EFIGE IS A PROJECT DESIGNED TO HELP IDENTIFY THE INTERNAL POLICIES NEEDED TO IMPROVE EUROPE'S EXTERNAL COMPETITIVENESS

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Export growth and factor market competition: theory and some evidence*

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Abstract

Empirical evidence suggests that sectoral export growth decreases exporters' survival probability, whereas this is not true for non-exporters. Models with firm heterogeneity in total factor productivity (TFP) predict the opposite. To solve this puzzle, we develop a two-factor framework where firms differ in factor intensities. Thus, export growth increases competition for the factor used intensively by exporters, forcing some of them to exit, while non-exporters benefit. Interacting both types of firm heterogeneity shows that factor market competition reduces TFP growth with trade liberalization. Our setup highlights the need for a richer analysis of factor market competition to understand firm dynamics.

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1 Introduction

Ever since detailed firm level trade data has become available, many studies have focused on the effects of import growth on firm dynamics. For instance, Bernard et al. (2006a) have shown that imports from low–wage countries have a negative impact on plant survival and growth among US firms. Similarly, Bernard et al. (2006b) show that declining trade costs invite more foreign varieties into the domestic market and reduce domestic sales and, accordingly, survival of all domestic firms.

On the other hand, little systematic evidence exists on the role of *export* growth on firm dynamics. The purpose of this paper is to help filling this gap in the literature. We start by documenting the effects of export growth on a sample of Chilean manufacturing firms during the period 1990–99. Interestingly, we find that the survival probability of an exporting firm is negatively correlated with sector–wide exports, whereas this is not true for non–exporting firms. This finding is remarkable, as it is at odds with the predictions of the existing theoretical literature, where the source of firm heterogeneity is total factor productivity (TFP). In fact, both the models by Melitz (2003) and Bernard et al. (2003) predict that export growth will lead the least productive non–exporting firms to exit the market, and the existing exporters to become larger. At the same time, there is abundant evidence suggesting that firm heterogeneity in factor input ratios is substantial and at least as important as firm heterogeneity in TFP.[1] Still, little is known about how this dimension contributes to explain the link between trade liberalization and firm survival.

In this paper, we develop a new theoretical model of trade in which differences in factor input ratios are the main source of heterogeneity among firms. Furthermore we also consider how this dimension of heterogeneity interacts with differences in TFP to shape the selection process brought about by trade liberalization. Thus, our analysis enriches the production side of the economy, highlighting the important role played by factor market competition in shaping firm dynamics.

We consider a general equilibrium model with one monopolistically competitive sector in each country. Each firm produces a unique variety of a differentiated final good using capital and labor. Ex–ante, firms are identical. Upon market entry, they choose the factor share parameter characterizing their CES production function. In general, firms find it optimal to choose different factor share parameters to limit the extent of factor market competition. After entry, and to start production, firms have to pay a fixed cost, which depends on the capital intensity of their technology.

We start by characterizing the autarkic equilibrium. We show that it is unique in the sense that the mass of firms which choose a specific factor intensity in production is uniquely determined by the parameters of the model. Furthermore, we argue that only if a country's relative capital endowment is "sufficiently" large, part of the firms will choose capital intensive technologies after

[1]This has been documented by Bernard and Jensen (1995), Alvarez and López (2005) and Leonardi (2007) among others.

entry. Since the coexistence of capital and labor intensive technologies in general equilibrium is crucial for our analysis, we focus on economies which are sufficiently well endowed with capital.[2]

Next, we study the trade equilibrium arising in a completely symmetric two–country world. In a setting with fixed export costs, which imply that only the more capital intensive firms can afford to serve the foreign market, we characterize the firm selection that is brought about by trade liberalization. The latter has three different effects on existing firms. First, it provides additional profit opportunities for the exporting firms. Second, it decreases domestic market shares for both exporters and non–exporters. Third, it increases factor market competition due to additional production for exports. In particular, since the exporters are the more capital intensive firms, the increase in factor market competition increases (decreases) the relative price of capital (labor) and negatively affects exporters, while positively affecting non–exporters. We also show that this effect becomes stronger, the larger is the difference in factor intensities between the two types of firms. As a result, the burden of increased factor market competition brought about by trade liberalization falls entirely on capital intensive exporters and some of the exporting firms might be forced to exit the market. Extending the model to multiple trading countries strengthens this result. Thus, our theoretical framework is able to rationalize the empirical facts we have documented for the case of Chile, which are instead at odds with the predictions of Melitz's (2003) model.

As discussed before, most of the existing literature has emphasized the role of productivity differences among firms. How does heterogeneity in factor shares interact with heterogeneity in TFP in shaping firm dynamics? To answer this question we extend our model and assume that *within* a group of firms with *identical* factor input ratios, firms differ with respect to TFP. Trade liberalization now leads to two distinct factor relocations between firms. On the one hand, factors move towards the more productive firms *within* the group of capital intensive exporters. On the other hand, factors also move between capital intensive exporters and labor intensive non–exporters. While the first process increases sector–wide TFP, the second has a priori an ambiguous effect. Still, under some mild assumptions, we are able to show that the larger is the difference in factor intensities between exporters and non–exporters, the smaller is the increase in sector–wide TFP due to trade liberalization. Thus, factor market competition dampens the positive effect on sector–wide TFP, which has been highlighted by Melitz (2003). This allows our model to provide a rationale for the findings of the recent literature, which has highlighted that the effects of trade liberalization on sector–wide TFP might be only moderate (Lawless and Whelan 2008).

Our model has identified two important channels through which export growth affects firm dynamics. First, increased factor market competition should be more detrimental for exporters the bigger is the difference in factor intensities between exporters and non–exporters. Second, the increase in TFP should be smaller the larger is the difference in factor intensities between the two types of firms. Using our Chilean dataset, we can show that both these mechanisms are at work, thus highlighting the importance of modeling heterogeneity in factor shares to explain firm

[2] Chile satisfies this requirement, as it is the richest Latin American country, and it has even become an OECD member in 2010.

dynamics.

Our paper builds upon the literature on trade with firm heterogeneity, which has been pioneered by Bernard et al. (2003) and Melitz (2003). The two papers in this literature that come closest to ours are Bernard et al. (2007) and Yeaple (2005). Bernard et al. (2007) extend the Melitz (2003) setup by considering two factors of production and, additionally, two monopolistically competitive sectors with different capital–labor ratios in production. In their model – differently from our setting – within each sector firms are homogeneous with respect to the capital–labor ratios, while they still differ with respect to TFP. Bernard et al. (2007) thus are able to provide important insights into the inter–industry and intra–industry factor relocations due to trade liberalization, but by construction, they do not analyze how the heterogeneity in capital–labor ratios interacts with globalization. This is because, *within* sectors, a firm's export status only depends on its TFP, and not on its factor shares in production.

In Yeaple (2005), on the other hand, firms are ex–ante identical and choose their technology after market entry. Labor is the only factor of production but workers differ with respect to their skills. The author assumes that for each technology, a higher skill level leads to higher profits per worker, and similarly a more advanced technology also leads to higher profits for any given skill level of the employee. Due to these monotone relationships trade liberalization leads to a firm selection like in Melitz (2003): the relative mass of exporters increases, whereas the relative mass of non–exporters decreases. In our setup, on the other hand, firms produce with a standard CES production function with two factors of production, and as a result we do not have a monotone relationship between factor intensities and profits. While the paper by Yeaple (2005) provides important insights into how trade liberalization affects workers' skill–premia, it does not consider factor share heterogeneity across firms and, thus it cannot explain those stylized facts about trade liberalization, which refer to factor market competition.

The remainder of the paper is organized as follows. In section 2 we present evidence on firm selection in the presence of export growth for Chile. Section 3 lies out our model, and in section 4 we solve for the autarkic equilibrium. In section 5 we consider the effects of trade liberalization in a two–country, symmetric setting. Section 6 extends the model to N countries, whereas section 7 combines our setting with the standard Melitz–type heterogeneity in TFP. In section 8 we provide an empirical evaluation of our model. Section 9 concludes the paper.

2 Motivation

To introduce our analysis, we use a well–known plant–level dataset on the manufacturing sector of Chile, which has been employed by several previous studies, focusing on the period 1990–1999.[3] We chose this period since in this decade the Chilean government signed several free trade agreements,

[3] This survey has been used, among others, by Pavcnik (2002), Pavcnik (2003) and Kasahara and Rodrigue (2008).

which significantly reduced the trade barriers faced by Chilean exporters.[4] The data come from the Annual Survey of Manufacturing Industries carried out by the National Institute of Statistics of Chile. The dataset covers all manufacturing plants with 10 or more workers, and it includes variables such as sales, value added, employment, wages, exports, imports of intermediate inputs, industry affiliation (ISIC Rev. 2),[5] and other plants' characteristics.[6] Each plant has a unique identification code which allows the researcher to follow it over time.

Table 1 shows the number of plants according to their export status. There is an average of 4911 plants during the period. About 21 percent of them are exporters, while the rest only produces for the domestic market. Table 2 presents one year, three year and five year survival rates. Exporters are systematically more likely to survive than non–exporters, especially over long periods of time. For instance, out of the total number of exporters in 1990, 85 percent continue operating five years later. The corresponding figure for non–exporters is only 77 percent. Table 3 shows the unconditional mean values for several characteristics of both exporters and non–exporters. Exporters are larger, more productive, more skill intensive, and are more likely to be foreign owned compared to non–exporters. Plants that export are also more likely to use imported intermediate inputs and purchase foreign technologies through licenses.

What is the effect of export growth on firm dynamics? To answer this question, we estimate the following probit model, separately for exporters and non–exporters:

$$Pr(S_{ij,t+\tau} = 1) = \Phi\left[\beta_1 \log(Exp_{jt}) + \lambda'\Omega_{ijt} + \delta_j + \delta_t\right] \tag{1}$$

where $S_{ij,t+\tau}$ equals one if plant i operating in sector j survived from year t to year $t+\tau$. Φ is the standard normal distribution function, Exp_{jt} measures the exports of sector j in year t, Ω_{ijt} is a vector of plant characteristics that includes size (measured by the log of employment), total factor productivity (in logs),[7] age (in logs), skill intensity,[8] and a set of dummy variables for plants that import intermediate inputs, plants with foreign ownership, and plants that use foreign technology licenses. The variables δ_j and δ_t are respectively 3–digit sector and year fixed effects that control for unobserved heterogeneity at the sector level and over time. Estimating a regression with plant level data, but including sector time–varying variables may underestimate the standard errors (Moulton 1990). To correct for this problem, standard errors are clustered at the 3–digit

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

[5]There are 29 manufacturing sectors at the 3–digit level. They include sectors such as food processing, textiles, paper products, chemicals and metal products.

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

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

[8]Skill intensity is the ratio between skilled workers' wages and total wages.

sector–year level. All specifications also include a measure of multinational corporations presence, which is calculated as the fraction of value added accounted by plants with foreign ownership at the 3–digit level.[9] Some specifications also include a measure of the size of the sector (either total employment or total value added).

A positive sign for β_1 would suggest that a firm is more likely to survive τ periods ahead if sector–wide exports increase. The analysis focuses on three–year survival rates ($\tau = 3$), but we have run the same specification using one– and five–year survival rates obtaining similar results. Table 4 presents our findings for both exporters and non–exporters. Consistent with previous studies,[10] larger plants, older plants, plants that are more productive, and those that use imported intermediate inputs are more likely to survive. Plants with foreign ownership, on the other hand, are more likely to exit, which is consistent with the findings of Alvarez and Görg (2009). As in Bernard et al. (2006a) the share of total wages paid to skilled workers is negatively correlated with plant survival, but only for the case of non–exporters. The estimates for the dummy for plants that use foreign technology licenses are not statistically significant. Finally, the presence of multinational corporations in the sector does not have any significant effect on survival.

The main variable of interest is the estimate of the effect of sector–wide exports. Table 4 shows that, for the case of exporters, higher export volumes at the sectoral level are negatively correlated with a plant's survival probability. Furthermore, this result is statistically significant at the conventional levels in all specifications. This result is robust if we control also for the sector size (employment and value added). It is possible, however, that the number of exporters (or the respective survival rate) might influence sector–wide exports. If this is the case then the estimates in Table 4 may suffer from an endogeneity bias. To address this concern, we instrument exports using a measure of the level of foreign income relevant for each 3–digit sector.[11] The exclusion restriction, in this case, requires foreign income to be correlated with exports but uncorrelated with any other factors that affect the exporters' survival probability. We believe this assumption to be satisfied as changes in foreign income directly affect the demand for Chilean products, thus affecting exports, but do not affect the probability of survival of exporters other than through exports. The instrument, on the other hand, is likely to be correlated with the level of exports. Indeed, the estimate for the instrument in the first stage is positive and statistically significant, and it passes the F–test for excluded instruments (see Staiger and Stock 1997). As shown in Table A1 in the appendix, the IV procedure confirms our previous results, i.e. that an exporting plant's survival probability is negatively correlated with sector–level exports.

This finding is puzzling in the light of the existing theoretical literature, which, following Melitz (2003), has focused on firm heterogeneity in total factor productivity. In fact, in a standard setting

[9] As a robustness check, the analysis also uses inflows of FDI at the 2–digit level. The results are not significantly affected when this alternative measure is used.

[10] See, for example, Dunne, Roberts, and Samuelson (1989), Salvanes and Tveteras (2004) and López (2006).

[11] This is computed as a weighted average of the per capita GDP of the 15 main export destination countries of each sector. The 15 main destination countries in each sector receive the majority of Chilean exports. Their share in total exports of the sector ranges from 81.2% to 99.5%. The average share across all sectors is 92%. See appendix A for details on how this variable is computed.

á la Melitz, an increase in exports at the sectoral level leads exporting plants to become larger, *without reducing* their number. In other words, exporting plants do not "die" due to the increase in overall export volumes. Instead, the adjustment takes place among the non–exporting plants, among which the least productive ones exit the market. These results hold also in the multi–factor extensions of the Melitz (2003) model, like the one proposed by Bernard et al. (2007), because in their setting, all firms *within* a sector use inputs in the same proportions. Thus, when exporters increase their production and factor prices rise accordingly, the least productive non–exporters within a sector will be those most adversely affected and will exit the market. Importantly, in our data, also this last prediction of the Melitz (2003) model is not supported. In fact, as shown in the second panel of Table 4 (and Table A1) non–exporting plants are not affected if sector–wide exports grow.

To account for this remarkable pattern, we need to develop a richer model, which will focus on how competition in the factor market affects the firm selection brought about by increased exports.

3 Model setup

Following the literature, we consider the working of an economy, Home, characterized by a representative consumer and one monopolistically competitive industry. We start by describing the demand side of the economy, and proceed then to consider production, focusing first on the technology available to the firms and then on the market entry decision.

The preferences of the representative consumer are given by a CES utility function of the type

$$U = \left[\int_{\phi \in \Phi} q(\phi)^{\frac{\sigma-1}{\sigma}} d\phi \right]^{\frac{\sigma}{\sigma-1}} \tag{2}$$

The parameter $\sigma > 1$ is the elasticity of substitution between different varieties, and Φ is the set of available goods, indexed by ϕ. The representative consumer is endowed with a fixed amount of capital $\overline{K}$ (human or physical) and labor $\overline{L}$ and his overall income is given by

$$M = w\overline{L} + r\overline{K} \tag{3}$$

where w is the wage rate and r is the return to capital. Utility maximization subject to the budget constraint leads to the demand for each individual variety, which is given by

$$q(\phi) = MP^{\sigma-1}p(\phi)^{-\sigma} \tag{4}$$

where $P = \left[\int_{\phi \in \Phi} p(\phi)^{1-\sigma} d\phi \right]^{\frac{1}{1-\sigma}}$ is the price index which is dual to the utility function.

Turning to the supply side of the economy, there is a continuum of potentially active firms, each of which produces a different variety of the same good, combining capital K and labor L

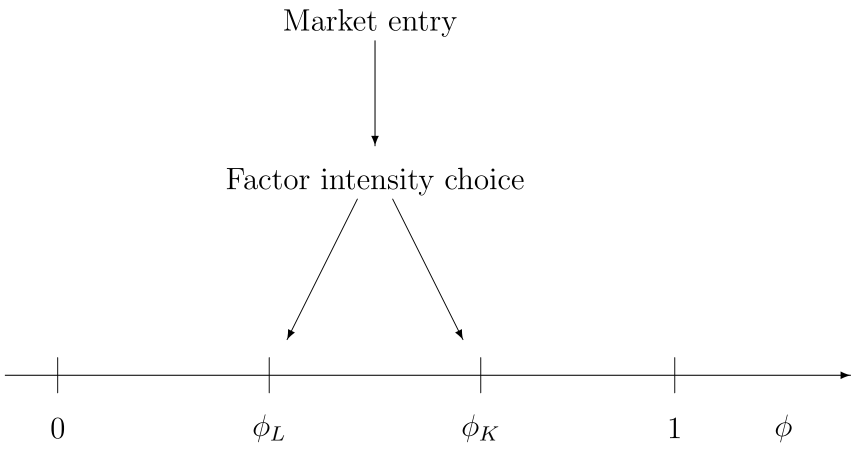

Figure 1: Market entry

according to the following CES production function:

$$q(\phi) = \left[\phi^{1-\alpha} K^{\alpha} + (1-\phi)^{1-\alpha} L^{\alpha}\right]^{1/\alpha}, \quad 0 < \alpha < 1 \tag{5}$$

where $q(\phi)$ is the firm's output. The elasticity of substitution between inputs is given by $\varsigma = \frac{1}{1-\alpha}$. In order to save on notation, we assume that $\varsigma = \sigma$.[12] Therefore, in the following we will only use σ to denote both the elasticity of substitution between inputs in production and between varieties in consumption. $\phi \in [0, 1]$ is a factor share parameter characterizing the technology. If a firm decides to produce, it faces a fixed production cost and a constant marginal cost $c(\phi)$. The latter is given by

$$c(\phi) = \left[\phi r^{1-\sigma} + (1-\phi) w^{1-\sigma}\right]^{1/(1-\sigma)}. \tag{6}$$

Clearly, as long as $r \neq w$, firms choosing different values of ϕ face different marginal costs. Production requires a fixed cost which takes the following form:[13]

$$F = c(\phi) f(\phi) \tag{7}$$

In other words, the fixed cost is made up by two components, the marginal cost $c(\phi)$ and the fixed input requirement $f(\phi)$, where we assume that $f(\phi_i) > f(\phi_j)$ if $\phi_i > \phi_j$, i.e. the more capital intensive is the technology, the higher is the fixed input requirement. This structure implies that a firm's fixed cost uses inputs in the same proportions as the firm's variety.

The entry process is illustrated by figure 1. Ex ante, all firms are identical. Market entry is costless. After entry, a firm chooses the parameter ϕ, which determines the factor intensity of

[12] This assumption simplifies the definition of the sector–wide average capital share parameter, without affecting the qualitative nature of the results.

[13] This structure of fixed costs is common in the literature; see, e.g., Markusen and Venables (2000). Our assumption implies that firms have to pay for their fixed cost with their final output.

production. We assume that firms have the choice between two different technologies: a capital intensive technology, characterized by ϕ_K, and a labor intensive technology, characterized by ϕ_L, with $\phi_K > \phi_L$. Firms maximize profits, which are given by

$$\pi(\phi) = \frac{Mp(\phi)^{-\sigma}}{P^{1-\sigma}} [p(\phi) - c(\phi)] - c(\phi) f(\phi) \tag{8}$$

which leads to the following standard pricing rule

$$p(\phi) = \frac{\sigma}{\sigma - 1} c(\phi). \tag{9}$$

4 Autarkic equilibrium

We choose labor as the numéraire, i.e. $w = 1$. The autarkic equilibrium is characterized by a set of factor market equilibrium and zero profit conditions, one for each possible technology choice. Applying Shephard's Lemma, the factor markets clearing conditions are given by:

$$\overline{L} = \sum_{i=L,K} a_{Li} [q(\phi_i) + f_i] \eta_i \tag{10}$$

$$\overline{K} = \sum_{i=L,K} a_{Ki} [q(\phi_i) + f_i] \eta_i. \tag{11}$$

η_i denotes the mass of firms of type i active in the market, whereas the terms $a_{Li} \equiv (1 - \phi_i) c(\phi_i)^\sigma$ and $a_{Ki} \equiv \phi_i r^{-\sigma} c(\phi_i)^\sigma$ are, respectively, the unit labor and capital requirements for variety i. Furthermore, let $f(\phi_i) \equiv f_i$ in order to save on notation. Since firms can choose among two different technologies, a zero profit condition has to be formulated for each separately, and is given by

$$MP^{\sigma-1} p(\phi_i)^{-\sigma} = q(\phi_i) = (\sigma - 1) f_i, \quad \text{with } i = L, K \tag{12}$$

Equation 12 highlights two important features of the equilibrium. First, firm size does not depend upon factor prices. Second, equation 12 holds for both technologies only if $r < 1$. This follows from the fact that if $f_K > f_L$, then $q(\phi_K) > q(\phi_L)$ for the two zero profit conditions to hold. Since $\phi_K > \phi_L$, the condition $p(\phi_K) < p(\phi_L)$ is satisfied only if $r < 1$, i.e. if a country's relative capital endowment $\frac{\overline{K}}{\overline{L}}$ is sufficiently large. If this is not the case, entering firms will choose only the labor intensive technology characterized by the factor share parameter ϕ_L. In order to have a general equilibrium with both technologies co–existing, we assume in the remainder of our analysis that $\frac{\overline{K}}{\overline{L}}$ is sufficiently large.

Equations 10 and 11 can be used to perform some comparative statics exercises, which will be useful later on in the analysis.

Lemma 1 *An exogenous increase in the aggregate production of the capital (labor) intensive firms increases (decreases) the relative price of capital r.*

Proof. The proof proceeds in three steps. First, notice that $\frac{a_{KK}}{a_{LK}} > 1$ and $\frac{a_{LL}}{a_{KL}} > 1$ since $\phi_K > \phi_L$. Second, dividing equations 10 and 11 by each other and considering that $\frac{q(\phi_i)}{\sigma-1} = f_i$ in general equilibrium leads to:

$$\frac{\overline{L}}{\overline{K}} = \underbrace{\frac{a_{LK}q(\phi_K)\eta_K + a_{LL}q(\phi_L)\eta_L}{a_{KK}q(\phi_K)\eta_K + a_{KL}q(\phi_L)\eta_L}}_{\equiv\Theta}. \tag{13}$$

The right hand side of equation 13, which we define Θ, denotes relative labor demand in the economy. The impact of an increase in aggregate production of capital intensive firms, which is given by $q(\phi_K)\eta_K$, on Θ can be calculated as follows:

$$\frac{\partial\Theta}{\partial[q(\phi_K)\eta_K]} = \frac{q(\phi_L)\eta_L(a_{LK}a_{KL} - a_{LL}a_{KK})}{[a_{KK}q(\phi_K)\eta_K + a_{KL}q(\phi_L)\eta_L]^2}. \tag{14}$$

$\frac{\partial\Theta}{\partial[q(\phi_K)\eta_K]} < 0$ since $a_{LK}a_{KL} - a_{LL}a_{KK} < 0$. Thus, an increase in $q(\phi_K)\eta_K$ decreases the relative labor demand. Third, since $\frac{\overline{L}}{\overline{K}}$ is exogenously given, r has to adjust so that equation 13 holds again after the exogenous increase in $q(\phi_K)\eta_K$. An increase in r increases a_{Li}, while it decreases a_{Ki}, i.e. the production of each variety becomes more labor intensive. Furthermore, an increase in r increases $\frac{p(\phi_K)}{p(\phi_L)}$ and, thus, it decreases $\frac{q(\phi_K)}{q(\phi_L)}$. An increase in r therefore ceteris paribus increases the relative labor demand Θ, so that equation 13 holds again. ■

Lemma 1 will be used later in the paper, when we consider the effect of trade liberalization on relative factor demands and relative factor prices. We can now establish a second result:

Lemma 2 *An increase in the relative price of capital increases the profits of the labor intensive firms, while it decreases the profits of the capital intensive firms.*

Proof. Substituting the terms for M, P and $p(\phi)$ into equation 8 allows us to express the profits $\pi(\phi_K)$ of a capital intensive firm as:

$$\pi(\phi_K) \;=\; \frac{\left(\overline{L} + r\overline{K}\right) c(\phi_K)^{1-\sigma}\,\sigma^{-1}}{\eta_K c(\phi_K)^{1-\sigma} + \eta_L c(\phi_L)^{1-\sigma}} - c(\phi_K)\, f_K. \tag{15}$$

The partial derivative of $\pi(\phi_K)$ with respect to r is given by:

$$\frac{\partial\pi(\phi_K)}{\partial r} \;=\; \frac{\overline{K}(1-\phi_K) - \overline{L}\phi_K r^{-\sigma}}{\sigma P^{1-\sigma}} + \frac{\left(\overline{L} + r\overline{K}\right)(1-\sigma)r^{-\sigma}N_L(\phi_K - \phi_L)}{\sigma P^{2-2\sigma}} < 0 \tag{16}$$

$\frac{\partial\pi(\phi_K)}{\partial r}$ is negative since $\frac{\overline{K}}{\overline{L}} < \frac{\phi_K}{1-\phi_K}r^{-\sigma}$, $\phi_K > \phi_L$ and $\sigma > 1$. It can be shown along the same lines that the profits of the labor intensive firms increase with r. ■

The intuition for lemma 2 is as follows. An increase in the relative price of capital ceteris paribus increases the relative price of the capital intensive goods. This shifts demand away from capital intensive goods and towards labor intensive ones, leading to higher (lower) profits for the labor (capital) intensive firms. We are now ready to establish our first proposition.

Proposition 1 *There exists a unique and stable autarkic equilibrium.*

Proof. The proof proceeds in two steps. First, considering the definition of a_{Li} and a_{Ki} and demand $q(\phi_i)$ for a single variety (equation 4), equation 13 can be simplified as follows:

$$\frac{\overline{L}}{\overline{K}} r^{-\sigma} = \frac{(1-\phi_K) + (1-\phi_L)\frac{\eta_L}{\eta_K}}{\phi_K + \phi_L \frac{\eta_L}{\eta_K}} \tag{17}$$

Equation 17 shows that the relationship between r and $\frac{\eta_L}{\eta_K}$ as it results from the factor market clearing condition is negative. Second, taking the ratio of the zero profit conditions for capital and labor intensive firms (equation 12) we have

$$\frac{q(\phi_K)}{q(\phi_L)} = \frac{(\phi_K r^{1-\sigma} + 1 - \phi_K)^{-\sigma/(1-\sigma)}}{(\phi_L r^{1-\sigma} + 1 - \phi_L)^{-\sigma/(1-\sigma)}} = \frac{f_K}{f_L}. \tag{18}$$

Equation 18 can be solved to determine the relative price of capital r in the autarkic equilibrium (subscript a):

$$r_a = \left[\frac{\left(\frac{f_K}{f_L}\right)^{(\sigma-1)/\sigma} (1-\phi_L) - (1-\phi_K)}{\phi_K - \left(\frac{f_K}{f_L}\right)^{(\sigma-1)/\sigma} \phi_L} \right]^{1/(1-\sigma)}. \tag{19}$$

Notice that we can find a general equilibrium with both zero profit conditions satisfied only if r_a is defined, i.e. only if $\frac{\phi_K}{\phi_L} > \left(\frac{f_K}{f_L}\right)^{(\sigma-1)/\sigma}$. If, in contrast, $\frac{\phi_K}{\phi_L} < \left(\frac{f_K}{f_L}\right)^{(\sigma-1)/\sigma}$, firms only choose the labor intensive technology. Since we focus on a general equilibrium with both types of firms active, we will consider only the case of $\frac{\phi_K}{\phi_L} > \left(\frac{f_K}{f_L}\right)^{(\sigma-1)/\sigma}$ in the following. Equation 19 also shows that r_a does not depend on $\frac{\eta_L}{\eta_K}$. Thus, substituting equation 19 into equation 17 we can solve for $\frac{\eta_L}{\eta_K}$. Once r_a and $\frac{\eta_L}{\eta_K}$ are known, we can determine all other variables of the model. ■

In the remainder of the paper, we will refer to equation 17 as the *relative factor market clearing* condition (FMC). This condition establishes a monotonously negative relationship between $\frac{\eta_L}{\eta_K}$ and r. Equation 19 determines instead the relative price of capital, given that both types of firms are active, and we will refer to it as the *price of capital* condition (PC). In the left panel of Figure 2, we depict the two curves. Their intersection establishes the relative price of capital r and the relative mass of labor intensive firms $\frac{\eta_L}{\eta_K}$ in the autarkic equilibrium. Once $\frac{\eta_L}{\eta_K}$ has been determined, we can also obtain the absolute number of active firms by using one of the two zero profit conditions. This is done in the right panel of the figure. Finally, to analyze the sector–wide consequences of trade liberalization, it is useful to define the capital share parameter of the average active firm $\widetilde{\phi}$:

$$\widetilde{\phi} = \frac{\phi_K \eta_K + \phi_L \eta_L}{\eta_K + \eta_L} \tag{20}$$

Notice that, as shown in appendix B, an industry with $\eta_L + \eta_K$ homogenous firms producing with

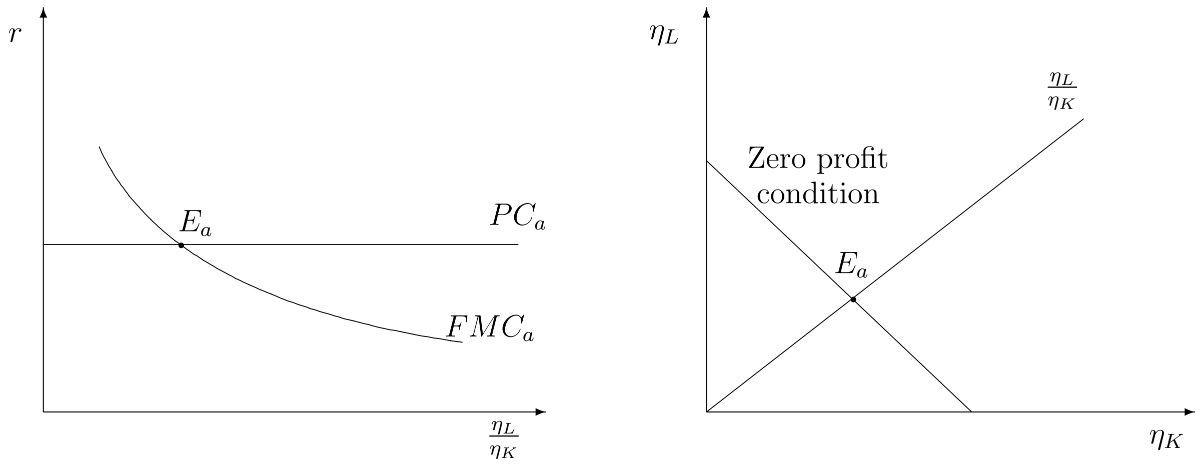

Figure 2: Autarkic equilibrium

the capital share parameter $\widetilde{\phi}$ leads to the same aggregate outcomes as an industry with η_L and η_K heterogeneous firms, each producing with the capital share parameters ϕ_L and ϕ_K, respectively.

5 Free trade equilibrium

In this section, we extend our analysis to a two–country setting to study the effect of a bilateral trade liberalization. In particular, we analyze the firm selection in each country, which is due to increased competition on goods and factor markets. The former is induced by the inflow of foreign varieties. The latter is instead the result of increased production by exporting firms. In order to provide intuition for our results, we consider first the impact of increased competition on goods markets, and then turn to increased competition on factor markets. In other words, we first focus on how the inflow of foreign varieties influences the mass of the two types of firms, holding factor prices fixed. We then consider the full general equilibrium effects, in which we also endogenously determine factor prices.

To keep the analysis tractable, we assume Home and Foreign to be completely symmetric. Utility maximization in Foreign results in the following demand function for a variety produced in Home:

$$q_F(\phi) = M_F P_F^{\sigma-1} p(\phi)^{-\sigma}. \tag{21}$$

In order to export a variety of the differentiated good, a domestic firm faces a fixed cost given by:

$$\Gamma = c(\phi) f_X \tag{22}$$

We make the following assumption on the magnitude of the export cost parameter f_X:

$$M_F P_F^{\sigma-1} p\left(\phi_L\right)^{-\sigma} \;<\; f_X(\sigma-1) \qquad \text{and} \qquad M_F P_F^{\sigma-1} p\left(\phi_K\right)^{-\sigma} \;\geq\; f_X(\sigma-1). \tag{23}$$

This assumption implies that only capital intensive firms will earn non–negative profits by serving the foreign market, whereas no labor intensive firm will find it optimal to export.[14] Total demand for a domestically produced capital intensive variety increases to

$$q\left(\phi_K\right) + q_F\left(\phi_K\right) = 2MP^{\sigma-1} p\left(\phi_K\right)^{-\sigma} \tag{24}$$

and the aggregate price index decreases to

$$P \;=\; \left[2\eta_K p\left(\phi_K\right)^{1-\sigma} + \eta_L p\left(\phi_L\right)^{1-\sigma}\right]^{1/(1-\sigma)} \tag{25}$$

following trade liberalization. For labor intensive firms, trade liberalization ceteris paribus does not affect the supply decision. The zero profit condition for capital intensive firms after trade liberalization is given by

$$2q\left(\phi_K\right) \;=\; (\sigma-1)(f_K + f_X), \tag{26}$$

while the zero profit condition for labor intensive firms is still given by equation 12. Dividing equations 26 and 12 by each other and remembering that $q(\phi_i) = MP^{\sigma-1}p(\phi_i)^{-\sigma}$, we can solve for r in the free trade equilibrium (subscript *ft*):

$$r_{ft} \;=\; \left[\frac{\Psi(1-\phi_L) - (1-\phi_K)}{\phi_K - \Psi\phi_L}\right]^{1/(1-\sigma)}, \tag{27}$$

with $\Psi = \left(\frac{f_K+f_X}{2f_L}\right)^{(\sigma-1)/\sigma}$. We will refer to equation 27 as the *PC*–equation in the free trade equilibrium. Finally, considering also the additional factor demand due to production for exports leads to the following FMC condition under free trade:

$$\frac{\overline{L}}{\overline{K}} r^{-\sigma} \;=\; \frac{2(1-\phi_K) + (1-\phi_L)\frac{\eta_L}{\eta_K}}{2\phi_K + \phi_L\frac{\eta_L}{\eta_K}}. \tag{28}$$

Summarizing our results so far leads to lemma 3:

Lemma 3 *Compared to autarky, a bilateral trade liberalization has the following consequences:*

i) the aggregate price index P decreases in each country due to the availability of additional varieties from abroad; the decrease in P ceteris paribus decreases the profits of exporting and non–exporting firms and reflects an increase in goods market competition;

[14] Remember that profits from exporting are given by $\pi(\phi_i) = M_F P_F^{\sigma-1} p(\phi_i)^{1-\sigma}\sigma^{-1} - c(\phi_i) f_X$ for $i \in \{K, L\}$. Substituting $p(\phi_i) = \frac{\sigma}{\sigma-1}c(\phi_i)$ in this equation lead to the conditions in equation 23.

ii) capital intensive firms increase their production due to additional profit opportunities abroad;

iii) the relative price of capital r increases due to additional production by capital intensive exporters; the increase in r ceteris paribus decreases the profits of capital intensive firms and increases the profits of labor intensive firms.

Proof. Parts *i)* and *ii)* follow from equations 24 and 25. Part *iii)* follows from lemma 1 and lemma 2. ■

However, it is a priori ambiguous whether trade liberalization leads to a firm selection in favor of or against either type of firms, i.e. whether $\frac{\eta_L}{\eta_K}$ increases or decreases. The additional availability of foreign varieties affects both capital and labor intensive firms negatively and ceteris paribus drives both types of firms out of the market. At the same time, the increased profit opportunities abroad affect capital intensive firms positively, ceteris paribus leading to additional entry of this type of firms. Finally, the increased competition on factor markets, which is reflected by the increase in r, affects capital intensive firms negatively and labor intensive firms positively, ceteris paribus leading to exit (entry) of capital (labor) intensive firms.

The *net* effect of trade liberalization on the two types of firms crucially depends on the difference in capital share parameters $\phi_K - \phi_L$. In the following, we will refer to $\phi_K - \phi_L$ as the *factor intensity gap* between exporters and non–exporters. The factor intensity gap determines (*i*) the extent to which r increases with trade liberalization and (*ii*) the extent to which firms are affected by the increase in r. This leads to the following proposition:

Proposition 2 *Bilateral trade liberalization leads to the following patterns of firm selection:*

i) if $\phi_K - \phi_L > \Phi$, $\frac{\eta_L}{\eta_K}$ increases, i.e. the relative mass of non–exporters increases, whereas the relative mass of exporters decreases.

ii) if $\phi_K - \phi_L < \Phi$, $\frac{\eta_L}{\eta_K}$ decreases, i.e. the relative mass of non–exporters decreases, whereas the relative mass of exporters increases.

In general, the larger is $\phi_K - \phi_L$, the more detrimental (beneficial) is trade liberalization for a single exporting (non–exporting) firm.

Proof. See appendix C. ■

Figure 3 illustrates the firm selection with trade liberalization. $(\frac{\eta_K}{\eta_L})_{ft}$ stands for the relative mass of capital intensive firms under free trade, while $(\frac{\eta_K}{\eta_L})_a$ stands for the relative mass of capital intensive firms under autarky. The minimum technological difference, which is denoted by $(\phi_K - \phi_L)_{min}$, is defined as that difference $\phi_K - \phi_L$, which leads to $(\frac{\eta_K}{\eta_L})_a = 0$.[15] In Appendix C we show that the relationship between $(\frac{\eta_K}{\eta_L})_{ft} - (\frac{\eta_K}{\eta_L})_a$ and $\phi_K - \phi_L$, as it is illustrated by figure 3, is negative.

[15] The minimum technological difference $(\phi_K - \phi_L)_{min}$ is uniquely defined. Even though the relationship between $\phi_K - \phi_L$ and $\frac{\eta_K}{\eta_L}$ is not necessarily monotonous, it can be shown that $\frac{\eta_K}{\eta_L}$ is strictly positive (negative) if the technological difference is larger (smaller) than $(\phi_K - \phi_L)_{min}$.

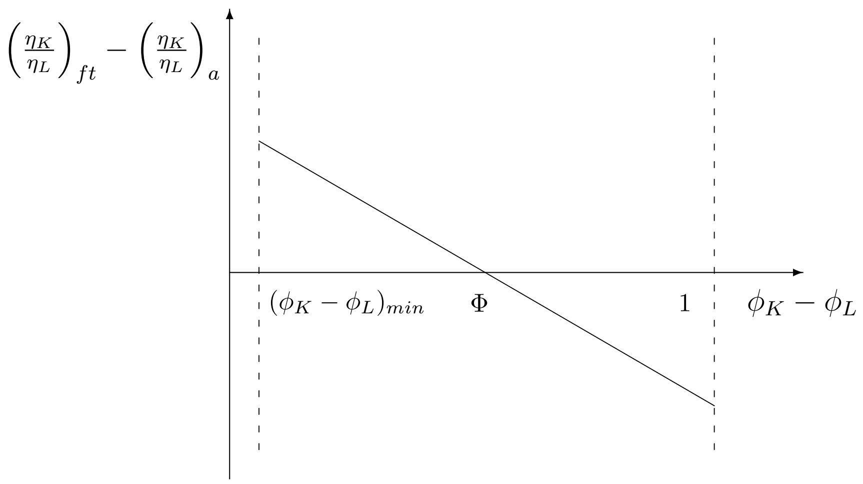

Figure 3: The role of the factor intensity gap

The intuition behind proposition 2 is as follows. First, the increase in r brought about by trade liberalization is larger, the larger is the difference $\phi_K - \phi_L$. Second, for a given increase in the relative price of capital r the losses (gains) for the capital (labor) intensive firms are larger, the larger (smaller) is $\phi_K - \phi_L$. Thus, we can conclude that labor (capital) intensive firms will unambiguously gain (lose) from trade liberalization and firms of this type will enter (exit) the market if the factor intensity gap is sufficiently large.

Finally, figure 4 illustrates the effect of trade liberalization on the mass of firms active in equilibrium. The left panel shows that, starting from the autarkic equilibrium E_a, trade liberalization shifts the PC curve upwards. This results from new profit opportunities abroad for capital intensive firms, which requires an increase in the relative price of capital r for the free entry conditions to hold again. Trade liberalization also leads to increased competition in factor markets, which shifts the FMC curve upwards. In fact, if relative demand for capital increases, the relative price of this factor must also increase to re–establish factor market clearing. The free trade equilibrium is illustrated by point E_{ft}, which consistently with the empirical evidence discussed in section 2, is drawn such that the relative mass of capital intensive firms decreases.

The right panel of the same figure captures also the role played by the increased availability of foreign varieties. We keep factor prices constant for the moment in order to separate the effects of increased factor market competition from those of the influx of foreign varieties. Starting from the autarkic equilibrium E_a, increased availability of foreign varieties and new profit opportunities abroad make the line illustrating the zero profit conditions for capital intensive firms shift inwards and become steeper (dotted line). Allowing factor prices to adjust (r increases) flattens the curve and makes it shift inwards. The new equilibrium point is indicated by E_{ft}. In general, the mass

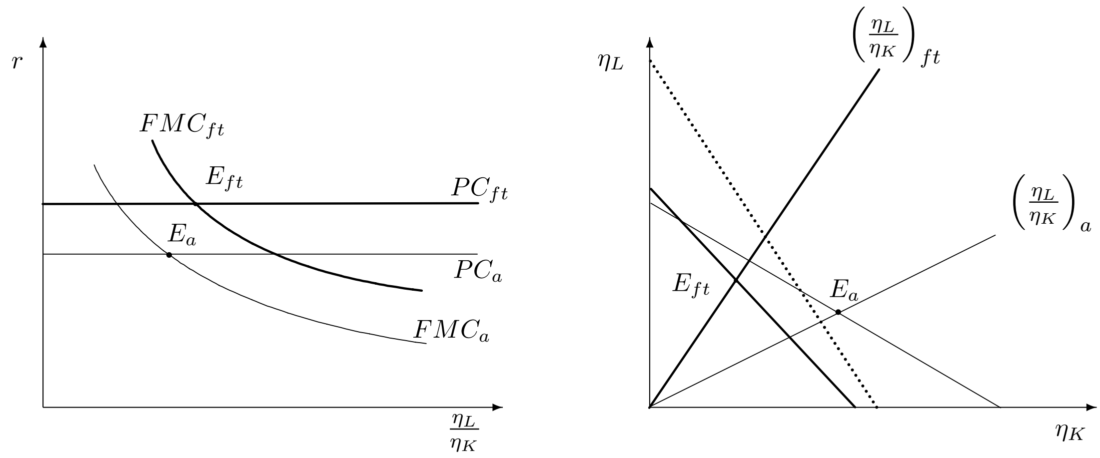

Figure 4: Trade liberalization

of capital intensive firms η_K decreases, whereas η_L can increase or decrease.[16]

Notice also that in our model a capital intensive firm will never react to the increase in the relative price of capital by exiting the foreign market, while still serving the domestic one. This is because an increase in the relative price of capital brought about by trade liberalization will negatively affect the profits of capital intensive firms in the domestic market, and only if the firm is able to make positive profits from exporting, it might be able to survive. This finding is in contrast with the standard results in the literature (see Melitz 2003, among others). In these models trade liberalization increases the wage rate, which decreases profits of all firms proportionately and leads the least productive firms to exit the market, whereas the marginal exporting firms become non–exporters. In our setting instead the increase in the relative price of capital brought about by trade liberalization leads to negative profits from serving the domestic market for capital intensive firms, which can survive only it they export and earn positive profits from exporting.

It is interesting to determine the effect of trade liberalization on the industry–wide average capital intensity parameter $\widetilde{\phi}$. This is done in the following

Proposition 3 *Compared to autarky, trade liberalization leads to an increase in the average industry–wide capital share parameter.*

Proof. See appendix E. ■

6 The N country case

We now extend our analysis to the case of $N \geq 2$ symmetric countries, which are freely trading among each other. We focus on a trade liberalization experiment that involves all countries simultaneously.

[16]Appendix D formally derives the shifts of the zero profit condition in the right panel.

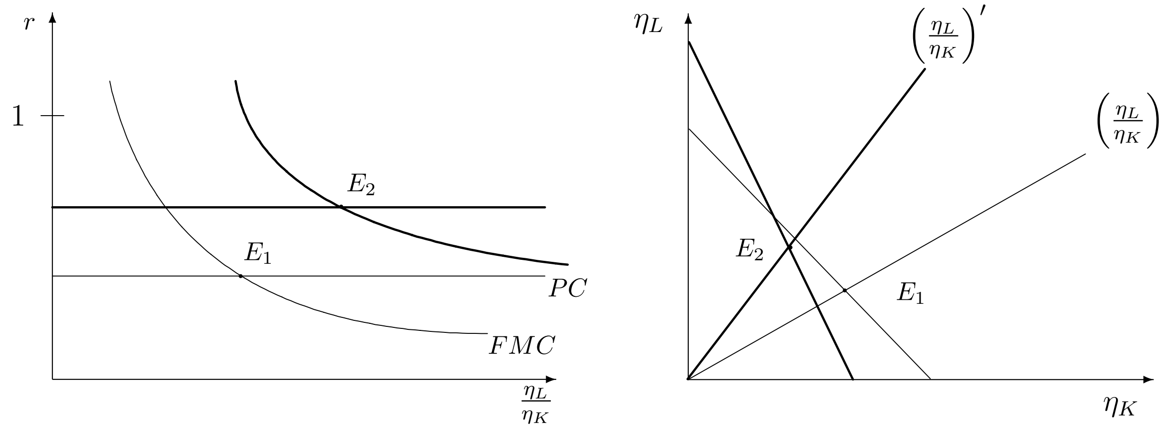

Figure 5: The effect of an increase in N

Compared to the two–country case, the aggregate output of a capital intensive firm now increases to

$$Nq(\phi_K) = NMP^{\sigma-1}\left[p(\phi_K)\right]^{-\sigma}, \quad N \geq 2 \tag{29}$$

with trade liberalization. The zero profit condition for a capital intensive firm is now given by

$$q(\phi_K) = \frac{(\sigma-1)[f_K + (N-1)f_X]}{N} \tag{30}$$

whereas the corresponding condition for labor intensive firms is still given by equation 12. Dividing equation 30 by equation 12 and solving for the relative price of capital, we obtain the N country version of the free trade PC–curve:

$$r_{ft} = \left[\frac{\Xi(1-\phi_L) - (1-\phi_K)}{\phi_K - \Xi\phi_L}\right]^{1/(1-\sigma)}, \tag{31}$$

with $\Xi = \left[\frac{f_K + (N-1)f_X}{f_L}\frac{1}{N}\right]^{(\sigma-1)/\sigma}$. The relative factor market clearing condition (FMC) for the N country case can be solved directly for $\frac{\eta_L}{\eta_K}$:

$$\frac{\eta_L}{\eta_K} = \frac{1-\phi_K - r^{-\sigma}\frac{\overline{L}}{\overline{K}}\phi_K}{r^{-\sigma}\frac{\overline{L}}{\overline{K}}\phi_L - (1-\phi_L)}N. \tag{32}$$

We can now study the effect of an increase in N on the firm selection induced by trade liberalization, starting from the initial equilibrium E_1 (see figure 5). Consider the PC–curve. It is straightforward to show that as N increases it shifts upwards (the thicker black line in the figure). Intuitively, since N ceteris paribus increases the profits of capital intensive firms, r has to increase as well for the zero profit condition of capital intensive firms to hold. Remember from lemma 2 that the capital intensive firms' profits decrease as r increases. Furthermore, in the limit, as N approaches infinity, r converges to the following value

$$\overline{r}_{ft} = \left[\frac{\left(\frac{f_X}{f_L}\right)^{(\sigma-1)/\sigma} (1-\phi_L) - (1-\phi_K)}{\phi_K - \left(\frac{f_X}{f_L}\right)^{(\sigma-1)/\sigma} \phi_L} \right]^{1/(1-\sigma)} . \tag{33}$$

and $\overline{r}_{ft} < 1$ if $f_X > f_L$ (see appendix F for the proof).

Turning now to the FMC–curve, as N becomes larger, the curve shifts rightward, i.e. $\frac{\eta_L}{\eta_K}$ increases for a given r (see equation 32). This is because as the number of trading partners becomes larger, aggregate relative capital demand ceteris paribus increases. Thus, the new equilibrium is given by E_2. Importantly, in equilibrium the relationship between $\frac{\eta_L}{\eta_K}$ and N is linear. Thus, if N goes to infinity, $\frac{\eta_L}{\eta_K}$ goes to infinity as well.

Consider now right panel of figure 5. An increase in the number of trading partners N shifts the zero profit condition further to the left and the curve becomes steeper. Thus, we can summarize our main finding for the N country case in the following proposition.

Proposition 4 *As the number N of trading partners becomes sufficiently large, trade liberalization always leads to a decrease in the mass of capital intensive firms η_K, and to an increase in the mass of labor intensive firms η_L.*

Proof. See appendix F. ■

7 Adding heterogeneity in TFP

So far we have considered firms which differ in the factor intensity of their technology. A large literature has empirically documented the existence of substantial variation in the total factor productivity across firms within a narrowly defined sector (Bernard and Jensen 1995, Alvarez and López 2005 etc.), and thus it is important to study how these two sources of heterogeneity interact in shaping the firm selection brought about by trade liberalization. In order to keep the analysis general, we focus on the case of $N \geq 2$ symmetric trading partners in the free trade situation.

To model firm heterogeneity in TFP we follow Melitz (2003). Thus, let $A > 0$ be the TFP parameter. The production function of a firm with capital share parameter ϕ is now given by:

$$q(\phi, A) \quad = \quad A \left[\phi^{1-\alpha} K^{\alpha} + (1-\phi)^{1-\alpha} L^{\alpha}\right]^{1/\alpha} . \tag{34}$$

If the firm produces, it faces a fixed cost and a constant marginal cost $c(\phi, A)$. The latter is given by

$$c\left(\phi, A\right) = \frac{1}{A} \left(\phi r^{1-\sigma} + 1 - \phi\right)^{1/(1-\sigma)} \tag{35}$$

As in Melitz (2003), we assume that the TFP parameter does not influence the fixed cost. We therefore choose the following specification

$$F = Ac(\phi, A)f_i = \left(\phi_i r^{1-\sigma} + 1 - \phi_i\right)^{1/(1-\sigma)} f_i, \quad i = K, L. \tag{36}$$

A firm's profits can then be expressed as

$$\pi\left(\phi_i, A\right) = \frac{Mp\left(\phi_i, A\right)^{1-\sigma}}{P^{1-\sigma}\sigma} - Ac\left(\phi_i, A\right) f_i. \tag{37}$$

In order to have heterogeneity in TFP in general equilibrium, the market entry procedure laid out in section 3 has to be modified. In particular, firms have to pay a sunk fee f_E upon entry.[17] Again, we assume that firms pay for f_E with their final output, so that the sunk market entry costs for a firm with capital share parameter ϕ_i, $i = L, K$, are given by:

$$\Upsilon\left(\phi_i\right) = Ac\left(\phi_i, A\right) f_E = \left(\phi_i r^{1-\sigma} + 1 - \phi_i\right)^{1/(1-\sigma)} f_E. \tag{38}$$

Notice that the TFP parameter will not affect the sunk entry cost either. After a firm has paid the sunk market entry fee, it draws a TFP parameter from an exogenously given probability distribution with density $g(A)$ and cdf $G(A)$, which, for simplicity, is assumed to be identical for the capital intensive and the labor intensive technologies. Once the TFP parameter becomes known to the firm, it decides whether or not to start production. We assume that f_L and f_K are large enough, so that only sufficiently productive firms decide to start with production after entry. The following zero cutoff profit condition determines the threshold TFP parameter A_i^* for firms with factor share parameter ϕ_i, $i = L, K$:

$$MP^{\sigma-1}p\left(\phi_i, A_i^*\right)^{-\sigma} = q\left(A_i^*, \phi_i\right) = A_i^*(\sigma-1)f_i \tag{39}$$

Given the threshold TFP parameter A_i^*, free entry implies that the ex–ante expected profits from market entry are equal to zero. This condition can be written as follows, for $i = L, K$:

$$[1 - G(A_i^*)] \int_{A_i^*}^{\infty} \pi(\phi_i, A)\mu(A)dA = \Upsilon(\phi_i) \tag{40}$$

where $\mu(A) = \frac{g(A)}{1-G(A_i^*)}$. The first term on the left hand side of equation 40 represents the probability that a firm of type i starts producing after entry. The second term describes the average profits of active firm. The term on the right hand side represents the sunk entry cost.

The following lemma characterizes the threshold TFP parameter for capital intensive and labor intensive firms.

[17] Notice that without a sunk entry fee, firms could enter and exit the market costlessly, and thus draw their productivity parameter repeatedly, until they obtain the highest possible productivity level.

Lemma 4 *The threshold TFP parameter A_i^* is independent from the threshold parameter A_j^*, for all $i, j \in \{L, K\}$ and is given by the solution to the following equation*

$$[1 - G(A_i^*)] \left[\left(\frac{\widetilde{A}_i}{A_i^*} \right)^{\sigma-1} - 1 \right] = \frac{f_E}{f_i} \tag{41}$$

where $\left(\frac{1}{\widetilde{A}_i}\right)^{1-\sigma} \equiv \int_{A_i^*}^{\infty} \left(\frac{1}{A}\right)^{1-\sigma} \mu(A) dA.$

Proof. See appendix F. ■

Notice that A_i^* depends only on σ, f_E, f_i and $g(A)$. To determine the autarkic equilibrium, we proceed as in section 4, and construct the modified version of the price of capital curve (PC) and of the factor market clearing condition (FMC). To derive the PC curve, we take the ratio of the zero cutoff profit conditions given by equation 39 defined for each type of firm, obtaining

$$\frac{q(A_K^*, \phi_K)}{q(A_L^*, \phi_L)} = \frac{A_K^* f_K}{A_L^* f_L}. \tag{42}$$

which, after a few manipulations can be rewritten as

$$r = \left[\frac{\left(\frac{f_K}{f_L}\right)^{(\sigma-1)/\sigma} \left(\frac{A_K^*}{A_L^*}\right)^{(1-\sigma)^2/-\sigma} (1-\phi_L) - (1-\phi_K)}{\phi_K - \left(\frac{f_K}{f_L}\right)^{(\sigma-1)/\sigma} \left(\frac{A_K^*}{A_L^*}\right)^{(1-\sigma)^2/-\sigma} \phi_L} \right]^{1/(1-\sigma)}. \tag{43}$$

Notice that if $A_K^* = A_L^*$ equation 43 simplifies to equation 19, i.e. we are back to our standard case. To derive the FMC condition, we need to consider that, compared to the baseline model, an increase in productivity decreases the unit factor requirements, whereas it increases aggregate output since the price of each variety declines. The modified FMC condition becomes:

$$\frac{\overline{L}}{\overline{K}} = \frac{(1-\phi_K)\left(\frac{1}{\widetilde{A}_K}\right)^{1-\sigma} + (1-\phi_L)\left(\frac{1}{\widetilde{A}_L}\right)^{1-\sigma} \frac{\eta_L}{\eta_K}}{\phi_K r^{-\sigma}\left(\frac{1}{\widetilde{A}_K}\right)^{1-\sigma} + \phi_L r^{-\sigma}\left(\frac{1}{\widetilde{A}_L}\right)^{1-\sigma} \frac{\eta_L}{\eta_K}}. \tag{44}$$

and we refer the reader to appendix G for the derivations. Combining the PC and the FMC conditions we can determine the autarkic equilibrium, which is characterized in the following

Proposition 5 *There exists a unique, stable autarkic equilibrium with firm heterogeneity in factor shares and TFP.*

Proof. See appendix H. ■

We are now ready to determine the industry–wide average capital share parameter $\widetilde{\phi}$ and the industry–wide average TFP parameter $\widetilde{A}$ in the autarkic equilibrium:

$$\widetilde{\phi} = \frac{\phi_K \widetilde{A}_K^{\sigma-1} + \phi_L \widetilde{A}_L^{\sigma-1} \frac{\eta_L}{\eta_K}}{\widetilde{A}_K^{\sigma-1} + \widetilde{A}_L^{\sigma-1} \frac{\eta_L}{\eta_K}} \tag{45}$$

$$\widetilde{A} = \left(\frac{\widetilde{A}_K^{\sigma-1} + \widetilde{A}_L^{\sigma-1} \frac{\eta_L}{\eta_K}}{1 + \frac{\eta_L}{\eta_K}} \right)^{1/(\sigma-1)} \tag{46}$$

Notice that an industry with $\eta_L + \eta_K$ homogeneous firms, each producing with technology parameters $\widetilde{\phi}$ and $\widetilde{A}$, leads to the same aggregate outcome as an industry with η_L and η_K heterogeneous firms, each producing with parameters ϕ_L, $\widetilde{A}_L$, ϕ_K and $\widetilde{A}_K$, respectively (see appendix I).

Now, we consider the effects of a multilateral trade liberalization among N countries. For simplicity, we focus on the case in which $f_X = f_K$.[18] This implies that all the capital intensive firms which can afford to serve the domestic market, will also be able to serve the foreign one and the zero cutoff profit condition for entry into the foreign market is identical to the one for entry into the domestic market. Notice that trade liberalization affects the free entry condition for capital intensive firms (equation 41), which now becomes:

$$N \left[1 - G\left(A_K^*\right)\right] \left[\left(\frac{\widetilde{A}_K}{A_K^*} \right)^{\sigma-1} - 1 \right] = \frac{f_E}{f_K}. \tag{47}$$

Our assumptions of symmetry across countries and $f_X = f_K$ imply that the threshold productivity level for capital intensive firms serving the domestic and the foreign markets are the same, and therefore the *ex–ante* probability of becoming an exporter equals the *ex–ante* probability of serving the domestic market. We can now establish the following result:

Lemma 5 *Trade liberalization increases the threshold and the average productivity level of capital intensive firms.*

Proof. See appendix J. ■

To understand the intuition behind lemma 5, notice that trade liberalization increases *ex–ante* expected profits and thus triggers additional entry. Competition becomes stronger, which implies that only the more productive capital intensive firms will survive. Notice though that the *PC* curve is only indirectly affected by trade liberalization, as it has been derived from the zero cutoff profit condition for the supply to the domestic market. In particular, the TFP threshold level for labor intensive firms is not affected, and the increase in the TFP threshold A_K^*, which is brought about by trade liberalization, will shift the *PC* curve upwards.[19]

As for the relative factor market clearing condition, following trade liberalization it takes the

[18] All our qualitative results continue to hold if $f_X \geq f_K$, and the results are available upon request.

[19] This follows immediately from equation 43.

following form:

$$\frac{\overline{L}}{\overline{K}} r^{-\sigma} = \frac{(1-\phi_K)N\widetilde{A}_K^{\sigma-1} + (1-\phi_L)\widetilde{A}_L^{\sigma-1}\frac{\eta_L}{\eta_K}}{\phi_K N\widetilde{A}_K^{\sigma-1} + \phi_L\widetilde{A}_L^{\sigma-1}\frac{\eta_L}{\eta_K}}. \tag{48}$$

Notice that, with trade liberalization, capital intensive firms increase their production by the factor N. In addition, the increase in $\widetilde{A}_K$ further increases the output of capital intensive firms, leading to an additional increase in relative capital demand. Thus, trade liberalization shifts the FMC–curve to the right.

The extent of the factor relocation between capital and labor intensive firms depends, as in section 5, on the factor intensity gap $\phi_K - \phi_L$ between exporters and non–exporters. We can show that $\frac{\eta_L}{\eta_K}$ increases (decreases) with trade liberalization if $\phi_K - \phi_L$ is at its maximum (minimum) level. Furthermore, trade liberalization is more detrimental (beneficial) for the exporting (non–exporting) firms, the larger is $\phi_K - \phi_L$ (see appendix L).

The theoretical models that have built upon Melitz's (2003) pioneering contribution, have emphasized the positive effect that trade liberalization has on aggregate TFP. At the same time, recent empirical evidence (Lawless and Whelan (2008)) has suggested that these effects might be only moderate. How does trade liberalization affect average productivity in the presence of heterogeneity in factor shares? Our model suggests that the consequences are a priori ambiguous. On the one hand, lemma 5 has established that trade liberalization increases A_K^* and $\widetilde{A}_K$. On the other hand, depending on the factor intensity gap between exporters and non–exporters, trade liberalization can lead to a factor relocation towards capital intensive exporters or towards labor intensive non–exporters. Since non–exporters are less productive than exporters, any factor relocation towards non–exporters counteracts the increase in A_K^* and $\widetilde{A}_K$.

Still, if we assume that the TFP parameter follows a Pareto–distribution with density $g(A) = \frac{k}{A_{i,min}}\left(\frac{A_{i,min}}{A}\right)^{k+1}$, $i = L, K$, where $A_{i,min}$ denotes the lower bound of the support and $k \geq \sigma - 1$, we can establish the following result:[20]

Proposition 6 *Trade liberalization implies that:*

i) the sector–wide average TFP parameter and the sector–wide average capital share parameter increase;

ii) if the factor intensity gap $\phi_K - \phi_L$ is sufficiently large (small), the increase in the sector–wide average TFP parameter is smaller (larger), compared to the standard Melitz (2003) model.

In general, the larger is the factor intensity gap $\phi_K - \phi_L$, the smaller is the increase in the sector–wide average TFP parameter brought about by trade liberalization.

[20] Axtell (2001) and Cabral and Mata (2003), among others, have shown that a Pareto–distribution describes appropriately the distribution of TFP across firms in manufacturing. The restriction $k > \sigma - 1$ is necessary in order to guarantee that $\widetilde{A}_K = \left(\frac{k}{1+k-\sigma}\right)^{1/(\sigma-1)} A_K^*$ is defined for all values of σ.

Proof. See appendix M. ■ The intuition for results *i*) and *ii*) is as follows: on the one hand, as shown in lemma 5, the increase in A_K^* and $\widetilde{A}_K$ does not depend on the factor intensity gap $\phi_K - \phi_L$. On the other, proposition 2 has shown that the factor relocation between exporters and non–exporters depends on the factor intensity gap. In particular, the larger is the latter, the smaller (larger) is the factor relocation towards capital (labor) intensive firms, which implies a smaller increase in the sector–wide average TFP parameter. Notice that the labor intensive firms are less productive than the capital intensive firms since $f_K > f_L$ and entry costs are identical. Thus, any factor relocation towards labor intensive firms counteracts the positive effect on $\widetilde{A}$, which results from the increase in A_K^* and $\widetilde{A}_K$. As long as trade liberalization leads to an increase in $\frac{\eta_L}{\eta_K}$, the increase in the sector–wide average TFP parameter is smaller than in the model by Melitz (2003).

8 Assessing the model

Having highlighted the role of heterogeneity in input shares in the firm selection process, we can now return to the data to determine whether the channels we have identified in the theoretical analysis do indeed play a role. In particular, we will focus on Propositions 2 and 6, which summarize the core of our findings. Thus, in this section, we will study how export growth and the factor intensity gap between exporters and non–exporters interact in shaping firm selection. In our empirical implementation we focus on differences in skill (human capital) intensities across firms.[21]

Proposition 2 suggests that, the larger is the factor intensity gap between exporters and non–exporters, the more adverse is the effect of an increase in sector–wide exports on the probability of survival for exporters. Non–exporters, on the other hand, should not be affected significantly. In order to assess this prediction, we first compute a measure of skill intensity for each plant as the share of skilled wages on the total wage bill.[22] Then we calculate the difference between the skill intensity of the median exporter and the skill intensity of the median non–exporter in each 3–digit ISIC sector and year. We call this difference the sector skill gap. Next, we divide the 3–digit sectors into two groups: those that have a sector skill gap above the median and those that fall instead below the median. We then define a dummy variable equal to one for sectors whose skill gap is above the median, and interact this variable with the aggregate exports of that sector. A negative and statistically significant estimate for the interaction term in the regression for exporters would support the predictions of our model.

The first three columns of Table 5 present the results of including the interaction term on the 3–year survival probability of exporting plants.[23] In all specifications, the impact of exports

[21] Using physical capital instead does not affect the direction of our results.

[22] This measure has been used, among others, by Pavcnik (2003), Bernard, Jensen, and Schott (2006a), and Alvarez and Lopez (2009).

[23] We have obtained similar results looking at 1– and 5–year survival probabilities, and these findings are available upon request.

on survival probability is still negative and significant. The dummy for high sector skill gap is positive and significant, whereas the estimate for the interaction term is negative and statistically significant in all cases. This implies that an increase in exports reduces the exporters' survival probability, and the effect is larger in sectors in which the skill intensity gap between exporters and non–exporters is larger. The same effect is, however, not found among non–exporters, as shown in columns 4-6. In this case, the sign of the interaction term is either positive or negative. Notice though that it is either similar or smaller in magnitude and of the opposite sign than the estimate for direct effect of exports, which implies that the negative effect of the interaction term and the positive estimate for exports cancel out. In other words, this confirms that export volumes do not affect the probability of survival of non–exporters.

A second important prediction of our model follows from our analysis of the interaction between heterogeneity in TFP and heterogeneity in factor shares. In particular, proposition 6 has shown that an increase in exports should increase sector–wide average productivity by less if the skill intensity gap between exporters and non–exporters is large. To assess this hypothesis, we estimate the effect of exports on productivity at the sector level, by including an interaction term between exports and the sector skill gap dummy defined above. Our measure of sector j average productivity at time t, TFP_{jt} is a weighted average of plant–level productivity, where weights are the share of the plant in industry output:

$$TFP_{jt} = \sum_{i=1}^{N_{jt}} s_{ijt} TFP_{ijt},$$

The s_{ijt} term represents plant i's share in total output at time t, TFP_{ijt} is total factor productivity of plant i at time t, and N_{jt} is the number of plants in industry j at time t. To assess the importance of factor relocation between firms on sector–wide TFP we follow Olley and Pakes (1996) and Pavcnik (2002) and decompose it into two elements: the unweighted mean of productivity and a covariance term between productivity and output:

$$TFP_{jt} = \overline{TFP}_{jt} + \sum_{i=1}^{N_{jt}} \Delta s_{ijt} \Delta TFP_{ijt},$$

where $\Delta s_{ijt} = s_{ijt} - \overline{s}_{jt}$, and $\Delta TFP_{ijt} = TFP_{ijt} - \overline{TFP}_{jt}$, with $\overline{s}_{jt}$ and $\overline{TFP}_{jt}$ representing unweighted mean market share and unweighted mean productivity respectively. The covariance term represents the contribution to the aggregate weighted productivity resulting from the reallocation of market shares and resources across plants of different productivity levels.

In order to control for unobserved heterogeneity at the industry level and for common shocks that may have affected all sectors, we include 3–digit level sector and year dummy variables.[24] To avoid potential simultaneity problems, exports are included lagged one period. The results are

[24]Including additional control variables, such as the share of MNC in total output, the size of the sector, and the skill intensity of the sector does not affect the results in any significant way.

presented in Table 6. The first column suggests that an increase in exports increases TFP. By looking at column 3, we see though that over a third of this increase is driven by the reallocation of resources towards the more productive firms. The effect, however, varies across sectors. To see this, notice how the estimate for the interaction term between exports and the dummy for sectors with high skill gap is negative and significant in column 1. This finding is completely explained by the negative effect on the covariance term in column 3, which suggests that an increase in the volume of exports generates a smaller reallocation of resources toward the more productive firms in sectors in which the skill intensity gap between exporters and non–exporters is high. This result is consistent with our theoretical model and highlights the importance of the channels we have identified.

9 Conclusions

In this paper, we have began our analysis by documenting how Chilean exporters are less likely to survive than non–exporters in the presence of export growth. We have argued that this stylized fact is a puzzle from the point of view of the existing theoretical literature, and to address it we have developed a new theoretical framework, in which the main driver of heterogeneity is given by differences in factor input ratios across firms.

We have obtained several interesting results. First, in a setting in which capital intensive firms have higher fixed production costs and fixed export costs exist, only the more capital intensive firms can afford to serve the foreign market after trade liberalization. Second, an increase in sector–wide exports increases competition for capital, and its relative price. This reduces the profits of capital intensive exporters, and increases those of labor intensive non–exporters. As a result, some of the exporters will have to cease production. This effect is stronger, the bigger is the difference in factor intensities between exporters and non–exporters.

Next, we have extended our analysis to include heterogeneity in TFP a la Melitz (2003), and have studied how the two sources of heterogeneity interact in shaping firm selection. We have shown that trade liberalization always increases sector–wide TFP, but that the size of the effect is negatively related to the difference in factor input ratios between exporters and non–exporters.

Last, we have tested the main predictions of our model using our Chilean firm–level dataset. Not only we have found broad support for the model, but we have also been able to verify that the main channels we have identified do play a key role in explaining the observed firm dynamics in Chile. Thus, our paper highlights the importance of taking into account heterogeneity in factor input ratios to explain firm dynamics.

Appendix

A Average foreign income

The level of foreign income is measured as a weighted average of the level of per capita GDP of the 15 main destination countries of Chilean exports for each industry. We divide the manufacturing sector into 28 sub–sectors according to the 3–digit ISIC code. For each of these sectors we use data from customs to calculate the main destinations of Chilean exports. The averages of the shares of each country are used as weights. Thus, we define the foreign income relevant for sector j at time t as:

$$GDP_{jt} = \sum_{c=1}^{15} GDP_{ct}\, s_{cj}, \tag{49}$$

where GDP_{ct} is the real per capita GDP of country c in year t (the per capita GDPs are in constant U.S. dollars and come from the PennWorld Table v. 6.1). We keep the weights s_{cj} constant for the entire period and compute them as:

$$s_{cj} = \sum_{t=1}^{T} \frac{1}{T} \frac{Exports_{cjt}}{Exports_{jt}}, \tag{50}$$

where $Exports_{cjt}$ is the value of exports from sector j to country c at time t, and $Exports_{jt}$ is the value of exports from sector j to all countries c at time t. T is the number of years.

B Average capital share parameter in autarky

The zero profit conditions (equation 12) imply that, in general equilibrium, $q(\phi_i) + f_i = q(\phi_i)\frac{\sigma}{\sigma-1}$ for $i = L, K$. Furthermore, if we define the average capital share parameter in autarky as $\widetilde{\phi}_a \equiv \frac{\phi_K + \phi_L\left(\frac{\eta_L}{\eta_K}\right)_a}{1+\left(\frac{\eta_L}{\eta_K}\right)_a}$ equations 10 and 11 can be rewritten as:

$$\overline{L} = M\,\frac{1-\widetilde{\phi}_a}{\widetilde{\phi}_a r^{1-\sigma} + 1 - \widetilde{\phi}_a}, \qquad \text{and} \qquad \overline{K} = M\,\frac{\widetilde{\phi}_a}{\widetilde{\phi}_a r^{1-\sigma} + 1 - \widetilde{\phi}_a}$$

Notice that these are the factor market equilibrium conditions that would result with $(\eta_K + \eta_L)$ average firms, each of which producing with the capital share parameter $\widetilde{\phi}_a$. Finally, using the definition of $\widetilde{\phi}_a$ it follows immediately that: $P^{1-\sigma} = \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}(\widetilde{\phi}_a r^{1-\sigma} + 1 - \widetilde{\phi}_a)(\eta_K + \eta_L)$.

C Proof of proposition 2

The proof proceeds in four steps. *First*, we show that $r_{ft} \geq r_a$. Let $\Psi_a \equiv \left(\frac{f_K}{f_L}\right)^{(\sigma-1)/\sigma}$ and $\Psi_{ft} \equiv \left(\frac{f_K+f_X}{2f_L}\right)^{(\sigma-1)/\sigma}$. The ratio $\frac{r_{ft}}{r_a}$ is then given by:

$$\frac{r_{ft}}{r_a} = \left\{\frac{[\Psi_{ft}(1-\phi_L) - (1-\phi_K)]\,[\phi_K - \Psi_a\phi_L]}{[\Psi_a(1-\phi_L) - (1-\phi_K)]\,[\phi_K - \Psi_{ft}\phi_L]}\right\}^{1/(1-\sigma)} \geq 1 \tag{51}$$

since $\Psi_{ft} \leq \Psi_a$ which follows from our assumption that $f_K \geq f_X$.

Second, we show that $\frac{r_{ft}}{r_a}$ is smaller, the larger is ϕ_K and the smaller is ϕ_L, i.e. the larger is the factor intensity gap between capital and labor intensive firms. In fact:

$$\frac{\partial(\frac{r_{ft}}{r_a})}{\partial\phi_K} = \frac{(\phi_K - \Psi_{ft}\phi_L)(\phi_K - \Psi_a\phi_L)\left(\phi_L r_{ft}^{1-\sigma} r_a^{1-\sigma} + 1 - \phi_L\right)}{(\frac{r_a}{r_{ft}})^\sigma \frac{1-\sigma}{\Psi_a - \Psi_{ft}} \{[\Psi_a(1-\phi_L) - (1-\phi_K)][\phi_K - \Psi_{ft}\phi_L]\}^2} < 0 \tag{52}$$

since $\Psi_a \geq \Psi_{ft}$ and $\phi_K - \Psi_m\phi_L > 0$, $m = a, ft$, if the two types of firms are active in general equilibrium. Furthermore

$$\frac{\partial(\frac{r_{ft}}{r_a})}{\partial\phi_L} = \frac{(\phi_K - \Psi_{ft}\phi_L)(\phi_K - \Psi_a\phi_L)\left(\phi_K r_{ft}^{1-\sigma} r_a^{1-\sigma} + 1 - \phi_K\right)}{(\frac{r_a}{r_{ft}})^\sigma \frac{1-\sigma}{\Psi_{ft} - \Psi_a} \{[\Psi_a(1-\phi_L) - (1-\phi_K)][\phi_K - \Psi_{ft}\phi_L]\}^2} > 0 \tag{53}$$

since, again, $\Psi_a \geq \Psi_{ft}$ and $\phi_K - \Psi_m\phi_L > 0$, $m = a, ft$, if the two types of firms are active in general equilibrium. Since the relationship between $\frac{r_{ft}}{r_a}$ and ϕ_i, $i = K, L$ is monotonic, we can assume in the following without loss of generality: $\phi_K = 1 - \phi_L$.

Third, we can show that the rightward shift of the *FMC*–condition with trade liberalization does not depend on the factor intensity gap $\phi_K - \phi_L$. Solving the *FMC*–conditions under autarky and free trade (equations 17 and 28) for $(\frac{\eta_L}{\eta_K})_a$ and $(\frac{\eta_L}{\eta_K})_{ft}$, and taking their ratio results in:

$$\frac{(\eta_L/\eta_K)_{ft}}{(\eta_L/\eta_K)_a} = \frac{\frac{2(1-\phi_K) - 2\frac{\overline{L}}{\overline{K}} r_{ft}^{-\sigma}\phi_K}{\frac{\overline{L}}{\overline{K}} r_{ft}^{-\sigma}(1-\phi_K) - \phi_K}}{\frac{1-\phi_K - \frac{\overline{L}}{\overline{K}} r_a^{-\sigma}\phi_K}{\frac{\overline{L}}{\overline{K}} r_a^{-\sigma}(1-\phi_K) - \phi_K}}. \tag{54}$$

Thus, for *each* constant level of $r = r_{ft} = r_a$ we get $\frac{(\eta_L/\eta_K)_{ft}}{(\eta_L/\eta_K)_a} = 2$, i.e. the relative mass of labor intensive firms doubles with trade liberalization. Therefore, the rightward shift of the *FMC*–curve does not depend on the factor intensity gap.

Fourth, we can show that $\frac{\eta_L}{\eta_K}$ decreases (increases) with trade liberalization if the factor intensity gap is at its maximum (minimum) level. The maximum value of the factor intensity gap is 1 since ϕ_K and ϕ_L are restricted by the interval $[0, 1]$. We define the minimum level of the factor intensity gap as that value which leads to $(\frac{\eta_K}{\eta_L})_a = 0$. $(\frac{\eta_K}{\eta_L})_a$ is given by (remember that $\phi_K = 1 - \phi_L$):

$$\left(\frac{\eta_K}{\eta_L}\right)_a = \frac{\frac{\overline{L}}{\overline{K}} r_a^{-\sigma}(1-\phi_K) - \phi_K}{1 - \phi_K - \frac{\overline{L}}{\overline{K}} r_a^{-\sigma}\phi_K} \tag{55}$$

Thus, $(\frac{\eta_K}{\eta_L})_a = 0$ if $\frac{\overline{L}}{\overline{K}} r_a^{-\sigma}(1 - \phi_K^{min}) - \phi_K^{min} = 0$ and the minimum factor intensity gap results as $\phi_K^{min} - (1 - \phi_K^{min}) = 2\phi_K^{min} - 1$. In order to prove that ϕ_K^{min} is uniquely defined, we substitute the expression for r_a into $\frac{\overline{L}}{\overline{K}} r_a^{-\sigma}(1 - \phi_K^{min}) - \phi_K^{min} = 0$. Rearranging terms leads to:

$$\left(\frac{\eta_K}{\eta_L}\right)_a = 0 \iff \underbrace{\left[\frac{\phi_K(\Psi_a + 1) - 1}{\phi_K(\Psi_a + 1) - \Psi_a}\right]^{\sigma/(\sigma-1)} \frac{1-\phi_K}{\phi_K}}_{\equiv\Pi} = \frac{\overline{K}}{\overline{L}}.$$

We are now able to determine the following partial derivative:

$$\frac{\partial \Pi}{\partial \phi_K} = \frac{\sigma}{\sigma-1}\left[\frac{\phi_K(\Psi_a+1)-1}{\phi_K(\Psi_a+1)-\Psi_a}\right]^{\frac{1}{1-\sigma}} \frac{(\Psi_a+1)(1-\Psi_a)}{[\phi_K(\Psi_a+1)-\Psi_a]^2} - \left(\frac{\phi_K(\Psi_a+1)-1}{\phi_K(\Psi_a+1)-\Psi_a}\right)^{\frac{\sigma}{\sigma-1}} \frac{1}{\phi_K^2} \quad (56)$$

Equation 56 shows that $\frac{\partial \Pi}{\partial \phi_K} < 0$ for all values of ϕ_K since $\Psi_a > 1$. Thus, $(\frac{\eta_K}{\eta_L})_a = 0$ only if $\phi_K = \phi_K^{min}$. Furthermore, notice that $(\frac{\eta_K}{\eta_L})_a > 0$ if the numerator in the term for $\frac{\eta_K}{\eta_L}$ (equation 55) is negative since the denominator is already negative due to $\frac{1-\phi_K}{r^{-\sigma}\phi_K} < \frac{\overline{L}}{\overline{K}}$. Thus, if $\phi_K > \phi_K^{min}$ we get $\frac{\overline{L}}{\overline{K}} r_a^{-\sigma}(1-\phi_K) - \phi_K < 0$ and $(\frac{\eta_K}{\eta_L})_a > 0$.

Therefore, since $\frac{\overline{L}}{\overline{K}} r_a^{-\sigma}(1-\phi_K^{min}) - \phi_K^{min} = 0$ and $r_{ft} > r_a$, it follows immediately that $\frac{\eta_K}{\eta_L}$ increases with trade liberalization if the factor intensity gap is at its minimum level. Finally, if the factor intensity gap between exporters and non–exporters is at its maximum, i.e. $\phi_K = 1$ and $\phi_L = 0$, we have that $(\frac{\eta_K}{\eta_L})_a = \frac{K f_L}{L f_K} > (\frac{\eta_K}{\eta_L})_{ft} = \frac{K f_L}{L(f_X+f_K)}$.

D The zero profit condition in the right panel of figure 2

In this appendix the subscript a denotes variables in the autarkic equilibrium, $ft1$ variables in the free trade equilibrium *before* any adjustment of relative factor prices and $ft2$ variables in the free trade equilibrium *after* any adjustment of relative factor prices. Considering equations 4, 12 and 26, we can derive the intercepts with the axes of the capital intensive firms' zero profit conditions. Under autarky, they are given by:

$$\eta_{K,a} = \left[\frac{M}{p(\phi_K)}\right]_a \frac{1}{(\sigma-1)f_K} \quad \text{and} \quad \eta_{L,a} = \left[\frac{Mp(\phi_K)^{-\sigma}}{p(\phi_L)^{1-\sigma}}\right]_a \frac{1}{(\sigma-1)f_K}.$$

After trade liberalization and *before* any adjustment of relative factor prices, the axis intercepts are given by:

$$\eta_{K,ft1} = \left[\frac{M}{p(\phi_K)}\right]_{ft1} \frac{1}{(\sigma-1)(f_K+f_X)} \quad \text{and} \quad \eta_{L,ft1} = \left[\frac{Mp(\phi_K)^{-\sigma}}{p(\phi_L)^{1-\sigma}}\right]_{ft1} \frac{2}{(\sigma-1)(f_K+f_X)}.$$

Since $\left[\frac{M}{p(\phi_K)}\right]_a = \left[\frac{M}{p(\phi_K)}\right]_{ft1}$ and $\left[\frac{Mp(\phi_K)^{-\sigma}}{p(\phi_L)^{1-\sigma}}\right]_a = \left[\frac{Mp(\phi_K)^{-\sigma}}{p(\phi_L)^{1-\sigma}}\right]_{ft1}$, we get the following result: $\frac{\eta_{K,ft1}}{\eta_{K,a}} = \frac{f_K}{f_K+f_X} < 1$ and $\frac{\eta_{L,ft1}}{\eta_{L,a}} = \frac{2f_K}{f_K+f_X} \geq 1$.

In order to determine how the increase in r affects the η_K–axis intercept, we have to consider the following partial derivative:

$$\frac{\partial[M/p(\phi_K)]}{\partial r} = -r^{-\sigma}c(\phi_K)^{\sigma-2}K\phi_K\left(\frac{L}{K} - \frac{1-\phi_K}{\phi_K r^{-\sigma}}\right) < 0. \quad (57)$$

Thus, $\left[\frac{M}{p(\phi_K)}\right]_{ft2} < \left[\frac{M}{p(\phi_K)}\right]_{ft1}$ and, concerning the η_K–axis intercepts, $\eta_{K,ft2} < \eta_{K,ft1}$.

In order to determine how the increase in r affects the η_L–axis intercept, we *first* have to consider that the increase in r makes the capital intensive firms' zero profit condition ceteris paribus flatter: the slope of the zero profit condition after trade liberalization is given by $\frac{d\eta_L}{d\eta_K} = -2\left[\frac{p(\phi_K)}{p(\phi_L)}\right]^{1-\sigma}$ and $\frac{\partial[p(\phi_K)/p(\phi_L)]}{\partial r} > 0$. *Second*, we have to consider that a division of the zero profit conditions of the two types of firms leads to $\left[\frac{p(\phi_K)}{p(\phi_L)}\right]^{-\sigma} = \frac{f_K}{f_L}$ in the autarkic equilibrium (see equation 12) and to $\left[\frac{p(\phi_K)}{p(\phi_L)}\right]^{-\sigma} = \frac{f_K+f_X}{2f_L}$ in the free trade equilibrium (see equations 26 and **??**). Thus:

$$\eta_{L,a} = \left[\frac{M}{p(\phi_L)}\right]_a \frac{1}{(\sigma-1)f_L} < \eta_{L,ft2} = \left[\frac{M}{p(\phi_L)}\right]_{ft2} \frac{1}{(\sigma-1)f_L} \tag{58}$$

since $\frac{\partial[M/p(\phi_L)]}{\partial(r/w)} > 0$. Finally, since the capital intensive firms' zero profit condition becomes flatter with the increase in r and since $\eta_{K,ft2} < \eta_{K,ft1}$, we can conclude that $\eta_{L,ft2} < \eta_{L,ft1}$.

E Proof of proposition 3

Remember that $\widetilde{\phi}_a = \frac{\phi_K+\phi_L\left(\frac{\eta_L}{\eta_K}\right)_a}{1+\left(\frac{\eta_L}{\eta_K}\right)_a}$. Since the production of each individual capital intensive firm ceteris paribus doubles, the average sector–wide capital share parameter is given by $\widetilde{\phi}_{ft} = \frac{2\phi_K+\phi_L\left(\frac{\eta_L}{\eta_K}\right)_{ft}}{2+\left(\frac{\eta_L}{\eta_K}\right)_{ft}}$. Thus, $\widetilde{\phi}_{ft} > \widetilde{\phi}_a$ if and only if $(\phi_K - \phi_L)\left[2\left(\frac{\eta_L}{\eta_K}\right)_a - \left(\frac{\eta_L}{\eta_K}\right)_{ft}\right] \geq 0$. This condition always holds since $\left(\frac{\eta_L}{\eta_K}\right)_{ft} = 2\left(\frac{\eta_L}{\eta_K}\right)_a$ if $f_K = f_X$ and $\left(\frac{\eta_L}{\eta_K}\right)_{ft} < 2\left(\frac{\eta_L}{\eta_K}\right)_a$ if $f_K > f_X$, for any factor intensity gap $\phi_K - \phi_L$.

F The effects of an increase in N

If we define $\Psi_N \equiv \left[\frac{f_K+(N-1)f_X}{Nf_L}\right]^{\frac{\sigma-1}{\sigma}}$, the PC–condition can be written as follows:

$$r_{ft} = \left[\frac{\Psi_N(1-\phi_L)-(1-\phi_K)}{\phi_K - \Psi_N\phi_L}\right]^{\frac{1}{1-\sigma}}, \tag{59}$$

The partial derivative of r_{ft} with respect to N results as follows:

$$\frac{\partial r_{ft}}{\partial N} = \frac{1}{1-\sigma} r_{ft}^{\sigma} \frac{\phi_K - \phi_L}{(\phi_K - \Psi\phi_L)^2}\frac{\partial \Psi}{\partial N}, \qquad \text{with} \quad \frac{\partial \Psi}{\partial N} = \frac{\sigma-1}{\sigma}\Psi^{1/(1-\sigma)}\frac{f_L\,(f_X - f_K)}{(Nf_L)^2}.$$

Since $f_K \geq f_X$ and $\phi_K > \phi_L$, it follows that the PC curve shifts upwards with an increase in the number of trading partners N. Notice also that $\lim_{N\to\infty}\Psi = \left(\frac{f_X}{f_L}\right)^{\frac{\sigma-1}{\sigma}}$. Thus, if $N \to \infty$, we get $r_{ft} > r_a$ if $f_X < f$ and $r_{ft} = r_a$ if $f_K = f_X$. Furthermore, it is straightforward to check that $\lim_{N\to\infty} r_{ft} < 1$ since $\left(\frac{f_X}{f_L}\right)^{(\sigma-1)/\sigma} > 1$, i.e. r_{ft} is always strictly smaller than 1, even if $N \to \infty$.

Turning now to the panel on the right of figure 5, the η_L–axis intercept of the zero profit condition for capital intensive firms is given by:

$$\eta_{L,ft} = \frac{NMp\,(\phi_K)^{-\sigma}}{p\,(\phi_L)^{1-\sigma}} \frac{1}{[f_K + (N-1)f_X]\,(\sigma-1)}. \tag{60}$$

The partial derivative with respect to N results as:

$$\frac{\partial \eta_{L,ft}}{\partial N} = \frac{Mp(\phi_K)^{-\sigma}}{p(\phi_L)^{1-\sigma}} \frac{f_K - f_X}{[f_K + (N-1) f_X]^2 (\sigma - 1)} \geq 0. \tag{61}$$

Furthermore, $\lim_{N\to\infty} \eta_{L,ft} = \frac{Mp(\phi_K)^{-\sigma}}{f_X p(\phi_L)^{1-\sigma}(\sigma-1)} \geq \eta_{L,a} = \frac{Mp(\phi_K)^{-\sigma}}{f_K p(\phi_L)^{1-\sigma}(\sigma-1)}$. Finally, the η_K–axis intercept of the zero profit condition for capital intensive firms is given by:

$$\eta_{K,ft} = \frac{M}{p(\phi_K)} \frac{1}{[f_K + (N-1) f_X](\sigma - 1)}. \tag{62}$$

Thus, if $N \to \infty$ we get $\eta_{K,ft} \to 0$ and $\eta_{L,ft} > 0$.

G Proof of lemma 4

Using our definition of $\widetilde{A}_i$, equation 40 can be rewritten as follows:

$$\left[\frac{1}{\sigma-1}\frac{1}{\widetilde{A}_i} q\left(\widetilde{A}_i, \phi_i\right) - f_i\right] = \frac{f_{Ei}}{[1 - G(A_i^*)]}. \tag{63}$$

Since $\frac{q\left(A_i^*, \phi_i\right)}{q\left(\widetilde{A}_i, \phi_i\right)} = \left(\frac{\widetilde{A}_i}{A_i^*}\right)^{-\sigma}$, the zero cutoff profit condition (equation 39) can be transformed to:

$$q\left(\widetilde{A}_i, \phi_i\right) = \left(\frac{\widetilde{A}_i}{A_i^*}\right)^{\sigma} A_i^*(\sigma-1) f_i. \tag{64}$$

Substituting equation 64 into equation 63 and simplification leads to equation 41 in the main part.

H *FMC* curve under TFP heterogeneity

With heterogeneity in TFP we get $a_{Ki} = A_i^{\sigma-1}\phi_i r^{-\sigma} c(A_i, \phi_i)^{\sigma}$ and $a_{Li} = A_i^{\sigma-1}(1-\phi_i) c(A_i, \phi_i)^{\sigma}$. Notice that $\frac{\partial a_{Ki}}{\partial A_i} < 0$ and $\frac{\partial a_{Li}}{\partial A_i} < 0$, since $c(A_i, \phi_i)^{\sigma} = \left[\frac{1}{A_i}\left(\phi_i r^{1-\sigma} + 1 - \phi_i\right)^{1/(1-\sigma)}\right]^{\sigma}$. Fixed costs are not influenced by the TFP parameter, and are still given by equation 7. Let $\widetilde{f}_i \equiv \frac{f_{Ei}}{1-G\left(A_i^*\right)} + f_i$, i.e. $\widetilde{f}_i$ stands for the total fixed costs in general equilibrium. The *FMC* condition can be rewritten as

$$\frac{\overline{L}}{\overline{K}} = \frac{\sum_{i=L,K} (1-\phi_i) \left[\left(\phi_i r^{1-\sigma} + 1 - \phi_i\right)^{1/(1-\sigma)}\right]^{\sigma} \left[\frac{1}{\widetilde{A}_i} q\left(\widetilde{A}_i, \phi_i\right) + \widetilde{f}_i\right] \eta_i}{\sum_{i=L,K} \phi_i r^{-\sigma} \left[\left(\phi_i r^{1-\sigma} + 1 - \phi_i\right)^{1/(1-\sigma)}\right]^{\sigma} \left[\frac{1}{\widetilde{A}_i} q\left(\widetilde{A}_i, \phi_i\right) + \widetilde{f}_i\right] \eta_i}. \tag{65}$$

Finally, remembering that $q\left(\widetilde{A}_i, \phi_i\right) = MP^{\sigma-1}\left[\frac{\sigma}{\sigma-1}\frac{1}{\widetilde{A}_i}\left(\phi_i r^{1-\sigma}+1-\phi_i\right)^{1/(1-\sigma)}\right]^{-\sigma}$ and that free entry implies $\frac{q\left(\widetilde{A}_i,\phi_i\right)}{\widetilde{A}_i(\sigma-1)} = \widetilde{f}_i = \frac{f_{Ei}}{1-G\left(A_i^*\right)} + f_i$, equation 65 can be simplified to:

$$\frac{\overline{L}}{\overline{K}} r^{-\sigma} \quad = \quad \frac{(1-\phi_K)\widetilde{A}_K^{\sigma-1} + (1-\phi_L)\widetilde{A}_L^{\sigma-1}\frac{\eta_L}{\eta_K}}{\phi_K\widetilde{A}_K^{\sigma-1} + \phi_L\widetilde{A}_L^{\sigma-1}\frac{\eta_L}{\eta_K}} \tag{66}$$

I Proof of proposition 5

To establish proposition 5, notice that from lemma 4 we know that A_K^* and A_L^* only depend on the parameters f_E and f_i and the distribution of A. Therefore, $\widetilde{A}_K^{\sigma-1}$ and $\widetilde{A}_L^{\sigma-1}$ are determined from equation 41 alone. Equations 43 and 44 can then be solved for r and η_L/η_K like in the autarkic equilibrium *without* firm heterogeneity with respect to TFP. Finally, notice that the right hand side of equation 66 still depends positively on $\frac{\eta_L}{\eta_K}$, i.e. equation 44 is still represented by a negatively sloping *FMC* curve.

J Aggregation under TFP heterogeneity — autarky

Adding the TFP–terms $\left(\frac{1}{\widetilde{A}_L}\right)^{1-\sigma}$ and $\left(\frac{1}{\widetilde{A}_K}\right)^{1-\sigma}$ to the factor market clearing conditions of appendix B and defining $\widetilde{A}_a^{\sigma-1} \equiv \frac{\widetilde{A}_{K,a}^{\sigma-1}+\widetilde{A}_L^{\sigma-1}\left(\frac{\eta_L}{\eta_K}\right)_a}{1+\left(\frac{\eta_L}{\eta_K}\right)_a}$ and $\widetilde{\phi}_a \equiv \frac{\phi_K\widetilde{A}_{K,a}^{\sigma-1}+\phi_L\widetilde{A}_L^{\sigma-1}\left(\frac{\eta_L}{\eta_K}\right)_a}{\widetilde{A}_{K,a}^{\sigma-1}+\widetilde{A}_L^{\sigma-1}\left(\frac{\eta_L}{\eta_K}\right)_a}$, the factor market equilibrium conditions can be rewritten as follows:

$$\overline{L} \;= M\frac{\left[1+\left(\frac{\eta_L}{\eta_K}\right)_a\right]\widetilde{A}_a^{\sigma-1}\left(1-\widetilde{\phi}_a\right)}{\left[1+\left(\frac{\eta_L}{\eta_K}\right)_a\right]\widetilde{A}_a^{\sigma-1}\left(\widetilde{\phi}_a r_a^{1-\sigma}+1-\widetilde{\phi}_a\right)} = \quad M\frac{1-\widetilde{\phi}_a}{\widetilde{\phi}_a r_a^{1-\sigma}+1-\widetilde{\phi}_a} \tag{67}$$

$$\overline{K} \;= M\frac{\left[1+\left(\frac{\eta_L}{\eta_K}\right)_a\right]\widetilde{A}_a^{\sigma-1}\widetilde{\phi}_a}{\left[1+\left(\frac{\eta_L}{\eta_K}\right)_a\right]\widetilde{A}_a^{\sigma-1}\left(\widetilde{\phi}_a r_a^{1-\sigma}+1-\widetilde{\phi}_a\right)} = \quad M\frac{\widetilde{\phi}_a}{\widetilde{\phi}_a r_a^{1-\sigma}+1-\widetilde{\phi}_a}. \tag{68}$$

These are the same conditions which would result in an economy with $\eta_a = \eta_{K,a} + \eta_{L,a}$ average firms, each of which producing with the technology parameters $\widetilde{A}_a$ and $\widetilde{\phi}_a$.

K Proof of lemma 5

In order to prove lemma 5, we show that the term $\left(1-G\left(A_K^*\right)\right)\left[\left(\frac{\widetilde{A}_K}{A_K^*}\right)^{\sigma-1}-1\right] \equiv \Lambda$ depends negatively on A_K^*. Remember that $\widetilde{A}_K = \left[\int_{A_K^*}^{\infty} A^{\sigma-1}\mu(A)dA\right]^{1/(\sigma-1)}$ is also a function of A_K^*. Then, using Leibniz's rule to calculate $\frac{\partial\widetilde{A}_K}{\partial A_K^*}$, we obtain

$$\frac{\partial\Lambda}{\partial A_K^*} \quad = \quad -\left[1-G\left(A_K^*\right)\right](\sigma-1)\left(\frac{\widetilde{A}_K}{A_K^*}\right)^{\sigma-2}\frac{\widetilde{A}_K}{\left(A_K^*\right)^2} < 0. \tag{69}$$

Since trade liberalization adds the ex–ante expected profits from serving $N-1$ foreign markets to the left hand side of the free entry condition (see equation 47), the threshold TFP–parameter A_K^*

has to increase so that Λ decreases and the free entry condition in the free trade situation holds again.

L Firm selection with trade liberalization and TFP heterogeneity

We can illustrate the relationship between the factor intensity gap and firm selection with trade liberalization again by the upward shift of the PC–curve and the rightward shift of the FMC–curve. The upward shift of the PC–curve is determined by the ratio $\frac{r_{ft}}{r_a}$, whereas the rightward shift of the FMC–curve is determined by the ratio $\frac{(\eta_L/\eta_K)_{ft}}{(\eta_L/\eta_K)_a}$.

If we define $\Psi_a \equiv \left(\frac{f_K}{f_L}\right)^{(\sigma-1)/\sigma}\left(\frac{A^*_{K,a}}{A^*_L}\right)^{(1-\sigma)^2/-\sigma}$ and $\Psi_{ft} \equiv \left(\frac{f_K}{f_L}\right)^{(\sigma-1)/\sigma}\left(\frac{A^*_{K,ft}}{A^*_L}\right)^{(1-\sigma)^2/-\sigma}$, the ratio $\frac{r_{ft}}{r_a}$ is given by:

$$\frac{r_{ft}}{r_a} = \left\{\frac{\left[\Psi_{ft}(1-\phi_L)-(1-\phi_K)\right]\left[\phi_K-\Psi_a\phi_L\right]}{\left[\Psi_a(1-\phi_L)-(1-\phi_K)\right]\left[\phi_K-\Psi_{ft}\phi_L\right]}\right\}^{1/(1-\sigma)}. \tag{70}$$

Notice that $\Psi_{ft} \leq \Psi_a$ since A^*_K increases with trade liberalization. Thus, $\frac{r_{ft}}{r_a} > 1$. Furthermore, the ratio $\frac{(\eta_L/\eta_K)_{ft}}{(\eta_L/\eta_K)_a}$ results as follows:

$$\frac{(\eta_L/\eta_K)_{ft}}{(\eta_L/\eta_K)_a} = \frac{\frac{(1-\phi_K)-\frac{\overline{L}}{\overline{K}}r_{ft}^{-\sigma}\phi_K}{\frac{\overline{L}}{\overline{K}}r_{ft}^{-\sigma}(1-\phi_K)-\phi_K}}{\frac{1-\phi_K-\frac{\overline{L}}{\overline{K}}r_a^{-\sigma}\phi_K}{\frac{\overline{L}}{\overline{K}}r_a^{-\sigma}(1-\phi_K)-\phi_K}}\, N\frac{\widetilde{A}^{\sigma-1}_{K,ft}}{\widetilde{A}^{\sigma-1}_L}. \tag{71}$$

Compared to the case *without* firm heterogeneity in TFP, the ratio $\frac{\widetilde{A}^{\sigma-1}_{K,ft}}{\widetilde{A}^{\sigma-1}_L}$ adds to the right hand side. Notice that $\frac{\widetilde{A}^{\sigma-1}_{K,ft}}{\widetilde{A}^{\sigma-1}_L}$ does not depend on the factor intensity gap $\phi_K-\phi_L$. Therefore, both $\frac{r_{ft}}{r_a}$ and $\frac{(\eta_L/\eta_K)_{ft}}{(\eta_L/\eta_K)_a}$ react to a change in the factor intensity gap the same way as we described in appendix C for the case *without* firm heterogeneity in TFP.

M Proof of proposition 6

As in appendix J we can define the average sector–wide TFP parameter and capital share parameter as $\widetilde{A}^{\sigma-1}_{ft} \equiv \frac{\widetilde{A}^{\sigma-1}_{K,ft}N+\widetilde{A}^{\sigma-1}_L\left(\frac{\eta_L}{\eta_K}\right)_{ft}}{N+\left(\frac{\eta_L}{\eta_K}\right)_{ft}}$ and $\widetilde{\phi}_{ft} \equiv \frac{\phi_K\widetilde{A}^{\sigma-1}_{K,ft}N+\phi_L\widetilde{A}^{\sigma-1}_L\left(\frac{\eta_L}{\eta_K}\right)_{ft}}{\widetilde{A}^{\sigma-1}_{K,ft}N+\widetilde{A}^{\sigma-1}_L\left(\frac{\eta_L}{\eta_K}\right)_{ft}}$. Using the definition of $\widetilde{A}^{\sigma-1}_{ft}$ and $\widetilde{\phi}_{ft}$, equation 48 can be rewritten as follows:

$$\frac{\overline{L}}{\overline{K}}r_{ft}^{-\sigma} = \frac{1-\widetilde{\phi}_{ft}}{\widetilde{\phi}_{ft}} \tag{72}$$

Furthermore, the sector–wide average TFP and capital share parameter in the autarkic equilibrium are respectively given by $\widetilde{A}^{\sigma-1}_a = \frac{\widetilde{A}^{\sigma-1}_{K,a}+\widetilde{A}^{\sigma-1}_L\left(\frac{\eta_L}{\eta_K}\right)_a}{1+\left(\frac{\eta_L}{\eta_K}\right)_a}$ and $\widetilde{\phi}_a = \frac{\phi_K\widetilde{A}^{\sigma-1}_{K,a}+\phi_L\widetilde{A}^{\sigma-1}_L\left(\frac{\eta_L}{\eta_K}\right)_a}{\widetilde{A}^{\sigma-1}_{K,a}+\widetilde{A}^{\sigma-1}_L\left(\frac{\eta_L}{\eta_K}\right)_a}$.

First, we will show that $\widetilde{A}^{\sigma-1}_{ft} > \widetilde{A}^{\sigma-1}_a$ even if trade liberalization leads to the maximum possible increase of $\frac{\eta_L}{\eta_K}$. Remember that the non–exporters do not experience a productivity–enhancing firm selection with trade liberalization. We have shown previously that a factor intensity gap $\phi_K - \phi_L = 1$ leads to the maximum possible increase of $\frac{\eta_L}{\eta_K}$ with trade liberalization. If $\phi_K = 1$ and $\phi_L = 0$, the *FMC* and the *PC*–conditions reduce respectively to:

$$\frac{\overline{L}}{\overline{K}} r_{ft}^{-\sigma} = \frac{\widetilde{A}_L^{\sigma-1}\left(\frac{\eta_L}{\eta_K}\right)_{ft}}{N\widetilde{A}_{K,ft}^{\sigma-1}} \qquad \text{and} \qquad r_{ft} = \left(\frac{f_L}{f_K}\right)^{\sigma}\left(\frac{A_L^*}{A_{K,ft}^*}\right)^{(1-\sigma)/\sigma}$$

Combining the two conditions, we obtain:

$$\frac{\overline{L}}{\overline{K}}\frac{f_K}{f_L} = \frac{\left(\frac{\widetilde{A}_L}{A_L^*}\right)^{\sigma-1}\left(\frac{\eta_L}{\eta_K}\right)_{ft}}{N\left(\frac{\widetilde{A}_{K,ft}}{A_{K,ft}^*}\right)^{\sigma-1}}. \tag{73}$$

Furthermore, assuming that A is Pareto distributed on the interval $[A_i^*; +\infty)$, $i = L, K$, with conditional density $\mu(A) = \frac{k\left(A_i^*\right)^k}{A^{k+1}}$, $k > 0$, leads to $\frac{\widetilde{A}_i}{A_i^*} = \left(\frac{k}{1+k-\sigma}\right)^{1/(\sigma-1)}$ for $i = K, L$. Therefore we can rewrite equation 73 as follows: $\frac{\left(\frac{\eta_L}{\eta_K}\right)_{ft}}{N} = \frac{\overline{L}}{\overline{K}}\frac{f_K}{f_L}$. Since the right hand side of this equation is constant, $\frac{\eta_L}{\eta_K}$ and N change proportionately if trade liberalization leads to the maximum possible increase in $\frac{\eta_L}{\eta_K}$. This implies immediately that $\widetilde{A}_{ft}^{\sigma-1} > \widetilde{A}_a^{\sigma-1}$ since $\widetilde{A}_K^{\sigma-1}$ increases with trade liberalization.

Second, we can argue along the same lines that the sector–wide average capital share parameter $\widetilde{\phi}$ increases with trade liberalization: even if $\frac{\eta_L}{\eta_K}$ and N change proportionately with trade liberalization, ϕ_K gets a larger weight in the definition of $\widetilde{\phi}$ since $\widetilde{A}_K^{\sigma-1}$ increases with trade liberalization.

Third, we can show that it depends on the factor intensity gap $\phi_K - \phi_L$ whether the increase in the sector–wide average TFP parameter in our setup is larger or smaller than in the setup by Melitz (2003). Notice that the group of capital intensive firms in our setup corresponds to the entire group of firms in Melitz's model. If we denote by $\Delta A^{\sigma-1}$ the change in the sector–wide TFP parameter with trade liberalization, we get the following for our setup and the setup by Melitz (2003) (subscript *Melitz*), respectively:

$$\Delta\widetilde{A}^{\sigma-1} = \widetilde{A}_{ft}^{\sigma-1} - \widetilde{A}_a^{\sigma-1}, \qquad \Delta\widetilde{A}_{Melitz}^{\sigma-1} = \widetilde{A}_{K,ft}^{\sigma-1} - \widetilde{A}_{K,a}^{\sigma-1}.$$

Substituting the terms for $\widetilde{A}_{ft}^{\sigma-1}$ and $\widetilde{A}_a^{\sigma-1}$ into the expression for $\Delta\widetilde{A}^{\sigma-1}$ and simplification leads to the following:

$$\Delta\widetilde{A}^{\sigma-1} - \Delta\widetilde{A}_{Melitz}^{\sigma-1} = \left(\widetilde{A}_{K,a}^{\sigma-1} - \widetilde{A}_L^{\sigma-1}\right)N\left(\frac{\eta_K}{\eta_L}\right)_{ft} - \left(\widetilde{A}_{K,ft}^{\sigma-1} - \widetilde{A}_L^{\sigma-1}\right)\left(\frac{\eta_K}{\eta_L}\right)_a + \widetilde{A}_{K,a}^{\sigma-1} - \widetilde{A}_{K,ft}^{\sigma-1} \tag{74}$$

If the factor intensity gap between exporters and non–exporters is at its *minimum* level, i.e. if $\left(\frac{\eta_K}{\eta_L}\right)_a = 0$, equation 74 simplifies as follows:

$$\Delta\widetilde{A}^{\sigma-1} - \Delta\widetilde{A}_{Melitz}^{\sigma-1} = \left(\widetilde{A}_{K,a}^{\sigma-1} - \widetilde{A}_L^{\sigma-1}\right)N\left(\frac{\eta_K}{\eta_L}\right)_{ft} + \widetilde{A}_{K,a}^{\sigma-1} - \widetilde{A}_{K,ft}^{\sigma-1}. \tag{75}$$

Equation 75 shows that for $\Delta\widetilde{A}^{\sigma-1} - \Delta\widetilde{A}^{\sigma-1}_{Melitz}$ to be positive, the increase in $\widetilde{A}^{\sigma-1}_{K}$ needs to be sufficiently small. Notice that the first term on the right hand side is positive since $\widetilde{A}^{\sigma-1}_{K,a} > \widetilde{A}^{\sigma-1}_{L}$. Thus, even in the case of the most favorable firm selection, only if the increase in $\widetilde{A}^{\sigma-1}_{K}$ is sufficiently small, our model generates a larger increase in the industry–wide average TFP parameter, compared to the setup by Melitz (2003).

If, in contrast, the factor intensity gap between exporters and non–exporters is at its *maximum* level, i.e. if $\left(\frac{\eta_K}{\eta_L}\right)_a = N\left(\frac{\eta_K}{\eta_L}\right)_{ft}$, equation 74 reduces to the following:

$$\Delta\widetilde{A}^{\sigma-1} - \Delta\widetilde{A}^{\sigma-1}_{Melitz} = \left[\left(\frac{\eta_K}{\eta_L}\right)_a + 1\right]\left(\widetilde{A}^{\sigma-1}_{K,a} - \widetilde{A}^{\sigma-1}_{K,ft}\right) < 0. \quad (76)$$

Thus, if the factor relocation with trade liberalization is such that $\frac{\eta_K}{\eta_L}$ decreases by the factor N, the increase in sector–wide average TFP in our setup is clearly smaller than in Melitz (2003).

Finally, we can show that the increase in $\widetilde{A}^{\sigma-1}$ in our setup becomes larger if $\left(\frac{\eta_K}{\eta_L}\right)_{ft}$ is ceteris paribus larger, i.e. if the factor intensity gap $\phi_K - \phi_L$ is smaller and trade liberalization is less detrimental for the capital intensive exporters:

$$\frac{\partial\left(\Delta\widetilde{A}^{\sigma-1}\right)}{\partial\left(\frac{\eta_K}{\eta_L}\right)_{ft}} = \frac{N\left(\widetilde{A}^{\sigma-1}_{K,ft} - \widetilde{A}^{\sigma-1}_{L}\right)}{\left[N\left(\frac{\eta_K}{\eta_L}\right)_{ft} + 1\right]^2} > 0. \quad (77)$$

References

Alvarez, R. and H. Görg (2009). Multinationals and plant exit: Evidence from Chile. *International Review of Economics and Finance 18*, 45–51.

Alvarez, R. and R. López (2005). Exporting and performance: evidence from Chilean plants. *Canadian Journal of Economics 38*, 1384–1400.

Alvarez, R. and R. Lopez (2009). Skill upgrading and the real exchange rate. *The World Economy 32*, 1165–1179.

Axtell, R. L. (2001). Zipf distribution of U.S. firm sizes. *Science 293*, 1818–1820.

Bernard, A. B., J. Eaton, S. Kortum, and J. B. Jensen (2003). Plants and productivity in international trade. *American Economic Review 93*, 1268–1290.

Bernard, A. B. and J. B. Jensen (1995). Exporters, jobs, and wages in U.S. manufacturing: 1976-1987. *Brookings Papers on Economic Activity: Microeconomics 1995*, 67–119.

Bernard, A. B., J. B. Jensen, and P. K. Schott (2006a). Survival of the best fit: Exposure to low-wage countries and the (uneven) growth of U.S. manufacturing plants. *Journal of International Economics 68*, 219–237.

Bernard, A. B., J. B. Jensen, and P. K. Schott (2006b). Trade costs, firms and productivity. *Journal of Monetary Economics 53*, 917–937.

Bernard, A. B., S. Redding, and P. K. Schott (2007). Comparative advantage and heterogeneous firms. *Review of Economic Studies 74*, 31–66.

Cabral, L. M. B. and J. Mata (2003). On the evolution of the firm size distribution: Facts and theory. *American Economic Review 93*, 1075–1090.

Dunne, T., M. Roberts, and L. Samuelson (1989). The growth and failure of U.S. manufacturing plants. *Quarterly Journal of Economics 104*, 671–698.

Kasahara, H. and J. Rodrigue (2008). Does the use of imported intermediates increase productivity? plant-level evidence. *Journal of Development Economics 87*, 106–118.

Lawless, M. and K. Whelan (2008). Where do firms export, how much, and why? mimeo, uc dublin.

Leonardi, M. (2007). Firm heterogeneity in capital labor ratios and wage inequality. *Economic Journal 117*, 1–24.

Levinsohn, J. and A. Petrin (2003). Estimating production functions using inputs to control for unobservables. *Review of Economic Studies 70*, 317–341.

López, R. A. (2006). Imports of intermediate inputs and plant survival. *Economics Letters 92*, 58–62.

Markusen, J. R. and A. J. Venables (2000). The theory of endowment, intra–industry and multi–national trade. *Journal of International Economics 52*, 209–234.

Melitz, M. (2003). The impact of trade on intra–industry reallocations and aggregate industry productivity. *Econometrica 71*, 1695–1725.

Moulton, B. R. (1990). An illustration of a pitfall in estimating the effects of aggregate variables on micro units. *Review of Economics and Statistics 72*, 334–338.

Olley, G. S. and A. Pakes (1996). The dynamics of productivity in the telecommunications equipment industry. *Econometrica 64*, 1263–1297.

Pavcnik, N. (2002). Trade liberalization, exit, and productivity improvements: evidence from chilean plants. *Review of Economic Studies 69*, 245–276.

Pavcnik, N. (2003). What explains skill upgrading in less developed countries? *Journal of Development Economics 71*, 311–328.

Salvanes, K. G. and R. Tveteras (2004). Plant exit, vintage capital and the business cycle. *Journal of Industrial Economics 52*, 255–276.

Staiger, D. and J. H. Stock (1997). Instrumental variables with weak instruments. *Econometrica 65*, 557–586.

Yeaple, S. R. (2005). A simple model of firm heterogeneity, international trade, and wages. *Journal of International Economics 65*, 1–20.

Tables

TABLE 1: Number of plants by export status

	Exporters	Non–exporters	Total	% of exporters
1990	758	3,816	4,574	16.6
1991	910	3,848	4,758	19.1
1992	979	3,952	4,931	19.9
1993	1,053	3,983	5,036	20.9
1994	1,112	3,966	5,078	21.9
1995	1,129	3,978	5,107	22.1
1996	1,163	4,284	5,447	21.4
1997	1,101	3,859	4,960	22.2
1998	1,052	3,763	4,815	21.8
1999	917	3,483	4,400	20.8
Average 1990-99	1,017	3,893	4,911	20.7

TABLE 2: Survival rates for exporters and non–exporters
(Fraction of plants in each year that survive 1, 3, or 5 years)

	Exporters			Non–exporters		
	1–year	3–year	5–year	1–year	3–year	5–year
1990	96.4	90.5	85.0	94.1	86.1	77.0
1991	95.6	89.3	82.0	93.9	84.8	73.2
1992	96.0	88.3	76.6	92.6	81.8	67.1
1993	95.6	86.1	72.1	93.0	79.5	62.3
1994	95.1	82.2	65.5	90.7	72.8	56.5
1995	94.8	78.2	-	90.1	69.4	-
1996	88.7	72.7	-	83.2	64.9	-
1997	92.7	-	-	89.6	-	-
1998	86.1	-	-	82.0	-	-

TABLE 3: Descriptive statistics: Mean values for 1990–1999

	Exporters	Non–exporters
Employment (log)	4.67	3.48
Importer intermediate inputs	0.56	0.18
TFP (log)	7.29	6.83
Share of skilled labor in total wage bill	0.47	0.35
Foreign ownership	0.15	0.03
Foreign technology licenses	0.15	0.03
Age (log)	2.21	2.11

TABLE 4: 3–year survival probability (probit, marginal effects)

	(1)	(2)	(3)	(4)	(5)	(6)
	Exporters			Non–exporters		
3–digit sector exports	-0.042	-0.036	-0.035	-0.001	-0.001	0.010
	(3.91)**	(3.45)**	(2.61)**	(0.11)	(0.14)	(1.07)
Employment	0.027	0.028	0.027	0.042	0.042	0.042
	(5.25)**	(5.32)**	(5.25)**	(9.31)**	(9.26)**	(9.27)**
Imports intermediate inputs dummy	0.036	0.036	0.036	0.057	0.057	0.056
	(3.86)**	(3.85)**	(3.87)**	(6.33)**	(6.33)**	(6.31)**
Productivity	0.046	0.045	0.046	0.059	0.059	0.060
	(7.87)**	(7.83)**	(7.81)**	(17.28)**	(17.34)**	(17.19)**
Share skilled wages total wage bill	-0.001	-0.001	-0.001	-0.066	-0.066	-0.066
	(0.03)	(0.05)	(0.04)	(4.41)**	(4.41)**	(4.41)**
Foreign ownership dummy	-0.041	-0.041	-0.041	-0.207	-0.207	-0.206
	(3.00)**	(3.00)**	(3.00)**	(10.68)**	(10.67)**	(10.67)**
Foreign technology licenses dummy	0.021	0.020	0.021	0.015	0.015	0.015
	(1.50)	(1.47)	(1.49)	(1.03)	(1.03)	(1.04)
Age	0.038	0.038	0.038	0.041	0.041	0.041
	(7.01)**	(6.94)**	(7.01)**	(10.84)**	(10.79)**	(10.84)**
3–digit share of MNC in value added	-0.100	-0.117	-0.099	0.049	0.050	0.048
	(1.16)	(1.39)	(1.17)	(0.85)	(0.84)	(0.85)
3–digit sector employment		-0.147			0.005	
		(3.42)**			(0.13)	
3–digit sector value added			-0.036			-0.058
			(0.94)			(2.27)*
Number of observations	6,666	6,666	6,666	23,291	23,291	23,291

Robust z statistics in parentheses. + significant at 10%; * significant at 5%; ** significant at 1%. Standard errors were clustered at the 3–digit sector–year level. Regressions include sector and year dummy variables. Exports, productivity, age, employment, and value added are in logs.

TABLE 5: 3–year survival probability and the skill intensity gap (probit, marginal effects)

	(1)	(2)	(3)	(4)	(5)	(6)
	Exporters			Non–exporters		
3–digit sector exports	-0.036	-0.027	-0.025	0.003	0.003	0.016
	(3.31)**	(2.62)**	(1.84)+	(0.30)	(0.33)	(1.70)+
3–digit sector exports × high sector skill gap	-0.012	-0.014	-0.013	-0.006	-0.006	0.007
	(2.14)*	(2.62)**	(2.20)*	(1.75)+	(1.75)+	(1.91)+
High sector skill gap	0.168	0.195	0.172	0.099	0.100	0.106
	(1.97)*	(2.36)*	(2.00)*	(1.63)	(1.64)	(1.86)+
Employment	-0.097	-0.117	-0.097	0.042	0.042	0.042
	(1.11)	(1.38)	(1.13)	(9.34)**	(9.29)**	(9.30)**
Imports intermediate inputs dummy	0.027	0.027	0.027	0.057	0.057	0.056
	(5.22)**	(5.28)**	(5.22)**	(6.36)**	(6.36)**	(6.33)**
Productivity	0.036	0.036	0.036	0.059	0.059	0.060
	(3.84)**	(3.83)**	(3.86)**	(17.26)**	(17.29)**	(17.24)**
Share skilled wages total wage bill	0.045	0.045	0.046	-0.066	-0.066	-0.066
	(7.86)**	(7.82)**	(7.82)**	(4.45)**	(4.45)**	(4.46)**
Foreign ownership dummy	0.000	-0.000	-0.000	-0.206	-0.206	-0.206
	(0.01)	(0.02)	(0.01)	(10.66)**	(10.66)**	(10.65)**
Foreign technology licenses dummy	-0.041	-0.040	-0.041	0.014	0.014	0.015
	(2.97)**	(2.96)**	(2.97)**	(1.02)	(1.02)	(1.03)
Age	0.021	0.020	0.021	0.041	0.041	0.041
	(1.50)	(1.46)	(1.49)	(10.86)**	(10.79)**	(10.86)**
3–digit share of MNC in value added	0.038	0.038	0.038	0.045	0.044	0.043
	(7.05)**	(6.98)**	(7.05)**	(0.78)	(0.74)	(0.75)
3–digit sector employment		-0.172			-0.006	
		(3.99)**			(0.15)	
3–digit sector value added			-0.050			-0.067
			(1.28)			(2.65)**
Number of observations	6,666	6,666	6,666	23,291	23,291	23,291

Robust z statistics in parentheses. + significant at 10%; * significant at 5%; ** significant at 1%. Standard errors were clustered at the 3–digit sector–year level. Regressions include sector and year dummy variables. Exports, productivity, age, employment, and value added are in logs.

TABLE 6: Effect of exports on TFP

	(1)	(2)	(3)
	TFP	Unweighted TFP	Covariance
3–digit sector exports	0.1810	0.1168	0.0642
	(3.43)**	(3.18)**	(1.41)
3–digit sector exports × high sector skill gap	-0.0079	0.0006	-0.0085
	(2.22)*	(0.30)	(2.46)*
No. observations	249	249	249
R–squared	0.945	0.970	0.775

Absolute value of robust t–statistics in parentheses. ** significant at 1%, * significant at 5%. Dummy variables for each year, sector, and for sectors highly skilled intensive were included but no reported. Exports are lagged one period.

TABLE A1: 3–year survival probability (IV probit, marginal effects)

	(3)	(4)	(5)	(4)	(5)	(6)
		exporters			Non–exporters	
3–digit sector exports	-0.094	-0.088	-0.097	0.007	0.008	0.014
	(2.53)*	(2.20)*	(2.35)*	(0.51)	(0.50)	(0.94)
Employment	0.027	0.028	0.027	0.042	0.042	0.042
	(5.34)**	(5.40)**	(5.33)**	(9.44)**	(9.38)**	(9.40)**
Imports intermediate inputs dummy	0.036	0.036	0.036	0.057	0.057	0.056
	(3.81)**	(3.80)**	(3.81)**	(6.73)**	(6.73)**	(6.69)**
Productivity	0.046	0.046	0.046	0.059	0.059	0.060
	(8.45)**	(8.45)**	(8.14)**	(17.63)**	(17.71)**	(17.55)**
Share skilled wages total wage bill	-0.003	-0.004	-0.002	-0.065	-0.065	-0.066
	(0.11)	(0.14)	(0.08)	(4.37)**	(4.37)**	(4.38)**
Foreign ownership dummy	-0.041	-0.041	-0.041	-0.207	-0.207	-0.206
	(2.83)**	(2.83)**	(2.80)**	(9.40)**	(9.40)**	(9.40)**
Foreign technology licenses dummy	0.020	0.019	0.020	0.015	0.015	0.015
	(1.48)	(1.46)	(1.52)	(1.07)	(1.07)	(1.07)
Age	0.038	0.038	0.038	0.041	0.041	0.041
	(7.09)**	(7.05)**	(7.11)**	(10.66)**	(10.62)**	(10.65)**
3–digit share of MNC in value added	-0.116	-0.128	-0.113	0.053	0.053	0.049
	(1.23)	(1.39)	(1.18)	(0.91)	(0.88)	(0.86)
3–digit sector employment		-0.101			-0.004	
		(1.83)+			(0.10)	
3–digit sector value added			0.039			-0.063
			(0.60)			(2.10)*
Number of observations	6,666	6,666	6,666	23,291	23,291	23,291
Wald test of exogeneity	2.01	1.74	2.49	0.40	0.39	0.07
(p–value)	(0.1559)	(0.1877)	(0.1145)	(0.5251)	(0.5321)	(0.7921)
F–test excluded instruments	44.44	38.84	35.48	61.31	46.79	68.06

Robust z statistics in parentheses. + significant at 10%; * significant at 5%; ** significant at 1%. Standard errors were clustered at the 3–digit sector–year level. Regressions include sector and year dummy variables. Exports, productivity, age, employment, and value added are in logs. Instrumented: 3–digit sector exports. Instrument: Weighted average of per capita GDP of the 15 main export destination countries of each sector.