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Abstract

This paper explores how trade openness affects both product and process innovation in a factor proportions model of trade and firm heterogeneity. Trade openness expands the profit opportunities of the most productive firms and expels the less efficient firms out of the market, making process innovation more attractive for the most productive firms in both industries. Incentives, however, are larger in the industry in which the country has the comparative advantage. Trade also increases the profits of prospective entrants leading to an increase in product innovation in the comparative advantage industry. In addition, I obtain a non-monotonic relationship between trade costs and a country's trade pattern: When the level of trade costs are high, a reduction in trade costs leads to an increase in process innovation in both industries, being stronger in the comparative advantage one; when the trade costs are low the effect is stronger in the comparative disadvantage one. This final result could rationalize recent empirical findings suggesting that in the last half century the Ricardian comparative advantage has become weaker over time.

Keywords: Innovation, Firm Heterogeneity, Comparative Advantage.

JEL Codes: F12, F43

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1 Introduction

Neoclassical trade theories emphasize the role of differences in technology (Ricardo (1817), Jones (1971), Dornbusch, Fischer and Samuelson (1977) Eaton and Kortum (2002)) or differences in factor endowments (Heckscher-Ohlin (1933), Samuelson (1948, 1953)) to explain trade flows and trade patterns across countries. New trade theories have incorporated scale economies at an industry and firm level to explain several features of the data that the neoclassical theories were finding difficult to explain like the intra-industry trade phenomenon, or the fact that only a small proportion of firms within each industry are exporting (Melitz (2003), Bernard, Jensen, Eaton and Kortum (2003), Melitz and Ottaviano (2008), Chaney (2008)). While these theories have identified different institutional factors that may affect a country's specialisation pattern still, technological and factor endowment differences across countries are at the heart of a country's specialisation pattern. At the empirical level, several studies have emphasized the importance of technology and factor endowments in accounting for trade patterns and trade volumes across countries. (Trefler (1993, 1995), Harrigan (1997), Romalis (2004) and Morrow (2010).[1]

The new new trade theory based on firm heterogeneity and increasing returns to scale developed by Melitz (2003) and Melitz and Ottaviano (2008), has outlined a new mechanism through which trade increases welfare in trading countries: The impact of trade on technology through selection. Trade through tougher competition expels the less efficient firms out of the market reallocating market shares across the most productive surviving incumbents. By concentrating the production in the most efficient industry units, this increases an industry's average productivity. A recent paper by Bernard, Redding and Schott (2007) outlines the importance of this mechanism to establish a link between the previously discussed two potential sources of comparative advantage: Differences in factor endowments through selection generates a Ricardian comparative advantage. Tougher selection in the comparative advantage industry leads to a relatively larger increase in the average productivity of that industry after trade openness.

This paper explores the link between technology and factor endowments, by expanding a 2x2x2 standard model of trade, factor proportions and firm

[1]Trefler (1993,1995) obtain that while a standard Heckscher-Ohlin-Vanek model performs poorly in the data, a slightly version of the model that include differences in technology across countries improves substantially the model fit. Harrigan (1997) and Morrow (2010) examine instead the contribution of differences in TFP and differences in factor abundance in determining specialisation.

heterogeneity in which firms are allowed to upgrade their current state of technology. In our setup there are two final good industries, each of them characterized by a continuum of differentiated goods. The structure of each industry, is similar to Melitz (2003): Firms pay a fixed cost to create a new variety which allows them to enter in the market. To produce, firms use a linear technology that involves the use of an industry specific intermediate input. However, the firms' productivity is uncertain at the moment of entry. The industry-specific intermediate inputs are produced according to a Cobb-Douglas production function that uses both skilled and unskilled labour in different proportions across both final goods. After entry, productivity is revealed to the firm and the firm chooses whether to stay in the market and paying a per period fixed cost to produce. Once the firm has decided to stay, the firm has the option to upgrade its current state of technology by paying a fixed cost. In this framework I distinguish between process innovation (technology upgrading) and product innovation (the creation of new varieties).

Our results suggest that the selection effect found in Melitz (2003) leads to a rise in technology upgrading in both industries. Interestingly, technology upgrading is stronger in the industry in which the country has a comparative advantage. The reason behind this result is the fact that trade expands the business opportunities for the most productive firms in both sectors. However, trade expands it to a greater extent in the comparative advantage industry since the economy is able to offer these goods relatively cheaper than the foreign counterpart. This rises the expected profits of prospective entrants and induces a disproportionate entry in the comparative advantage industry. As a consequence, the relative demand for the abundant factor rises and this has a positive impact on the relative factor remuneration. Domestic firms see their profits reduced and the less efficient ones need to exit. The combination of a stealing business effect in the foreign country and a reallocation of market shares from the less efficient firms which exit, towards the most productive ones, induce a larger proportion of firms to upgrade their technology. Overall, technology upgrading rises in both industries and the comparative advantage industry enjoys more product and process innovations compared to an autarkic scenario. Using R&D intensities as a measure of innovation activity, the model predicts that trade openness increases the relative R&D intensity favouring the comparative advantage industry one. These last results reinforce the Ricardian-led-factor endowment comparative advantage by having a positive effect on within plant productivity improvements.

A further section in the paper explores the evolution of the comparative advantage by considering a reduction of trade costs when both industries are opened to trade. The results establishes a non-monotonic relationship between the level of trade costs and the evolution of comparative advantage: When trade costs are high, a reduction in trade costs increases technology upgrading and R&D intensities relatively more in the comparative advantage industry. This induces TFP divergence across sectors. However, if the trade costs are low enough a reduction in trade barriers increases technology upgrading and R&D intensities in the comparative disadvantage industry leading to TFP convergence across industries. Overall, average productivity, the proportion of firms that upgrade their technology and R&D intensities increase in both industries as trade costs fall. However, provided that there is self-selection into exporting markets, these three dimensions are always larger in the comparative advantage industry. This suggests that a gradual reduction in trade costs may eventually strengthen the pattern of comparative advantage at the initial stages while weaken it when the trade costs become sufficiently low.

This paper is related to several literatures. The first one is the literature on the effects of trade openness and trade liberalisation on innovation. A recent literature based on models with firm heterogeneity outlines the importance of selection effects in promoting process innovation (Atkeson and Burstein (2010), Bustos (2011), Impulliti and Licandro (2011), Navas and Sala (2007,2013), Long et al. (2010) and Mrazova and Neary (2011) among others). Unlike those papers we study the role played by factor endowments in determining the effect that trade has on innovation at the industry level. My model suggests that differences in factor intensities across industries and factor endowments across trade partners, may generate asymmetries in productivity and innovation across industries that in autarky exhibit identical productivity distributions. The second dimension is clearly a determinant of the dynamic evolution of the industry's average productivity.

This paper is also related to the literature that incorporates differences in factor endowments in models of trade with economies of scale(Krugman (1981), Helpman and Krugman (1987) (HK)). Those papers obtain the interesting result that most of the findings in the Heckscher-Ohlin model are also present in an environment in which there are increasing returns to scale at the firm level. More recently, Bernard, Redding and Schott (2007) (BRS) incorporates a factor proportions theory into a standard Melitz (2003) model of trade with firm heterogeneity and finds that the same H-O results are also present when we allow productivity to vary across firms. They also find that differences in factor endowments together with trade openness can generate a Ricardian comparative advantage as explained above. This paper goes in line with the above papers and reinforces the idea that the H-O results are robust to richer environments. In addition, by including the possibility of firms to technology upgrade, this paper finds that differences in factor intensities across industries and factor endowments across countries generates a different impact on trade-induced plant productivity improvements across firms with the same initial productivity. This result reinforces the early findings by BRS on Ricardian-led-factor endowment comparative advantage by having an impact on average industry productivity while it also suggests that this Ricardian advantage may persist along time.

Finally, this paper is related to a recent literature that investigates the evolution of comparative advantage. In a very interesting study, Levchenko and Zhang (2011) obtain that, contrary to the common knowledge, in the last 50 years on average, productivity has increased by more in a country's revealed comparative disadvantage industries. My paper suggests a non-monotonic relationship between trade costs and the pattern of comparative advantage and for sufficiently low level of trade costs, a reduction in trade barriers may benefit the comparative disadvantage industry, narrowing the differences in TFP across industries within a country. The evidence of Levchenko and Zhang (2011) could be consistent within this framework with a gradual reduction in trade barriers across countries provided that the initial level of trade costs were sufficiently low in the 1960s.

Section 2 of the paper describes the main elements of the model in autarky. On section 3, I discuss the main properties of the model in costless trade. In section 4, I discuss the most realistic case in which the economy is open to trade but trade is costly (both in variable and fixed trade barriers). In section 5, I analyze the effect of trade liberalisation (understood as a reduction in variable trade barriers). Section 6 concludes.

2 The model

Consider an economy inhabited by a continuum of consumers. There are two final goods. Let denote with C_i the consumption of good $i = 1, 2$. Each C_i is a composite good defined over a continuum of varieties belonging to the set Ω_i. Preferences over these goods are given by the following utility function:

$$U(C_1, C_2) = (C_1)^{\alpha} (C_2)^{1-\alpha}$$

$$C_1 = \left(\int\limits_{\omega \epsilon \Omega_1} \left(q_1\left(\omega\right)\right)^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}}$$

$$C_2 = \left(\int\limits_{\omega \epsilon \Omega_2} \left(q_2\left(\omega\right)\right)^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}}$$

Solving the consumer's problem we arrive to the standard CES aggregate demand function for each variety of the composite good:

$$q_i\left(\omega\right) = \frac{R_i}{P_i}\left(\frac{p_i(\omega)}{P_i}\right)^{-\sigma}$$

where R_i denotes consumer's expenditure dedicated to good i. Under Cobb-Douglas preferences $R_i = \alpha_i R$ where R denotes total revenue.

To produce, firms use an intermediate input (x_i) that is homogeneous to all products within the same industry but differ across industries. This intermediate input is produced competitively combining both capital and labor using the following Cobb-Douglas technology:

$$x_1 = A_1\left(S_1\right)^{\beta_1}\left(L_1\right)^{1-\beta_1}$$

$$x_2 = A_2\left(S_2\right)^{\beta_2}\left(L_2\right)^{1-\beta_2}$$

with $A_i = \left(\beta_i\right)^{\beta_i}\left(1-\beta_i\right)^{1-\beta_i}$.

We assume without loss of generalization that $\beta_1 > \beta_2$.This implies that the industry 1 uses intermediate inputs that are more skilled labour intensive. Perfect competition in the intermediate input sector implies that:

$$p_{mi} = \left(w_s\right)^{\beta_i}\left(w_l\right)^{1-\beta_i}$$

The production side in the final good sector is identical to Melitz (2003). To enter in the market, a firm needs to invest f_e units of the intermediate input to create a new variety. Once the firm has created this variety the firm obtains the monopoly rights to produce it. To produce, firms use a technology which is linear in the intermediate input. More precisely:

$$q_i(\varphi_i) = \varphi_i x_i$$

However, firms' productivity φ_i is unknown before the creation of this new variety. More precisely, the firm knows that the productivity parameter φ follows a random process with support $[0, \infty)$ and a cumulative continuous distribution function $G(\varphi)$. After the investment in the creation of this variety is undertaken, the productivity is revealed to the firm. The creation of new varieties of the same composite good is considered here as product innovation. To operate the technology the firm needs to pay a per period fixed investment of f_d units of the intermediate input. At this moment she needs to decide whether to stay and produce.

Once the firm decides to stay and produce, the firm has the possibility to adopt a new technology which improves their productivity by a factor of θ_i by investing a fixed amount f_I of the intermediate input of units. The process of a firm's technology upgrading will be denoted as process innovation. In this version of the model, I consider that all activities within an industry (product, process innovation, production and exporting when applies) use the same intermediate input. Consequently, all activities within an industry has the same factor intensity. However, these activities differ in factor intensities across industries.

The firms' problem is solved by backward induction. First, I solve for the firm's decision of technology upgrading. Then I solve for the the firm's decision of staying in the market taking into account its future decision of technology upgrading. Finally, I solve for the firm's entry decision, taking into account the flow of expected profits in the industry.

Since the variety produced by each firm is unique, a firm charges the standard monopoly price:

$$p_i(\varphi) = \frac{\sigma}{\sigma - 1} \frac{p_{mi}}{\varphi} = \frac{\sigma}{\sigma - 1} \frac{\omega_i}{(\theta_i)^d \varphi}$$

where d is the indicator function taking the value of 1 if the firm adopts the new technology and $\omega_i = (w_s)^{\beta_i} (w_l)^{1-\beta_i}$. The firm's operating profits are given by the following expression:

$$\pi_{vi}(\varphi) = \frac{R_i}{\sigma (P_i)^{1-\sigma}} \left(\rho (\theta_i)^d \varphi\right)^{\sigma-1} (\omega_i)^{1-\sigma} = \frac{r_{iD}(\varphi)}{\sigma}.$$

Notice that the ratio between the revenue of two non innovative firms is given by productivity ratio as in Melitz (2003) ($\frac{r_{iD}(\varphi_i)}{r_{iD}(\varphi_j)} = \left(\frac{\varphi_i}{\varphi_i}\right)^{\sigma-1}$).

A firm decides to adopt the new technology iff:

$$\left((\theta_i)^{\sigma-1} - 1\right)\left(\frac{r_{iD}(\varphi)}{\sigma}\right) \geq \delta f_{iI}\omega_i \tag{1}$$

with equality if the firm is indifferent between adopting the technology or staying with its current technology. Let denote with φ_{iI} the value of the productivity of the indifferent firm, which we call the marginal innovator.

The firm is indifferent between staying or exiting the market when:

$$\frac{r_{iD}(\varphi_{iD})}{\sigma} = f_{iD}\omega_i \tag{2}$$

This condition is known in the Melitz (2003) model as the ZP condition. Dividing (1) and (2) we have that:

$$\left(\frac{\varphi_{iI}}{\varphi_{iD}}\right)^{\sigma-1} = \left(\frac{\delta f_{iI}}{f_{iD}}\right)\frac{1}{\left((\theta_i)^{\sigma-1} - 1\right)}$$

Notice that the proportion of surviving firms undertaking process innovation is independent of the factor prices and therefore on factor endowments in autarky. This is the consequence of the fact that both activities are using the same intermediate input and therefore they use the production factors with the same intensity. Allowing for differences in factor intensities across activities within an industry breaks this result. We leave this possibility for future research.

Finally, a firm decides to enter in the industry iff $E(V) \geq f_{ei}\omega_i$. In this model we focus on steady state solutions. In steady state a firms' value function is given by the following expression:

$$V_i = \max\left\{0, \frac{\pi_{vi}(\varphi)}{\delta}, \frac{\pi_{vi}(\theta\varphi)}{\delta} - f_{iI}\omega_i\right\} \tag{3}$$

2.1 Equilibrium in a Closed-Economy Model

One of the interesting properties of the Melitz-type models is that the equilibrium of the economy, in our case perfectly characterized by the two productivity thresholds $\varphi_{iI}, \varphi_{iD}$, can be summarised with two conditions: The Zero Profit Condition (ZP) (Condition (2) in our model) and the Free Entry condition (FE). In this framework however, we need an extra equation that comes from the Zero Innovation Profits condition (Condition (1) in our model). The FE condition in this model becomes:

$$\left(\left(\frac{\tilde{\varphi}_{iD}}{\varphi_{iD}}\right)^{\sigma-1}-1\right)f_{iD}+\frac{(1-G(\varphi_{iI}))}{(1-G(\varphi_{iD}))}\left(\left(\frac{\tilde{\varphi}_{iI}}{\varphi_{iI}}\right)^{\sigma-1}-1\right)\delta f_{iI}=\frac{\delta f_{ei}}{(1-G(\varphi_{iD}))}.$$

The left hand side (lhs) of our FE condition is similar to a standard heterogenous-firm trade model. There is, however, an extra term, the second one, which represents the innovation profits. The possibility of technology upgrading increases the expected value of profits from entry by increasing the profits of the most productive firms.[2] Compared to Melitz (2003), the possibility of technology upgrading reallocates market shares from the less productive firms to the most productive ones, making survival more difficult in this economy. Consequently, φ_{iD} is larger in this case.

Despite the fact that this model exhibits a larger industry average productivity compared to a model without innovation due to the firm's possibility of technology upgrading, both sectors share the same productivity thresholds, $\varphi_{iD}, \varphi_{iI}$ and consequently the same average productivity, provided that the rest of the parameters are identical in both industries. In autarky, differences in factor endowments across countries are not generating differences in average productivity across industries.[3] In the skilled-labour abundant country, initially firms have larger expected profits in the comparative advantage industry (Industry 1) because marginal costs of production in that industry are relatively smaller. Consequently, firms can charge relatively lower prices and have relatively larger sales. However, the costs of entry are also smaller in that industry, and this together with the rise in the expected profits of the representative firm increases entry. The increase in entry offsets the positive effect that the comparative advantage mechanism is having on firms' profits.

However, as discussed above, there is more entry in the industry in which the economy has the comparative advantage. Thus, the model generates differences in the mass of surviving firms in equilibrium. To see this, notice that:

$$\frac{M_1}{M_2}=\frac{R_1}{R_2}\frac{\bar{r}_2}{\bar{r}_1}=\frac{\alpha}{1-\alpha}\frac{\left(\frac{\tilde{\varphi}_{2D}}{\varphi_{2D}}\right)^{\sigma-1}\sigma f_{2D}\left(\omega_2\right)}{\left(\frac{\tilde{\varphi}_{1D}}{\varphi_{1D}}\right)^{\sigma-1}\sigma f_{1D}\left(\omega_1\right)}=\frac{\alpha}{1-\alpha}\left(\frac{w_s}{w_L}\right)^{\beta_2-\beta_1} \quad (4)$$

[2]In Navas and Sala (2013) we show uniqueness of φ_D (and consequently φ_I). An identical proof to show uniqueness of each φ will apply in this context.

[3]The same result has been found in Bernard, Redding and Schott (2007).

Our country is skilled-labor abundant. We show in the appendix that this implies that:

$$\left(\frac{w_s^H}{w_L^H}\right) < \left(\frac{w_s^F}{w_L^F}\right)$$

, since $\beta_1 > \beta_2$, this implies that: $\frac{M_1^H}{M_2^H} > \frac{M_1^F}{M_2^F}$.

This result is already present in standard models of trade with imperfect competition and increasing returns to scale (Helpman and Krugman, 1985). Unlike existing work, the innovation resources in this economy are not constant across industries. The comparative advantage industry invests more resources in both product and process innovation. $R\&D$ expenditures in each sector are given by:

$$R\&D\exp_i = \underbrace{(f_{ei}M_{ei} + \delta f_{iI}M_{iI})}_{\text{amount of resources}} \quad \underbrace{(\omega_i)}_{\text{Resource cost}}$$

Considering the stationarity condition for each sector and rearranging terms:

$$R\&D\exp_i = \left(\frac{\delta f_{ei}}{(1 - G(\varphi_{iD}))} + \delta f_{iI}\frac{(1 - G(\varphi_{iI}))}{(1 - G(\varphi_{iD}))}\right) M_i\left(\omega_i\right)$$

Since φ_{iD}, φ_{iI} are identical across industries, considering the ratio of $R\&D\exp_i$ across industries we have that:

$$\frac{R\&D\exp_1}{R\&D\exp_2} = \frac{M_1}{M_2}\left(\frac{w_s}{w_L}\right)^{\beta_1-\beta_2} = \frac{\alpha}{1-\alpha}.$$

While the relative R&D expenditures just depend on the size of the sector α the amount of resources invested is larger in the industry in which the economy has a comparative advantage. To see this, consider the simpler case in which $\alpha = \frac{1}{2}$. In this case the economy is investing the same amount of income in innovation in both industries. However, in the industry in which the economy has the comparative advantage, the cost of resources is cheaper, and consequently this industry is investing in more resources.

A common indicator used in the industrial organization literature to measure the intensity of innovative activity within an industry is $R\&D$ intensity ($\frac{R\&D\text{ expenditures}}{sales}$).This measure corrects for the fact that R&D expenditures are positively affected by the size of the industry. The model suggests that R&D intensities are identical across industries as it can be seen below.

$$\frac{R\&Dint_1}{R\&Dint_2} = \frac{R\&D\exp_1}{R\&D\exp_2}\frac{R_2}{R_1} = 1.$$

3 Costless Trade

In this section, I explore the implications of the model for innovation when we consider a movement from autarky to free trade. Common to the new literature on firm-heterogeneity and factor endowments, including innovation in this environment does not alter the main properties of the Heckscher-Ohlin model. Moreover, R&D intensities are still invariant across industries and innovation does not have any impact on average productivity. In contrast to the one derived in this section, under costly trade, R&D intensities differ according to the comparative advantage. This has a clear impact on average productivity across industries.

Consider the possibility that the firm can serve the foreign market at no cost. The operating profits of a domestic firm in the domestic market is now given by:

$$\pi^{H}_{viD}(\varphi) = \left(\frac{R^{H}}{\sigma\left(P^{H}_{i}\right)^{1-\sigma}}\right)\left(\rho\left(\theta_{i}\right)^{d}\varphi\right)^{\sigma-1}\left(\omega^{H}_{i}\right)^{1-\sigma}$$

and the operating profits of a domestic firm in the foreign market is given by:

$$\pi^{F}_{viD}(\varphi) = \left(\frac{R^{F}}{\sigma\left(P^{F}_{i}\right)^{1-\sigma}}\right)\left(\rho\left(\theta_{i}\right)^{d}\varphi\right)^{\sigma-1}\left(\omega^{H}_{i}\right)^{1-\sigma}.$$

The marginal innovator in the Home country (H) must satisfy the following condition:

$$\left(1+\frac{R^{F}}{R^{H}}\left(\frac{P^{F}_{i}}{P^{H}_{i}}\right)^{\sigma-1}\right)\left(\left(\theta_{i}\right)^{\sigma-1}-1\right)\frac{r_{iD}(\varphi_{iI})}{\sigma} = \delta f_{iI}\left(\omega^{H}_{i}\right)$$

where $r_{iD}(\varphi_{iI}) = \left(\frac{R^{H}}{\left(P^{H}_{i}\right)^{1-\sigma}}\right)\left(\rho\varphi_{iI}\right)^{\sigma-1}\left(\omega^{H}_{i}\right)^{1-\sigma}$

The marginal survival, the one indifferent between staying on leaving the market is defined by the following condition:

$$\left(1+\frac{R^{H}}{R^{F}}\left(\frac{P^{H}_{i}}{P^{F}_{i}}\right)^{\sigma-1}\right)\frac{r_{iD}(\varphi_{iD})}{\sigma} = f_{iD}\left(\omega^{H}_{i}\right)$$

Then we have that:

$$\left(\frac{\varphi_{iI}}{\varphi_{iD}}\right)^{\sigma-1} = \left(\frac{\delta f_{iI}}{f_{iD}}\right)\left(\frac{1}{\left(\theta_{i}\right)^{\sigma-1}-1}\right) \tag{5}$$

which is the same as in autarky. In fact since the operating profits for each firm is a constant times the operating profits in autarky we have that the FE condition is given by:

$$\left(\left(\frac{\tilde{\varphi}_{iD}}{\varphi_{iD}}\right)^{\sigma-1}-1\right)f_{iD}+\frac{(1-G(\varphi_{iI}))}{(1-G(\varphi_{iD}))}\left(\left(\frac{\tilde{\varphi}_{iI}}{\varphi_{iI}}\right)^{\sigma-1}-1\right)\delta f_{iI}=\frac{\delta f_{ei}}{(1-G(\varphi_{iD}))} \tag{6}$$

which is identical to the one in autarky. Therefore productivity thresholds are unchanged after trade openness when trade is costless. This implies that the productivity distributions remain unchanged after trade openness but costless trade.

The standard results in the Heckscher-Ohlin model are held in this environment. Factor Price Equalisation holds provided that economies do not experience factor intensity reversals (i.e. factor endowments not to be very different across countries). Unlike previous studies, trade has an impact on innovation. Trade promotes investment in product innovation in the industry in which the country has a comparative advantage.

In contrast, the relative R&D intensities are unchanged after trade openness. To see this notice that the R&D intensity ratio is given by:

$$\frac{R\&Dint_1}{R\&Dint_2}=\frac{M_1}{M_2}\frac{R_2}{R_1}\left(\frac{w_s}{w_L}\right)^{\beta_1-\beta_2}$$

But $R_i = M_i\bar{r}_i$, then substituting we have that:
$\frac{R\&Dint_1}{R\&Dint_2}=\frac{\bar{r}_2}{\bar{r}_1}\left(\frac{w_s}{w_L}\right)^{\beta_1-\beta_2}$

$$\frac{R\&Dint_1}{R\&Dint_2}=\frac{\left(\left(\left(\frac{\tilde{\varphi}_{2D}}{\varphi_{2D}}\right)^{\sigma-1}\right)\sigma f_{2D}+\frac{(1-G(\varphi_{2I}))}{(1-G(\varphi_{2D}))}\left(\frac{\tilde{\varphi}_{2I}}{\varphi_{2I}}\right)^{\sigma-1}\sigma\delta f_{2I}\right)(\omega_2)}{\left(\left(\left(\frac{\tilde{\varphi}_{iD}}{\varphi_{iD}}\right)^{\sigma-1}\right)\sigma f_{1D}+\frac{(1-G(\varphi_{1I}))}{(1-G(\varphi_{1D}))}\left(\frac{\tilde{\varphi}_{1I}}{\varphi_{1I}}\right)^{\sigma-1}\sigma\delta f_{1I}\right)(\omega 1)}\left(\frac{\omega_1}{\omega_2}\right)=1$$

Costless trade does not have any impact on process innovation because it does not alter the distribution of profits within the industry. When trade is costless, trade openness widens the profit opportunities of all firms although this increase is more pronounced in the industry in which the country has the comparative advantage because the relative cost of factors is cheaper. This induces entry and an increase in the relative demand for skilled labour. The increase in entry perfectly offsets the increase in profit opportunities and leaves the market share of each firm in each market unaltered. Since the global size of the firm is unchanged under this setting, firms' incentives to undertake process innovation activities have not been altered This result is challenged in the next section.

4 Costly Trade

The recent literature on trade and firm heterogeneity has suggested that both fixed and variable trade costs are important in international trade activities (Roberts and Tyebout, 1998). In this section, I introduce both types of costs and show that the main implication of it, self-selection into exporting markets, together with differences in factor endowments generate important consequences for innovation. Self-selection into exporting creates asymmetries across firms within an industry. Differences in factor endowments create asymmetries across sectors. The interaction between both expand business opportunities of the most productive firms to a larger extent in the comparative advantage industry. This induces differences in innovation outcomes across industries and consequently differences in the average productivity across industries. Unlike BRS these differences in productivity arise through two channels: an effect on the survival productivity threshold due to tougher selection which creates a reallocation effect towards most productive plants, and an effect on the within-plant productivity.

In this economy, to get one unit of the product sold in the foreign market, a firm must ship $\tau_i \geq 1$ units of the product incurring into a variable trade cost of $\tau_i - 1$. To serve the foreign market the firm needs to incur also in a fixed cost f_{iX} units of the intermediate input used in production. As commented before, we assume that exporting activities uses the same intermediate input as innovation and production activities within the same industry. A great part of this fixed cost of exporting consists on advertisement and complying with regulation standards. I assume that these costs are proportional to the unitary production cost. To outline the role played by factor endowments on innovation outcomes, we assume that sectoral structural parameters other than factor endowments are identical across countries.

As it is discussed in Navas and Sala (2013) this model exhibits different equilibria depending on the parameter configuration. These are associated with different partitions of firms according to innovation and export status. In the world I describe here, the variety of equilibria becomes more interesting since different industries could in principle sustain different type of equilibria depending on the value of fixed costs of exporting, innovation and trade barriers. Rather than describing a large variety of cases, in this paper, I focus on a symmetric equilibrium (by assuming that all industries share the same structural parameters) and an equilibrium in which innovators are a subset of the most productive exporters for both industries and countries, in line with recent evidence found by Aw, Roberts and Xu (2011). Consequently, both industries are characterized by a partition of firms across status given by the following hierarchy: Innovators and exporters (the most productive ones), exporters and domestic firms. In a further section I describe the conditions under which this equilibrium holds, and through simulations we show that this equilibrium holds provided that the level of variable trade costs are low enough.[4]

For further analysis we denote with superscript $j = H, F$ the variables associated with the home country and with superscript $k = H, F$ the variables associated with the destination country (both of them can be either Home (H) or Foreign (F)).

In this equilibrium, the marginal innovator is an exporter. Consequently, the marginal innovator in country j and industry i is defined by the following condition:

$$\left(1+\tau_i^{1-\sigma}\frac{R^k}{R^j}\left(\frac{P_i^k}{P_i^j}\right)^{\sigma-1}\right)\left((\theta_i)^{\sigma-1}-1\right)\left(\frac{r_{iD}(\varphi_{iI}^j)}{\sigma}\right)=\delta f_{iI}\left(\omega_i^j\right)\quad i=1,2 \tag{7}$$

where we have used the fact that $R_1^j = \alpha R^j$ and $R_1^k = \alpha R^k$ The marginal exporter in country j is described by the following expression:

$$\left(\tau_i^{1-\sigma}\frac{R^k}{R^j}\left(\frac{P_i^k}{P_i^j}\right)^{\sigma-1}\right)\left(\frac{r_{iD}(\varphi_{iX}^j)}{\sigma}\right)=f_{iX}\left(\omega_i^j\right) \tag{8}$$

and the marginal survival is given by the following condition:

$$\frac{r_{iD}(\varphi_{iI}^j)}{\sigma}=f_{iD}\left(\omega_i^j\right). \tag{9}$$

Dividing (8) and (9) we find that:

$$\frac{\varphi_{iX}^j}{\varphi_{iD}^j}=\underbrace{\tau_i\left(\frac{P_i^j}{P_i^k}\right)\left(\frac{R^j}{R^k}\frac{f_{iX}}{f_{iD}}\right)^{\frac{1}{\sigma-1}}}_{\Lambda_i^j} \tag{10}$$

[4]Robustness checks available upon request analyse how the results vary under industry symmetry with different hierarchical structures.

Dividing (7) and (9) I obtain:

$$\left(\frac{\varphi_{iI}^{j}}{\varphi_{iD}^{j}}\right)^{\sigma-1} = \frac{\delta f_{iI}}{f_{iD}\left((\theta_i)^{\sigma-1}-1\right)\left(1+\left(\Lambda_i^j\right)^{1-\sigma}\frac{f_{iX}}{fiD}\right)} \tag{11}$$

Notice that as a consequence of trade openness, there is a larger proportion of firms undertaking process innovation in both industries, and this result is independent of factor endowments. This is the consequence of the fact that innovators have access to a larger market where they can take advantage of the increasing returns to scale nature of innovation. Taking the ratio across industries we have that:

$$\frac{\left(\frac{\varphi_{1I}^{j}}{\varphi_{1D}^{j}}\right)^{\sigma-1}}{\left(\frac{\varphi_{2I}^{j}}{\varphi_{2D}^{j}}\right)^{\sigma-1}} = \frac{\left(1+\left(\Lambda_2^j\right)^{1-\sigma}\frac{f_{iX}}{fiD}\right)}{\left(1+\left(\Lambda_1^j\right)^{1-\sigma}\frac{f_{iX}}{fiD}\right)} \tag{12}$$

and therefore we can conclude that $\left(\frac{\varphi_{1I}^{j}}{\varphi_{1D}^{j}}\right)^{\sigma-1} < \left(\frac{\varphi_{2I}^{j}}{\varphi_{2D}^{j}}\right)^{\sigma-1}$ iff $\Lambda_1^j < \Lambda_2^j$. This implies that those industries exhibiting a larger proportion of firms innovating are also those industries in which there is a larger proportion of firms exporting.

In the appendix I discuss the aggregation properties of the model under costly trade. Compared to the benchmark case of firm heterogeneity without technology upgrading, I observe that the difference in profits between autarky and trade is larger in this setup due to the effect that trade has on process innovation. Trade openness increases the size of the market for the most productive firms and consequently their sales. For a given innovation productivity threshold, the innovators are able to exploit their knowledge advantage across more production units since they are able to sell more. This increases profits. Substituting the expression for profits in the Free Entry condition and rearranging terms it can be obtained:

$$\left[\pi_{iD}^{j} + p_{iX}^{j}\pi_{iX}^{j} + p_{iI}^{j}\pi_{iI}^{j}\right] = \frac{\delta f_{ei}}{1-G(\varphi_{iD}^{j})} \tag{13}$$

Looking at this condition we can deduct several properties. First, trade openness improves the average productivity in both industries by increasing the productivity threshold to survive in the market. Second the inclusion of process innovation increases the effect that trade has on average productivity. This is due to the fact that trade increases technology upgrading across the most productive firms helping them to increase their market share in detrimental of the local competitors.

Specific to this paper is the asymmetric impact on innovation across industries. More precisely I show in the appendix that:

Proposition 1 *Under costly trade:*

1. *The increase in the survival productivity threshold is larger in the industry in which the economy has a comparative advantage.*

2. *In the industry in which the economy has a comparative advantage there is a relative larger share of incumbent firms undertaking process innovation.*

3. *Assuming a Pareto-Distribution for productivity, the R&D intensities are larger in the sector in which the economy has comparative advantage and this is due to a joint effect of more product and process innovation.*

Proof. See Appendix. ■

The intuition behind these results underlies on the fact that when the economy opens to trade, firms are asymmetrically exposed to different industry opportunities. In the home skilled-abundant country, the marginal cost of production in industry 1 is lower than in the Foreign Country. When the economy opens up to trade, firms see their opportunities expanded in trade because the access to a larger market allows them to exploit the increasing returns to scale associated with both production and innovation. However, these profit opportunities are larger in the industry in which the economy has the comparative advantage since this industry is able to offer the good cheaper than its analogous counterpart in the foreign country (Industry 1). This promotes a disproportionate entry in that industry, and consequently more *product innovation.* The massive entry of firms makes profits fall and it becomes more difficult to survive. The less productive firms can no longer make positive profits and consequently the productivity threshold needed to survive in the market increases. The expulsion of the less efficient firms generates a reallocation of market shares across the most productive firms. Process innovation increases due to a combination of larger opportunities and market share reallocation.

For this equilibrium to hold the following parameter constraints need to be satisfied:

1. The marginal innovator must be an exporter. (i.e. $\left(\frac{\varphi_{iI}^j}{\varphi_{iX}^j}\right)^{\sigma-1} > 1$). This implies:
$$\left(\left(\left(\Lambda_i^j\right)^{\sigma-1}\frac{f_{iD}}{f_{iX}}\right)+1\right) < \frac{\delta f_{iI}}{f_{iX}\left(\left(\theta_i\right)^{\sigma-1}-1\right)}$$
Substituting (10) and rearranging terms, we have that:
$$\tau_i^{\sigma-1}\left(\frac{R^j}{R^k}\right)\left(\frac{P_i^j}{P_i^k}\right)^{\sigma-1} < \frac{\delta f_{iI}}{f_{iX}\left(\left(\theta_i\right)^{\sigma-1}-1\right)}-1$$

2. The productivity threshold of an exporter must be larger than the domestic one which implies $\left(\frac{\varphi_{iX}^j}{\varphi_{iD}^j}\right)^{\sigma-1} > 1$:
$$\tau_i^{\sigma-1}\left(\frac{R^j}{R^k}\right)\left(\frac{P_i^j}{P_i^k}\right)^{\sigma-1} > \frac{f_{iD}}{f_{iX}}$$
Writing both conditions together we have that:
$$\frac{f_{iD}}{f_{iX}} < \tau_i^{\sigma-1}\left(\frac{R^j}{R^k}\right)\left(\frac{P_i^j}{P_i^k}\right)^{\sigma-1} < \frac{\delta f_{iI}}{f_{iX}\left(\left(\theta_i\right)^{\sigma-1}-1\right)}-1 \qquad (14)$$

If the following condition is satisfied:
$$\tau_i^{\sigma-1}\left(\frac{R^j}{R^k}\right)\left(\frac{P_i^j}{P_i^k}\right)^{\sigma-1} < \frac{f_{iD}}{f_{iX}}$$
then all firms will be able to export. In that case the economy will be in an equilibrium with costly trade but no selection into exporting markets.

Condition (14) depends on four endogenous variables and the model does not exhibit a closed form solution for these variables. The next simulation exercise suggests that this equilibrium holds in the case in which transportation costs are not large enough and there are no substantial differences in factor endowments across countries. In the next section I look at the properties of this equilibrium. As it becomes apparent, while trade has introduced technological divergence across industries, due to a combination of trade barriers and differences in factor intensity usage, these technological differences across industries could become smaller as the trade costs are reduced. This suggests that while trade openness create a Ricardian comparative advantage across industries, the width of the comparative advantage depends clearly on the level of trade costs. If the initial situation is one of low trade costs, this comparative advantage becomes weaker over time, as trade costs are reduced over time. This could be consistent with recent empirical evidence found by Levchenko and Zhang (2011).

5 Simulation Exercises

In this section I undertake several simulation exercises which corroborates the results discussed in the theoretical part. Firstly, I compare the results in autarky with the results in Free Trade and second, I discuss the effects of a partial trade liberalisation experiment (a reduction in trade costs). In this subsection for the common parameters, we stick to the parameter values provided by Bernard, Redding and Schott (2007). These ones can provide us with a better comparison between the two models and the role played by innovation in the productivity convergence across industries.

INSERT TABLE 1 HERE.

Table 1 shows the results in autarky and free trade for the home country (similar ones you can find for the foreign country). Notice that a movement towards free trade increases the survival productivity cutoff and reduces the innovation productivity cutoff promoting technology upgrading. However, these effects are not the same across industries. In the comparative advantage industry there is more selection due to an increase in the mass of entrants (attracted by larger expected profits) and a lower innovation productivity cutoff (since trade expand the business opportunities of local firms more in the comparative advantage industry). The effects on the average productivity for the benchmark case are large (taking into account that under the current parametrization only 3.75 and 3.5% of the incumbent firms undertake process innovation). In the comparative advantage industry there is an increase in the mass of varieties created while in the comparative disadvantage industry is clearly reduced. This reflects the differences in profitability between both industries which reallocates potential entrants from the comparative disadvantage industry to the comparative advantage one. However, although the proportion of surviving firms is clearly large in the comparative advantage industry, there is a clear drop in surviving in both industries.[5]

[5] As commented above, I have used BRS parameter values for the common parameters

INSERT FIGURE 1 HERE.

Figure 1 shows the export and domestic productivity cutoffs for both industries in the home country. The continuous line displays the survival productivity thresholds for both industries while the discontinuous one shows the export productivity cutoffs. The red lines represent the industry in which the industry has the comparative advantage (industry 1) while the green one does it for the industry with the comparative disadvantage (industry 2). It is clear that the survival productivity cutoff is larger and the export productivity cutoff is smaller in the industry in which the economy has the comparative advantage. The former reflects tougher competition in that industry due to the larger expanded opportunities for firms in that industry. Compared to a model without innovation, the survival productivity cutoffs in both industries have increased considerably. In the comparative advantage industry for the case of the trade costs equal to 20% the productivity cutoff is 3.8% larger while in the comparative disadvantage industry it is 3.67% larger. Although small, we can also observe that when we introduce the possibility of firms to upgrade their own technologies in a model with firm heterogeneity and comparative advantage the difference between productivity cutoffs due to comparative advantage mechanisms across industries exacerbates.

Considering a more general case in which the fixed costs of exporting are not equal to the fixed costs of production, just confirm the qualitative results that we have obtained as figure 2 provides.

INSERT FIGURES 2 AND 3 HERE.

Figure 3 displays the relative survival productivity cutoffs of Industry 1 versus Industry 2 for both the home and the foreign country. It becomes apparent that for high level of transportation costs a reduction in transportation costs increases the survival productivity cutoff by more in the comparative advantage industry. However for sufficiently low levels of transportation costs, the opposite happens. This suggests that when the trade costs are high selection becomes tougher in the industries in which the economy has the comparative advantage but as the trade costs fall survival is more difficult in the comparative disadvantage industry.

in the model. This provides a more accurate interpretation of the results by comparing a model with and without process innovation. For the value innovation jump we have used 20% ($\theta = 1.2$) and for the innovation cost we have used 25 times the cost of entry. Changes in the parameter values do not generate qualitative changes in the results, provided that the economy is in the analysed equilibrium. Robustness checks are available on request.

INSERT FIGURE 4 HERE.

Figure 4 displays the innovation productivity cutoff across both industries for the home country. The continuous line represents the innovation productivity cutoff in the industry 1 while the discontinuous line represents the productivity cutoff in industry 2 for different values of trade costs. It becomes apparent that a reduction in trade costs, decreases the innovation productivity cutoffs in both industries, or in another words increases the mass of firms that upgrade their technology. Yet, it can be also observed that the innovation productivity cutoff is smaller in the industry in which the home country has the comparative advantage and consequently the mass of firms engaging in process innovation is larger in the comparative advantage industry.

INSERT FIGURE 5 HERE.

Figure 5 represents the relative innovation productivity cutoffs (industry 1 versus industry 2) for both the home country (continuous line) and the foreign country (discontinuous line). The results suggest an interesting finding. While the relative innovation cutoff is systematically larger in each country's comparative disadvantage industry there is a non-monotonic relationship between the trade costs and the relative evolution of both cutoffs, which is a measure of the process innovation activity. When the trade costs are high, a reduction in trade costs decreases by more the innovation cutoff in the comparative advantage industry, (decreasing the relative cutoff for industry 1 in the home country and increasing the relative cutoff in the foreign country). However, when the trade costs are low enough we find the opposite result: A reduction in trade costs decreases the innovation cutoff more in the comparative disadvantage industry (and consequently the relative cutoff increases in the home country and decreases in the foreign country).

These results suggest that a reduction in trade costs increases process innovation in both industries. When the trade costs are substantially high however, the reduction in trade costs favours the comparative advantage industry and when the trade costs are low the trade cost reduction favours the comparative disadvantage one. The implications for the evolution of the average productivity across industries are straightforward: A process of globalisation induces an increase in TFP in both industries provided that the trade costs are not relatively high (we are in the parameter configuration consistent with this equilibrium). Yet, globalisation induces TFP divergence across sectors when trade costs are high, but it induces TFP convergence across sectors when countries are low. This prediction is consistent with the findings of Levchenko and Zhang (2011), provided that trade costs have been declining over time, and they were relatively low at the start of the sample. More precisely, the threshold level below which a reduction in trade costs induce TFP convergence is around 15%, although this threshold is much higher for innovation cutoffs and R&D intensities (30%).[6] Figures 6 and 7 illustrate this point.

INSERT FIGURES 6 AND 7 HERE.

Figure 8 shows the effects of trade liberalisation on product innovation in both industries. As it becomes apparent, product innovation is already larger in the comparative advantage relative to the comparative disadvantage industry in each of the countries. As trade costs are reduced the differences between product innovation across industries are enlarged: Product innovation becomes larger in the comparative advantage industry. This is the consequence of the fact that trade liberalisation expands the opportunities of the most productive firms in the comparative advantage sector and the increase in the expected profits in this sector promotes entry. In the comparative disadvantage sector domestic firms face disproportionate tougher competition, the average expected profit falls and this deters entry.

INSERT FIGURE 8 HERE.

A common measure of innovative activity across industries is to look at R&D intensities. Figure 9 displays the evolution of the R&D intensities for both industries in the home country. Notice that R&D intensities increase in both industries as trade costs fall. Although the differences across industries are not substantially large there are still differences in R&D intensities when the economy is open to trade favouring the comparative advantage industry in the home country. This is the consequence of the fact that in the comparative advantage industry there is more product and process innovation.

INSERT FIGURE 9 AND 10 HERE.

If we compare the relative evolution of R&D intensities in the home country (continuous line) and the foreign country (discontinuous line) we obtain a similar message (figure 10). The figure displays a similar functional form to figure 3. When the trade costs are large, a reduction in the trade costs

[6] That is, the relative innovation cutoffs and R&D intensities increase by more in the comparative disadvantage industry when trade costs are below 30%

increases the R&D intensity by more in the comparative advantage industry in each country. However, if the trade costs are sufficiently small, the reverse happens and the R&D intensities increases by more in the comparative disadvantage industry. When trade costs are high further liberalisation leads to divergence in innovative activity across industries but this result is reversed if the trade costs are sufficiently small.

6 Conclusions

This paper introduces technology upgrading into a factor proportions' model with firm heterogeneity to explore how factor endowments shape the impact that trade has on innovation at an industry level.

Our results suggest that factor endowments affect the distribution of innovative activity across industries within a country when the economy opens to trade. More precisely, firms in the industry where the economy has a comparative advantage undertake more product and process innovation. This reinforces previous results that outline the importance of the relative factor endowments in generating a Ricardian comparative advantage.

In addition I explore how the evolution of technology is affected by a reduction in trade costs under the presence of differences in factor endowments across countries and factor intensities across industries. The results suggest that the reduction in variable trade costs promotes technology upgrading and increases R&D intensities in both industries. However, the results establish a non-monotonic relationship between the pattern of comparative advantage and trade costs: When the trade costs are high, a reduction in trade costs pushes technology upgrading more in the comparative advantage industry leading to TFP divergence across industries. However, when the trade costs are low enough, a reduction in trade costs pushes technology upgrading in the comparative disadvantage industry leading to a process of TFP convergence across both industries.

This paper could be extended in several directions. First, the paper has considered a simple process of technology upgrading where the degree of technology upgrade is fixed across firms. Generalising the results to a richer environment in which firms can choose how much to upgrade is a promising area for future research. Second, the paper could allow for a more complete and realistic description of the intermediate input sector and establishes the complementarities between importing, exporting and innovation under the presence of differences in factor endowments. Both dimensions are currently taking part on my research agenda.

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7 Appendix

7.1 Aggregation in a Closed Economy Model

Define the following productivity distributions:

$$\Pr\left(\varphi/\varphi \geq \varphi_{iD}\right) = \mu_{iD}(\varphi) = \left\{ \begin{array}{ll} \frac{g(\varphi)}{1-G(\varphi_{iD})}, & \text{if } \varphi \geq \varphi_{iD} \\ 0 & \text{otherwise} \end{array} \right\}$$

$$\Pr\left(\varphi/\varphi \geq \varphi_{iI}\right) = \mu_{iI}(\varphi) = \left\{ \begin{array}{ll} \frac{g(\varphi)}{1-G(\varphi_{iI})}, & \text{if } \varphi \geq \varphi_{iI} \\ 0 & \text{otherwise} \end{array} \right\}$$

the second one, that is more associated to heterogenous firm models of process innovation will be the ex-ante productivity distribution of innovators.

We can show that parallel to the Melitz (2003) model the aggregation property also holds in this model. This allows to write the sectoral aggregate variables of the model as a function of the average productivity of the sector.

The right average productivity of each industry is given by the following expression:

$$\tilde{\varphi} = \left[\left(\tilde{\varphi}_{iD}\right)^{\sigma-1} + \frac{(1 - G(\varphi_{iI}))}{(1 - G\left(\varphi_{iD}\right))} \left[(\theta_i)^{\sigma-1} - 1 \right] \left(\tilde{\varphi}_{iI}\right)^{\sigma-1} \right]$$

where:

$$\left(\tilde{\varphi}_{iD}\right)^{\sigma-1} = \int_{\varphi_{iD}}^{\infty} \varphi^{\sigma-1} \mu\left(\varphi\right) d\varphi$$

and

$$\left(\tilde{\varphi}_{iI}\right)^{\sigma-1} = \int_{\varphi_{iI}}^{\infty} \varphi^{\sigma-1} \mu_I\left(\varphi\right) d\varphi$$

In equilibrium we must have that:

$$E(V_i) = f_{ei}\omega_i$$

This condition is known in the Melitz (2003) framework as the Free Entry condition (FE). It can be rearranged to:

$$E(V_i) = \frac{(1 - G(\varphi_{iD}))}{\delta} \underbrace{\left[\pi\left(\tilde{\varphi}_{iD}\right) + \overbrace{\frac{(1 - G(\varphi_{iI}))}{(1 - G\left(\varphi_{iD}\right))} \left[\left((\theta_i)^{\sigma-1} - 1 \right) \left(\frac{r\left(\tilde{\varphi}_{iI}\right)}{\sigma} \right) - f_{iI}\omega_i \right]}^{\text{innovation profits}} \right]}_{\bar{\pi}_i} = f_{ei}\omega_i$$

Compared to a standard model of firm heterogeneity without technology upgrading, this new FE condition exhibits a new element in the left hand side of the equation. More precisely, the second element captures the expected profits from technology upgrading which are given by the probability of innovate conditional on surviving and the innovation rents.

8 Aggregation in Costly Trade.

Define the following productivity distribution:

$$\Pr\left(\varphi/\varphi \geq \varphi_{iX}^{j}\right) = \mu_{iX}(\varphi) = \left\{ \begin{array}{ll} \frac{g(\varphi)}{1-G\left(\varphi_{iX}^{j}\right)}, & \text{if } \varphi \geq \varphi_{iX}^{j} \\ 0 & \text{otherwise} \end{array} \right\}$$

This is the conditional productivity distribution of exporters to country j. Define also the following average productivity:

$$\left(\tilde{\varphi}_{iX}^{j}\right)^{\sigma-1} = \int_{\varphi_{iX}^{j}}^{\infty} \varphi^{\sigma-1} \mu_X(\varphi)\, d\varphi$$

and consider as well the following productivity averages:

$$\left(\tilde{\varphi}_{iX}^{j}\right) = \left[\frac{M_{iX}^{j}\left(\tilde{\varphi}_{iX}^{j}\right)^{\sigma-1} + \left((\theta_i)^{\sigma-1} - 1\right) M_{iI}^{j}\left(\tilde{\varphi}_{iI}^{j}\right)^{\sigma-1}}{M_{iX}^{j}}\right]^{\frac{1}{\sigma-1}}$$

Then the aggregate price index for each sector in each market will remain as follows:

$$\left(P_i^{j}\right)^{1-\sigma} = \left[M_i^{j}\left(p\left(\tilde{\varphi}_i^{j}\right)\right)^{1-\sigma} + M_{iX}^{k}\left(p\left(\tilde{\varphi}_{iX}^{k}\right)\right)^{1-\sigma}\right].$$

The expected profits from a potential entrant are given by:

$$E(V_i^{j}) = \frac{\left(1-G(\varphi_{iD}^{j})\right)}{\delta} \underbrace{\left[\pi\left(\tilde{\varphi}_{iD}^{j}\right) + p_{iX}^{j}\pi\left(\tilde{\varphi}_{iX}^{j}\right) + p_{iI}^{j}\pi_{iI}\left(\tilde{\varphi}_{iI}^{j}\right)\right]}_{\bar{\pi}_i}$$

where $\pi\left(\tilde{\varphi}_{iD}^{j}\right) = \left(\left(\frac{\tilde{\varphi}_{iD}^{j}}{\varphi_{iD}^{j}}\right)^{\sigma-1} - 1\right) f_{iD} = \pi_{iD}^{j}$, $\pi\left(\tilde{\varphi}_{iX}^{j}\right) = \left(\left(\frac{\tilde{\varphi}_{iX}^{j}}{\varphi_{iX}^{j}}\right)^{\sigma-1} - 1\right) f_{iX} = \pi_{iX}^{j}$ and $\pi_{iI}\left(\tilde{\varphi}_{iI}^{j}\right) = \left[\left((\theta_i)^{\sigma-1} - 1\right)\left(1 + \left(\Lambda_i^{j}\right)^{1-\sigma}\frac{f_{iX}}{f_{iD}}\right)\left(\frac{r\left(\tilde{\varphi}_{iI}^{j}\right)}{\sigma}\right) - \delta f_{iI}\right]$ are the innovation profits.

Compared to autarky this equation has two extra terms. The second term captures the profits from exporting. The third term captures the innovation profits in which we can distinguish between the innovation gains in the domestic market and the ones in the foreign market. Both are positive so this implies that the expected profits increase after trade openness.

Proposition 2 *Under costless trade FPE holds.*

Proof. As in HK (1985) or BRS (2007), first we are going to characterize the equilibrium in an hypothetical integrated economy. Then we are going to show that there is a vector of prices and initial allocations that support this equilibrium in the non-integrated economies.

The very first thing to show is that total revenue equals total expenditure in each sector. To see this notice that:

$$w_L L_{ip} + w_S S_{ip} + w_L L_{ei} + w_S S_{ei} + w_L L_{iI} + w_S S_{iI} = R_i$$

In each sector, the following needs to hold:

$$w_L L_{ip} + w_S S_{ip} + w_L L_{iI} + w_S S_{iI} = R_i - \Pi_i$$

Since now the aggregate profits also include the benefits from innovation. Developing the expression for profits we obtain:

$$\Pi_i = M_i \left[\frac{r(\tilde{\varphi})}{\sigma} - f_D \omega_i - \frac{(1 - G(\varphi_{iI}))}{(1 - G(\varphi_{iD}))} f_I \omega_i \right]$$

On the other hand we know that the FE implies that:

$$\Pi_i = M_i \bar{\pi}_i = \frac{M_i \delta f_{ei} \omega_i}{(1 - G(\varphi_{iD})} = M_{ei} \delta f_{ei} \omega_i = w_L L_{ei} + w_S S_{ei}.$$

Then we have that

$$w_L L_i + w_S S_i = R_i$$

aggregating across industries implies that:

$$w_L \bar{L} + w_S \bar{S} = R \tag{15}$$

Now let us characterize the equilibrium of the integrated economy. The assumption of Cobb-Douglas technologies ensure that:

$$w_L L_i = (1 - \beta_i) R_i \qquad w_S S_i = \beta_i R_i$$

Labor market clearing condition implies:

$$\frac{(1 - \beta_1)\alpha}{w_L} R + \frac{(1 - \beta_2)(1 - \alpha)}{w_L} R = \bar{L}$$

$$\frac{\beta_1 \alpha}{w_S} R + \frac{\beta_2 (1 - \alpha)}{w_S} R = \bar{S}$$

and dividing both:

$$\frac{w_L}{w_S} = \frac{(1-\beta_1)\,\alpha + (1-\beta_2)\,(1-\alpha)}{\beta_1\alpha + \beta_2\,(1-\alpha)}\,\frac{\bar{S}}{\bar{L}} \tag{16}$$

Notice also that manipulating both labour market clearing conditions we find that:

$$\frac{R}{w_L} = \frac{\bar{L}}{(1-\beta_1)\,\alpha + (1-\beta_2)\,(1-\alpha)}; \frac{R}{w_S} = \frac{\bar{S}}{\beta_1\alpha + \beta_2\,(1-\alpha)}$$

which leads to:

$$L_1 = \frac{(1-\beta_1)\,\alpha}{(1-\beta_1)\,\alpha + (1-\beta_2)\,(1-\alpha)}; \qquad S_1 = \frac{\beta_1\alpha}{\beta_1\alpha + \beta_2\,(1-\alpha)}$$

$$L_2 = \frac{(1-\beta_2)\,\alpha}{(1-\beta_1)\,\alpha + (1-\beta_2)\,(1-\alpha)}; \qquad S_2 = \frac{\beta_2\,(1-\alpha)}{\beta_1\alpha + \beta_2\,(1-\alpha)}$$

Consider w.l.o.g. that $w_S = 1$. Notice that the productivity and innovation cutoffs $(\varphi_{iD}), (\varphi_{iI})$ can be easily solved using (6) and (5) and with this we obtain $p\left(\varphi_i^k\right)$. Equation (15) can be used together with (16) to obtain R. Using (6) and the information about $(\varphi_{iD}), (\varphi_{iI})$ we obtain an expression for $\bar{r}_i$. This help us to compute $P_i, \tilde{\varphi}_{iD}, \tilde{\varphi}_{iI}$. With this the integrated equilibrium is characterized. To obtain the number of surviving firms in each industry we use 4 and the fact that for each industry $M_i = R_i/\bar{r}_i$.

Now let us show that this relative wage satisfies the equilibrium conditions of the open economy but costless trade.

To do so let us consider without loss of generalisation that.$w_S^H = w_S^F = 1$.

Notice that perfect competition in the intermediate input sector implies that:

$S_i^H = \beta_i R_i^H \Rightarrow w_L L_i^H = (1-\beta_i) R_i^H$

then $\frac{S_i^H}{L_i^H} = \frac{\beta_i}{1-\beta_i}\frac{w_L}{w_S} = \frac{\beta_i}{1-\beta_i} w_L$.

The factor market conditions can be expressed as:

$$\lambda_{L1}^j \left(\frac{S_1^j}{L_1^j}\right) + \left(1-\lambda_{L1}^j\right)\left(\frac{S_2^j}{L_2^j}\right) = \left(\frac{\bar{S}^j}{\bar{L}^j}\right)$$

$$\lambda_{S1}^j \left(\frac{L_1^j}{S_1^j}\right) + \left(1-\lambda_{L1}^j\right)\left(\frac{L_2^j}{S_2^j}\right) = \left(\frac{\bar{L}^j}{\bar{S}^j}\right)$$

where $\lambda_{Li}^j = \frac{L_i^j}{\bar{L}^j}$ and $\lambda_{S1}^j = \frac{S_i^j}{\bar{S}^j}$.Given that we are able to get:

$$L_1^j = \frac{\frac{\bar{S}^j}{w_L} - \left(\frac{\beta_2}{1-\beta_2}\right)\bar{L}^j}{\left(\frac{\beta_1}{1-\beta_1}\right) - \left(\frac{\beta_2}{1-\beta_2}\right)}; \qquad L_2^j = \frac{\left(\frac{\beta_1}{1-\beta_1}\right)\bar{L}^j - \frac{\bar{S}^j}{w_L}}{\left(\frac{\beta_1}{1-\beta_1}\right) - \left(\frac{\beta_2}{1-\beta_2}\right)};$$

$$S_1^j = \frac{\left(\frac{\beta_1}{1-\beta_1}\right)\bar{S}^j - \left(\frac{\beta_1}{1-\beta_1}\right)\left(\frac{\beta_2}{1-\beta_2}\right) w_L \bar{L}^j}{\left(\frac{\beta_1}{1-\beta_1}\right) - \left(\frac{\beta_2}{1-\beta_2}\right)}; \qquad S_2^j = \frac{\left(\frac{\beta_1}{1-\beta_1}\right)\left(\frac{\beta_2}{1-\beta_2}\right) w_L \bar{L}^j - \left(\frac{\beta_2}{1-\beta_2}\right)\bar{S}^j}{\left(\frac{\beta_1}{1-\beta_1}\right) - \left(\frac{\beta_2}{1-\beta_2}\right)}$$

Aggregate Income in each country equals aggregate revenue and so:

$$R^j = \bar{S}^j + w_L \bar{L}^j$$

We know that total industry payments to unskilled labour are a constant fraction $(1-\beta_i)$ of the total industry revenue and the total industry revenue is a fraction α of the total revenue. Substituting the values of L_1^k in

$$w_L \left(L_1^H + L_1^F\right) = (1-\beta_1)\,\alpha \left[\bar{S}^H + \bar{S}^F + w_L\left(\bar{L}^H + \bar{L}^F\right)\right]$$

we obtain an expression for w_L that coincides with the one obtained in the integrated equilibrium. Notice that this determines $p\left(\varphi_i^j\right)$ which determines P_i. We have shown that there exists a vector of allocations and competitive prices that replicates the equilibrium of the integrated economy. ■

8.1 Proof of $\Lambda_1^H < \Lambda_2^H$ and $\Lambda_1^F > \Lambda_2^F$

This proof is very similar to the analogous one in BRS (2007). The firs step is to obtain the relative aggregate price indexes in autarky. Notice that:

$$\frac{P_1^j}{P_2^j} = \left(\frac{M_1^j}{M_2^j}\right)^{\frac{1}{1-\sigma}} \frac{p_1(\tilde{\varphi}_1^j)}{p_2(\tilde{\varphi}_2^j)}$$

Since the innovation and the survival productivity cutoffs are the same, the price of the average firm in each industry is only determined by differences in the cost of the intermediate input and consequently,

$$\frac{P_1^j}{P_2^j} = \left(\frac{M_1^j}{M_2^j}\right)^{\frac{1}{1-\sigma}} \left(\frac{w_S^j}{w_L^j}\right)^{\beta_1-\beta_2}$$

Substituting the expression for $\frac{M_1^k}{M_2^k}$ and rearranging terms it can be obtained:

$$\frac{P_1^j}{P_2^j} = \frac{\alpha}{1-\alpha}\left(\frac{w_S^j}{w_L^j}\right)^{\frac{\sigma(\beta_1-\beta_2)}{1-\sigma}}$$

and consequently in autarky: $\frac{P_1^H}{P_2^H} < \frac{P_1^F}{P_2^F}$ since $\frac{w_S^H}{w_L^H} < \frac{w_S^F}{w_L^F}$ and $\beta_1 > \beta_2$.

In Costless trade $\frac{w_S^H}{w_L^H} = \frac{w_S^F}{w_L^F}$ and consequently, $\frac{P_1^H}{P_2^H} = \frac{P_1^F}{P_2^F}$.
In Costly trade:

$$\frac{P_1^j}{P_2^j} = \left[\frac{M_1^j \left[\left(p \left(\tilde{\varphi}_1^j \right) \right)^{1-\sigma} + p_{1X}^k \left(p \left(\tilde{\varphi}_{1X}^k \right) \right)^{1-\sigma} \right]}{M_2^j \left[\left(p \left(\tilde{\varphi}_2^j \right) \right)^{1-\sigma} + p_{iX}^k \left(p \left(\tilde{\varphi}_{2X}^k \right) \right)^{1-\sigma} \right]} \right]$$

where $p_{iX}^j = \left(\frac{\varphi_{iX}}{\varphi_{iD}} \right)^{-\gamma}$. Notice that if $\tau \to \infty$, $p_{iX} \to 0$ and $\frac{P_1^j}{P_2^j} = \left(\frac{M_1^j}{M_2^j} \right)^{\frac{1}{1-\sigma}} \left(\frac{w_S^j}{w_L^j} \right)^{\beta_1 - \beta_2}$ since the productivity and the innovation cutoffs are the same across industries (autarkic case). Then $\frac{P_1^H}{P_2^H} < \frac{P_1^F}{P_2^F}$. In the case of $\tau \to 1$,and $f_{iX} \to 0$ then $p_{iX}^j \to 1$ and $\varphi_{iX}^j = \varphi_{iD}^j \ \forall \ i, j$. We are consequently in the case of free trade where the relative prices are equalised across countries. For intermediate cases of fixed and variable trade costs the relative prices underlie between the two values: the autarkic and the free trade value.

Notice that $\frac{\Lambda_1^j}{\Lambda_2^j} = \frac{\alpha}{1-\alpha} \frac{P_1^j}{P_2^j}$ provided that the fixed and variable trade costs are the same across industries. Consequently in costly trade we have that $\Lambda_1^H < \Lambda_2^H$ and $\Lambda_1^F > \Lambda_2^F$.

8.2 Proof of Proposition 1

8.2.1 Point 1.

To see the first point, notice that we can express condition (13) in terms of the productivity threshold φ_{iD}. Using equation (10) and the expression for π_{ix} I can express the expected value of profits from exporting as:

$$p_{iX}^j \pi_{iX}^j = \frac{\left(1 - G(\Lambda_i^j \varphi_{iD})\right)}{\left(1 - G\left(\varphi_{iD}^j\right)\right)} \left(\left(\frac{\tilde{\varphi}_{iX}^j}{\varphi_{iD}^j} \right)^{\sigma-1} \left(\Lambda_i^j\right)^{1-\sigma} - 1 \right) f_{iX} \left(\omega_i^j\right)$$

This expression is decreasing in Λ_i^j. Using (11) I obtain the expected profits from innovation, which are given by:

$$p_{iI}^j \pi_{iI}^j = \frac{\left(1 - G(\varphi_{iI}^j)\right)}{\left(1 - G\left(\varphi_{iD}^j\right)\right)} \left(\left(\frac{\tilde{\varphi}_{iI}^j}{\varphi_{iD}^j} \right)^{\sigma-1} \left(\frac{f_{iD} \left((\theta_i)^{\sigma-1} - 1 \right) \left(1 + \left(\Lambda_i^j\right)^{1-\sigma} \frac{f_{iX}}{f_{iD}} \right)}{\delta f_{iI}} \right) - 1 \right) \delta f_{iI}$$

that is also decreasing in Λ_i^j.

Since before we have shown that $\Lambda_1^H < \Lambda_2^H$ and $\Lambda_1^F > \Lambda_2^F$, then we have that the left hand side of condition (13) is larger in industry 1 than in industry 2 in the home country. Consequently the productivity threshold is larger in industry 1 than in industry 2.

Consequently, The second part of the statement (2) is just a consequence of this result together with the condition (12).

8.2.2 Point 2.

Condition (12). suggests that $\left(\frac{\varphi_{1I}^j}{\varphi_{1D}^j}\right)^{\sigma-1} < \left(\frac{\varphi_{2I}^j}{\varphi_{2D}^j}\right)^{\sigma-1}$ iff $\Lambda_1^j < \Lambda_2^j$. Since $\Lambda_1^H < \Lambda_2^H$ and $\Lambda_1^F > \Lambda_2^F$, then $\left(\frac{\varphi_{1I}}{\varphi_{1D}}\right)^H < \left(\frac{\varphi_{2I}}{\varphi_{2D}}\right)^H$ and $\left(\frac{\varphi_{1I}}{\varphi_{1D}}\right)^F > \left(\frac{\varphi_{2I}}{\varphi_{2D}}\right)^F$.

8.2.3 Point 3

Let us focus on the home country but the result is similar for the foreign country. We therefore omit the superscript j for simplicity. The relative R&D intensities are given by:

$$\frac{R\&Dint1}{R\&Dint2} = \frac{\left(\frac{\delta f_{ei}}{(1-G(\varphi_{1D}))} + \delta f_{iI}\frac{(1-G(\varphi_{1I}))}{(1-G(\varphi_{1D}))}\right)M_1\left(\omega_1\right)}{\left(\frac{\delta f_{ei}}{(1-G(\varphi_{2D}))} + \delta f_{iI}\frac{(1-G(\varphi_{2I}))}{(1-G(\varphi_{2D}))}\right)M_2\left(\omega_2\right)}\frac{R_2}{R_1}$$

Using the fact that $R_i = M_i\bar{r}_i$ and rearranging terms we have that:

$$\frac{R\&Dint1}{R\&Dint2} = \frac{\left(\frac{\delta f_{ei}}{(1-G(\varphi_{1D}))} + \delta f_{iI}\frac{(1-G(\varphi_{1I}))}{(1-G(\varphi_{1D}))}\right)}{\left(\frac{\delta f_{ei}}{(1-G(\varphi_{2D}))} + \delta f_{iI}\frac{(1-G(\varphi_{2I}))}{(1-G(\varphi_{2D}))}\right)}\frac{\bar{r}_2\omega_1}{\bar{r}_1\omega_2}$$

The first term is larger in industry 1 since on the one hand, $\varphi_{1D} > \varphi_{2D}$ and therefore in principle there's more entry in industry 1 and on the other hand we have that $\frac{(1-G(\varphi_{1I}))}{(1-G(\varphi_{1D}))} > \frac{(1-G(\varphi_{2I}))}{(1-G(\varphi_{2D}))}$, and then the proportion of firms undertaking process innovation is larger. However, the average revenue in industry 1 is larger since this is the industry in which the economy has a comparative advantage. To derive the net effect we are going to focus on the particular case of the Pareto Distribution. Assuming that the productivity cumulative distribution function takes the following functional form:

$$\Pr(\varphi \leq \varphi_0) = 1 - \left(\frac{m}{\varphi_0}\right)^{\gamma} \quad \gamma > \sigma - 1.$$

The average revenue is given by the following expression:

$$\bar{r}_i = \frac{\gamma}{\gamma - (\sigma - 1)} \left[f_{iD} + p_{iX} f_{ix} + p_{iI} f_{iI} \right] (\omega_i) \tag{17}$$

and the average profit is given by the following expression:

$$\bar{\pi}_i = \frac{\sigma - 1}{\gamma - (\sigma - 1)} \left[f_{iD} + p_{iX} f_{iX} + p_{iI} f_{iI} \right] (\omega_i) \tag{18}$$

Using (13), (17) and (18) we have that:

$$\bar{r}_i = \frac{\gamma}{(\sigma - 1)} \frac{\delta f_{ei} (\omega_i)}{(1 - G(\varphi_{iD}))}$$

and consequently:

$$\frac{R\&Dint1}{R\&Dint2} = \frac{\left(\frac{f_{ei}}{(1-G(\varphi_{1D}))} + f_{iI} \frac{(1-G(\varphi_{1I}))}{(1-G(\varphi_{1D}))} \right) (1 - G(\varphi_{1D}))}{\left(\frac{f_{ei}}{(1-G(\varphi_{2D}))} + f_{iI} \frac{(1-G(\varphi_{2I}))}{(1-G(\varphi_{2D}))} \right) (1 - G(\varphi_{2D}))} = \frac{(\delta f_{ei} + \delta f_{iI} (1 - G(\varphi_{1I})))}{(\delta f_{ei} + \delta f_{iI} (1 - G(\varphi_{2I})))}$$

Clearly, $\left(\frac{R\&Dint1}{R\&Dint2} \right)^H > 1$ iff $(\varphi_{1I})^H < (\varphi_{2I})^H$.

Under the Pareto Distribution, the survival productivity cutoffs are given by:

$$\varphi_{iD} = \left(\frac{\sigma - 1}{\gamma - (\sigma - 1)} \left[\frac{f_{iD} + p_{iX} f_{iX} + p_{iI} \delta f_{iI}}{\delta f_{ei}} \right] \right)^{\frac{1}{\gamma}} m$$

and using (11), the innovation cutoff is given by:

$$\varphi_{iI} = (p_{iI})^{-\gamma} \left(\frac{\sigma - 1}{\gamma - (\sigma - 1)} \left[\frac{f_{iD} + p_{iX} f_{iX} + p_{iI} \delta f_{iI}}{\delta f_{ei}} \right] \right)^{\frac{1}{\gamma}} m$$

Rearranging terms, I get:

$$\varphi_{iI} = \left(\frac{\sigma - 1}{\gamma - (\sigma - 1)} \left[\frac{\frac{f_{iD}}{p_{iI}} + \frac{p_{iX}}{p_{iI}} f_{iX} + \delta f_{iI}}{\delta f_{ei}} \right] \right)^{\frac{1}{\gamma}} m \tag{19}$$

Below $\frac{d\varphi_{iI}}{d\Lambda_i} > 0$. is shown.

For the sake of simplicity, let us make the following transformation. Let call $z = (\Lambda_i)^{1-\sigma} \frac{f_{iX}}{f_{iD}}$. Notice that then show $\frac{d\varphi_{iI}}{d\Lambda_i} > 0$ is equivalent to show

$\frac{d\varphi_{iI}}{dz} < 0$. Without loss of generalization I am going to show it for sector 1. Recall that:

$$p_{1I} = \left(\frac{\delta f_{1I}}{f_{1D}\left((\theta_1)^{\sigma-1}-1\right)(1+z)}\right)^{\frac{-\gamma}{\sigma-1}}$$

and that

$$\frac{p_{1X}}{p_{1I}} = \left(\frac{z\delta f_{1I}}{f_{1X}\left((\theta_1)^{\sigma-1}-1\right)(1+z)}\right)^{\frac{\gamma}{\sigma-1}}$$

Notice that $\frac{d\varphi_{iI}}{dz} < 0$ is equivalent to show that $\frac{df}{dz} < 0$,
where $f = (1+z)^{\frac{-\gamma}{\sigma-1}}\left((f_{1D})^{\frac{\sigma-\gamma-1}{\sigma-1}} + z^{\frac{\gamma}{\sigma-1}}(f_{1X})^{\frac{\sigma-\gamma-1}{\sigma-1}}\right)$.

Taking derivatives we have that:

$$\frac{-\gamma}{\sigma-1}(1+z)^{\frac{-\gamma}{\sigma-1}-1}\left((f_{1D})^{\frac{\sigma-\gamma-1}{\sigma-1}} + z^{\frac{\gamma}{\sigma-1}}(f_{1X})^{\frac{\sigma-\gamma-1}{\sigma-1}}\right) + \frac{\gamma}{\sigma-1}z^{\frac{\gamma}{\sigma-1}-1}(f_{1X})^{\frac{\sigma-\gamma-1}{\sigma-1}}(1+z)^{\frac{-\gamma}{\sigma-1}}$$

Rearranging terms we get:

$$\frac{\gamma(1+z)^{\frac{-\gamma}{\sigma-1}}}{\sigma-1}\left[-(1+z)^{-1}\left((f_{1D})^{\frac{\sigma-\gamma-1}{\sigma-1}} + z^{\frac{\gamma}{\sigma-1}}(f_{1X})^{\frac{\sigma-\gamma-1}{\sigma-1}}\right) + \frac{1}{z}z^{\frac{\gamma}{\sigma-1}}(f_{1X})^{\frac{\sigma-\gamma-1}{\sigma-1}}\right]$$

Multiplying the entire expression by z and rearranging terms:

$$\frac{\gamma(1+z)^{\frac{-\gamma}{\sigma-1}}}{\sigma-1}\left[-\frac{z}{1+z}(f_{1D})^{\frac{\sigma-\gamma-1}{\sigma-1}} + \frac{1}{1+z}z^{\frac{\gamma}{\sigma-1}}(f_{1X})^{\frac{\sigma-\gamma-1}{\sigma-1}}\right]$$

This is negative if the second term is negative, which implies

$$z^{\frac{\gamma-(\sigma-1)}{\sigma-1}}\left(\frac{f_{1X}}{f_{1D}}\right)^{\frac{\sigma-\gamma-1}{\sigma-1}} < 1$$

This condition therefore requires that: $\left(\frac{f_{1X}}{zf_{1D}}\right)^{\frac{\sigma-\gamma-1}{\sigma-1}} < 1$ or expressed in another terms: $(\Lambda_i)^{\sigma-\gamma-1} < 1$. Since $\gamma > \sigma-1$, this condition is satisfied as to get the partition between exporters and nonexporters we need that $\Lambda_i > 1$.

Notice that as Λ_i^j increases the innovation productivity threshold increases. Since in this free trade equilibrium $\Lambda_1^H < \Lambda_2^H$ and $\Lambda_1^F > \Lambda_2^F$ then we can conclude that $\varphi_{1I}^H < \varphi_{2I}^H$ and $\varphi_{1I}^F > \varphi_{2I}^F$. Therefore, there is a larger proportion of firms undertaking process innovation in the comparative advantage industry.

Paremeter	Autarky	Free Trade	Percentage Variation
φ_{1D}	0.42886	0.5171	20.57
φ_{2D}	0.42886	0.50675	18.16
φ_{1I}	1.20211	1.13761	-5.36
φ_{2I}	1.20211	1.13963	-5.19
$\tilde{\varphi}_1$	0.79419	1.0876	36.95
$\tilde{\varphi}_2$	0.79419	1.06432	34.01
M_1	499.376	271.409	-45.65
M_2	481.494	113.380	-77.29
M_1^e	152.93	171.511	12.63
M_2^e	152.27	66.87	-56.09

Table 1: A movement from autarky towards FreeTrade

9 Tables and figures

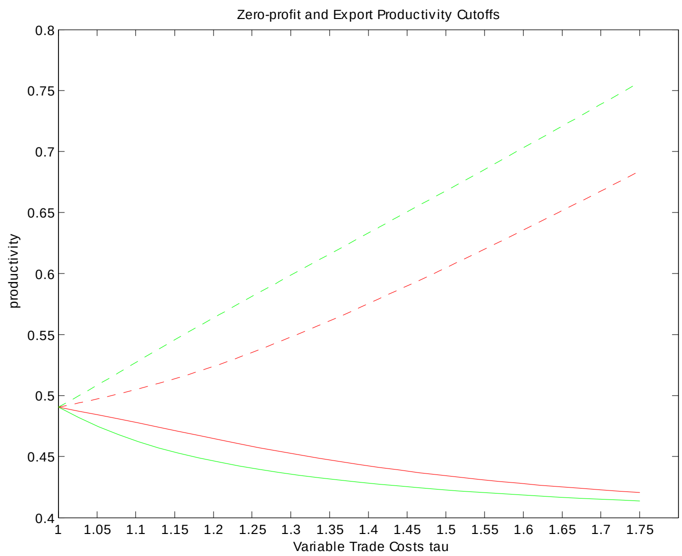

Figure 1: Export and domestic productivity cutoffs: The continuous line represents the survival productivity cutoffs for both industries while the discontinuous line represents the export productivity cutoff for both industries. The red line represents the industry in which the economy has the comparative advantage. As it can be seen, in the industry in which the economy has the comparative advantage the survival productivity threshold is definitely larger. However, the export productivity cutoff is smaller.

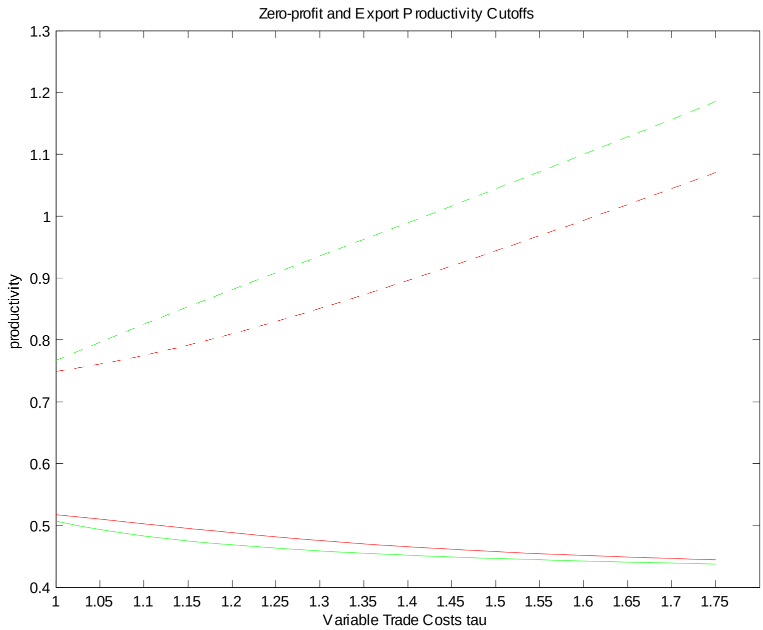

Figure 2: Export and domestic productivity cutoffs (Selection into exporting with $\tau = 1$): The continuous line represents the survival productivity cutoffs for both industries while the discontinuous line represents the export productivity cutoff for both industries. The red line represents the industry in which the economy has the comparative advantage. As it can be seen, in the industry in which the economy has the comparative advantage the survival productivity threshold is definitely larger. However, the export productivity cutoff is smaller.

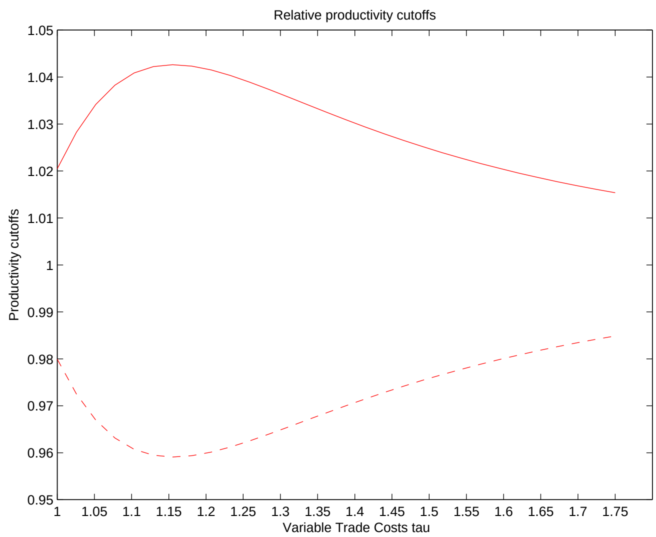

Figure 3: Relative productivity cutoffs. The figure displays the relative productivity cutoffs of Industry 1 vs Industry 2 for both the home country (continuous line) and foreign country (discontinuous line).

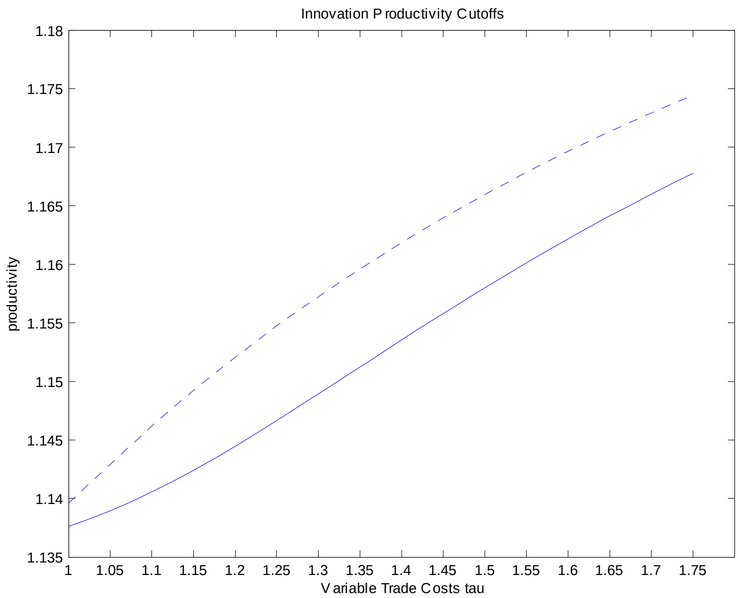

Figure 4: Industry 1 productivity cutoff is represented by the continuous line while the discontinuous line while the discontinuous line represents the industry 2 productivity cutoff

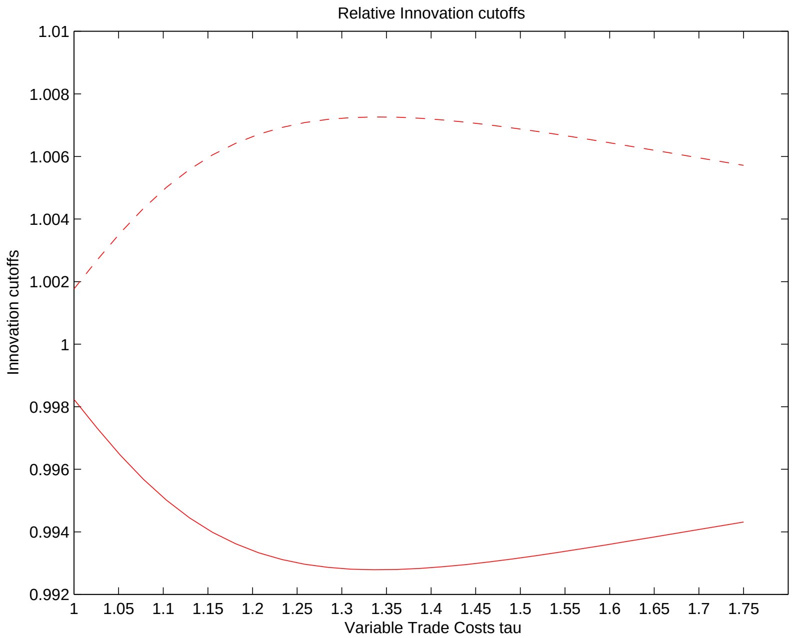

Figure 5: Relative Innovation Cutoffs. This figure displays the relative innovation cutoffs (Industry 1 vs Industry 2) for both the Home (continuous line) and the Foreign country (discontinuous line) as a function of the trade costs.

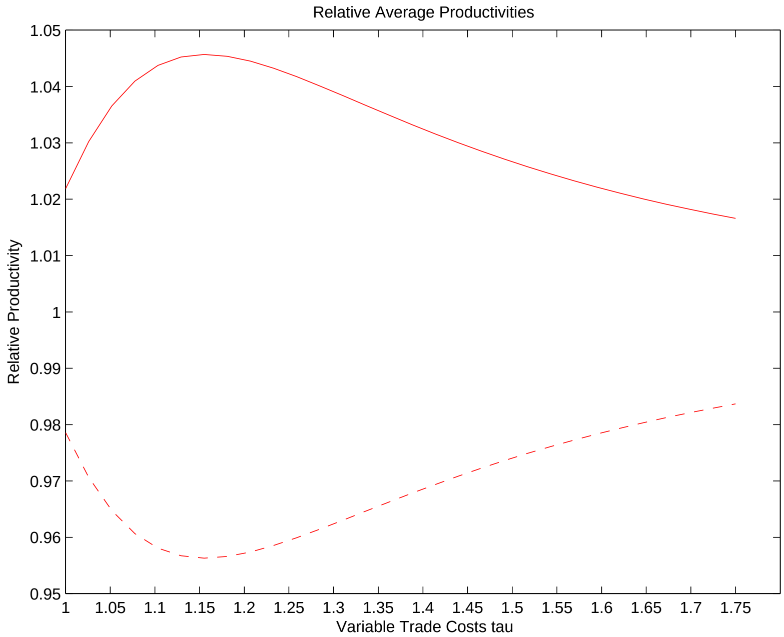

Figure 6: Evolution of the relative average Productivity (Industry 1/Industry 2) in the home (Continuous line) versus the foreign country (Discontinuous line.

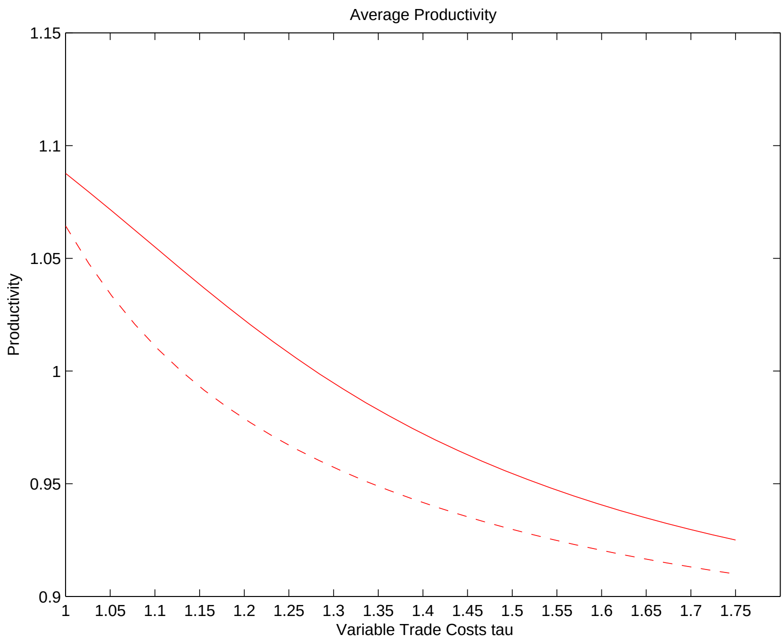

Figure 7: Evolution of the Average Productivity in Industry 1 (Continuous line) and Industry 2 (Discontinuous line) in the Home Country.

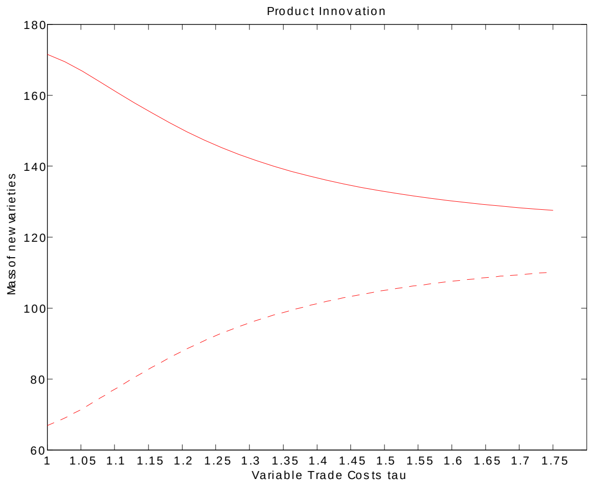

Figure 8: Product Innovation in the Home Country. This figure displays the creation of new varieties for different variable trade costs for both industries, industry 1 (continuous line) and industry 2 (discontinuous line).

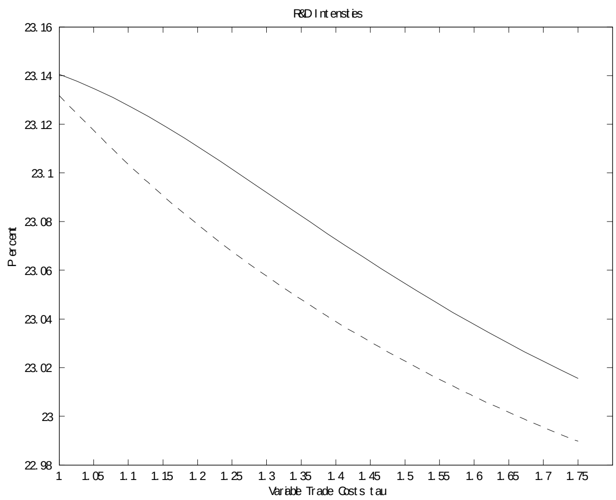

Figure 9: R&D intensities across industries in the home country. The figure displays the R&D intensities for industry 1 (continuous line) and industry 2 (discontinuous line) for the home country.

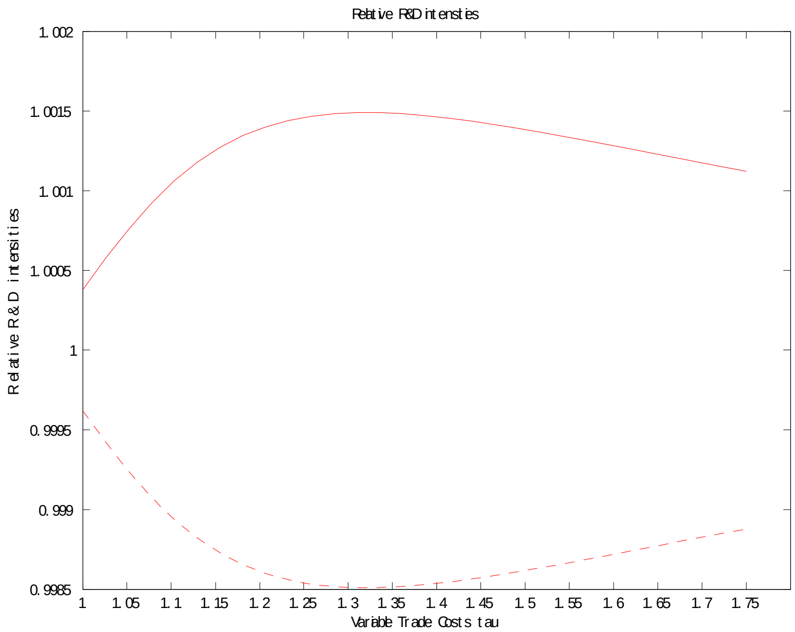

Figure 10: R&D intensities across industries in the home country. The figure displays the R&D intensities for industry 1 (continuous line) and industry 2 (discontinuous line) for the home country.