.0
small	240.2	24.5
medium	373.4	38.1
large	365.4	37.3

Source: Authors' calculations based on the *ENIA*. Note: small: plants with 10 to 49 employees; medium: plants with 50–149 employees; large: plants with 150 employees or more.

Table 3: Skill, capital intensity, and productivity differentials between exporters and non–exporters

	(1)	(2)	(3)
non–production/total workers	0.111 (6.72)***	0.018 (4.12)***	0.005 (1.86)*
average wage	0.422 (30.62)***	0.214 (15.60)***	0.040 (6.10)***
non–production wage	0.604 (38.12)***	0.291 (18.94)***	0.059 (5.10)***
production wage	0.283 (22.69)***	0.142 (11.20)***	0.034 (4.41)***
value added per worker	0.608 (26.50)***	0.380 (15.91)***	0.074 (5.95)***
TFP	0.508 (24.71)***	0.214 (10.52)***	0.044 (3.54)***
capital–labor ratio	0.906 (28.83)***	0.630 (19.24)***	0.080 (5.25)***

Note: All variables are in logs except the ratio non–production/total workers. All regressions include year, sector, and region dummy variables. (2) and (3) also include controls for size (dummy variables for medium and large plants) and foreign ownership. (3) was estimated using plant fixed effects. Absolute value of t–statistics in parentheses. Standard errors were clustered at the plant level in (1) and (2). ***, **, *: significant at 1%, 5%, and 10%.

Table 4: Skill intensity, productivity and the initial export orientation

	OLS			fixed effects		
	domestic established as exporter (1)	domestic became exporter (2)	$H0 : (1) > (2)$ (p–value) (3)	domestic established as exporter (4)	domestic became exporter (5)	$H0 : (3) > (4)$ (p–value) (6)
non–production/total workers	0.014 (2.43)**	0.020 (3.11)***	(0.226)	0.000 (0.10)	0.003 (0.99)	(0.313)
average wage	0.227 (12.60)***	0.181 (9.90)***	(0.974)	0.062 (5.24)***	0.034 (4.11)***	(0.976)
non–production wage	0.325 (16.76)***	0.249 (11.52)***	(0.998)	0.0956 (4.61)***	0.049 (3.44)***	(0.967)
production wage	0.150 (9.06)***	0.111 (6.25)***	(0.958)	0.049 (3.55)***	0.029 (3.04)***	(0.884)
value added per worker	0.429 (13.28)***	0.284 (8.98)***	(1.000)	0.164 (7.27)***	0.029 (1.85)*	(1.000)
TFP	0.252 (9.16)***	0.153 (5.52)***	(0.996)	0.134 (5.89)***	–0.002 (0.10)	(1.000)
capital–labor ratio	0.720 (16.18)***	0.461 (11.36)***	(1.000)	0.054 (1.94)*	0.092 (4.86)***	(0.126)

Note: All variables are in logs except the ratio non–production/total workers. All regressions include year, sector, and region dummy variables, and controls for size (dummy variables for medium and large plants) and foreign ownership. Absolute value of t–statistics in parentheses. Standard errors were clustered at the plant level in (1) and (2). ***, **, *: significant at 1%, 5%, and 10%.

Table 5: The probability of beginning to export

	OLS			fixed effects		
	(1)	(2)	(3)	(4)	(5)	(6)
TFP	0.011 (5.82)***	0.004 (1.63)	0.004 (1.75)*	0.002 (0.85)	0.001 (0.55)	0.001 (0.44)
medium	0.053 (11.97)***	0.051 (11.44)***	0.050 (11.26)***	0.038 (6.36)***	0.039 (6.57)***	0.039(6.55)***
large	0.093 (9.99)***	0.087 (9.40)***	0.086 (9.26)***	0.053 (4.52)***	0.056 (4.76)***	0.056 (4.73)***
foreign ownership	0.045 (3.78)***	0.039 (3.27)***	0.040 (3.35)***	0.051 (2.78)***	0.051 (2.78)***	0.051 (2.78)***
foreign licenses	0.034 (3.02)***	0.031 (2.74)***	0.032 (2.82)***	0.017 (2.11)**	0.017 (2.06)**	0.017 (2.07)**
age	–0.012 (0.88)	–0.009 (0.70)	–0.009 (0.67)	0.118 (4.11)***	0.117 (4.09)***	0.117 (4.08)***
age squared	0.001 (0.38)	0.000 (0.11)	0.000 (0.09)	–0.054 (3.40)***	–0.053 (3.36)***	–0.053 (3.35)***
non–production/total workers		0.021 (2.54)**	0.039 (4.78)***		0.023 (2.21)**	0.030 (2.66)***
average wage		0.022 (6.22)***			0.008 (1.63)**	
non–production wage			0.013 (6.07)***			0.005 (1.69)*
production wage			0.006 (1.71)*			0.003 (0.82)
number of observations	25,604	25,604	25,604	25,604	25,604	25,604
R–squared	0.048	0.050	0.051	0.010	0.010	0.010

Note: *TFP*, age, and wages are in logs. All regressions include year, sector, and region dummy variables. Absolute value of t–statistics in parentheses. Standard errors were clustered at the plant level in (1), (2), and (3). ***, **, *: significant at 1%, 5%, and 10%.