UNIVERSIDAD CARLOS III DE MADRID
working papers

Working Paper 07-67
Economic Series (37)
August 2007

Departamento de Economía
Universidad Carlos III de Madrid
Calle Madrid, 126
28903 Getafe (Spain)
Fax (34) 916249875

TECHNOLOGY ADOPTION AND THE SELECTION EFFECT OF TRADE*

Antonio Navas-Ruiz† (GREQAM and European University Institute)
Davide Sala‡ (Eberhard Karls University Tübingen and European University Institute)

First draft: January 2005.
This draft: August 2007.

Abstract

The reallocation of output across plants and the productivity growth at individual plants are both important sources of productivity growth at the industry level. Recent evidence has shown that trade liberalization is related to both effects. While a trade model with firm heterogeneity can account for the first effect, it can not explain the second effect. We add to this model the option for firms to costly adopt more productive technologies and show that plant productivity actually rises in response to lower trade costs. Following trade liberalization, selection into exporting raises the market share only for some exporters. Therefore, a greater scale of operation amplifies their return from costly productivity-enhancement investments and leads a greater proportion of them to implement a more innovative technology.

Keywords: International Trade, Technology Adoption, Productivity
JEL Classification: F12, F15, L11, O33, O47

* We are indebted to Prof. Gian Marco Ottaviano for supporting us in this research project and to prof. Wilhelm Kohler for his comments on a early draft of this paper. We would also like to thank Prof. Robert Feenstra, Prof. Gabriel Felbermayr, Prof. Omar Licandro, prof. Morten Ravn, Prof. Pascalis Raimondos-Møller, the EUI trading group and seminar-participants at the EUI, in Copenhagen, in Tuebingen, in Lisabon, in Budapest for their helpful suggestions and insightful discussions.
† Current affiiation: Universidad Carlos III Madrid, C/ Madrid, 126 - 28903 Getafe Spain. Email: antonio.navas@univmed.fr. Tel: +34 916249845
‡ Chair of International Economics - Eberhard Karls University Tuebingen. Corresponding address: davide.sala@uni-tuebingen.de

1 Introduction

Productivity is a key element for the success of a firm in the market and forms part of the management´s targets. Being part of the managerial strategy, it responds also to the external environment. In particular, recent evidence has highlighted that firms have reacted to new trading opportunities incrementing their productivity. As shown in Trefler (2004), the estimates for Canadian manufacturing firms in the context of Canada-US free trade area are substantial: "*U.S. tariff concessions raised labor productivity by ... 1.9 percent annually in the most impacted, export-oriented group of industries*". Likewise - as reported by Bernard, Jensen and Schott (2006) - plant-productivity improvements are associated to declining industry-level trade costs in the US manufacturing industry. Similar patterns are shown by Topolova (2004) for India, by Alvarez and Lopez (2005) for Chile and by Bustos (2005) for Argentina.

In spite of its empirical relevance, this firm behavior is hardly explained by the recent trade literature with heterogenous firms pioneered by Melitz (2003) and Bernard et. al. (2003). At the heart of this literature, there is a distinct response of firms to new trading opportunities, including entry into exporting by some and increased failure by others. Therefore, trade in these models entails a reallocation of economic activities across firms, but do not provide any incentive for intra-firm productivity increments.

This is also reflected at the industry level. Such reallocation of economic activity across firms necessarily boosts industry productivity, but, in absence of within-firm productivity adjustments, these models can not account for an important channel of industry productivity growth, which constitutes for the bulk of overall labour productivity growth in industrial economies.[1]

In this paper, we focus on how trade can affect the adoption of a new technology by a firm, just one possible option managements have to increase the firm´s productivity. We think broadly of the adoption of a new technology, embedding all activities aimed at reducing the marginal cost of production.[2]

We contribute to the literature showing that the productivity of some plants actually rises in response to lower trade costs, so that trade models with heterogenous firms embedding an endogenous technology choice are consistent with the firm-level evidence.

[1] See Bartelsman, Haltiwanger, and Scarpetta (2004) and Trefler (2004).

[2] Examples are appointing a new management or chief-executers, the internal re-organization of labour, the qualification and training of employees

More specifically, it is sensible that a new and unexperienced firm starts up with a well established "*baseline*" technology and - as in Melitz (2003)- learn about its productivity only upon becoming operative into the market. Having assessed the firm´s potentials, the management can target higher productivity levels and opt to costly implement an "*innovative*" technology, featuring lower variable costs and higher implementation costs, relative to the "*baseline*" technology. This trade-off shapes the "*modus operandi*" of the firm which constitutes the novelty of the paper and reflects the endogenous technology choice available to all firms. It is very much like the proximity-concentration trade off determining the export mode in Helpman, Melitz and Yeaple [HMY henceforth, (2004)]. The return of a process innovation are associated to a reduction of the variable costs and, therefore, to the firm's scale of production.

Since trade liberalization entails a larger access to product markets and a higher demand for the firm's product, it increases production of domestic exporters, increasing the returns from technology adoption. A group of exporters will find the option for the innovative technology more attractive. However, trade liberalization also increases competition, so that exporters will not necessarily increase his sales. In addition, both adoption and exporting require extra-labour, rising labour demand, and therefore the cost of adoption. The latter effect only holds in a general equilibrium setting, whereas it is absent in a partial equilibrium model, which abstract from factor markets, like in Bustos (2005).

Overall trade liberalization has ambiguous effects on the innovation activity of a firm. We show that the positive effect prevails, so that when trade costs fall, productivity can increase at the plant level, in particular among exporters. In addition we show that selection into exporting markets -which is related to fixed costs of export- is a necessary condition for our result to hold. When all firms export, the effects of a larger market is perfectly offset by the increase in the mass of competitors.[3] Output and profits are then unchanged and, so are the incentives for innovation. The asymmetric access to export markets limits entry within each market. Market size for exporters rises by more than the increase in the number of competitors, expanding their outputs and rising their incentives to innovate. This is the new and main result of our model, and mostly important, not only holds true in the transition from autarky to trade (i.e. when a country first opens to trade), but it also applies when transportation costs, - a proxy for trade barriers- are reduced. It also suggests that empirical studies should control appropriately for "self-selection " when testing the "learning by exporting" hypothesis. Finally our result is related to the effects of trade on industry productivity.[4] Not only the reallocation of activity across firms, but also

[3] see Freenstra (2004). This result depends crucially on CES preferences which we assume in our model

[4] See Delgado et. al. (2002), Girma et. al. (2004), Alvarez and Lopez (2005) and De Loecker (2006). The *self selection hypothesis* relates to the fixed cost of exporting, so that only the more productive firms can successfully do

intra-firm productivity growth boosts industry productivity.

Our model is closely related to some recent papers in the literature. Bernard et. al. (2006) complement our analysis and propose the product scope of a firm as a further plausible mechanism through which trade favours productivity increments at the plant level.

Like us, Costantini and Melitz (2007) and Atkeson and Burstein (2007) emphasize the technological side. Differently from us, the first paper focuses on stochastic innovation and analyze the transitional dynamics induced by a trade reform. The second paper presents a general equilibrium dynamic model of firm innovations, emphasizing the interaction of process and product innovation. While we focus on technology adoption with firms facing a trade-off between different alternatives, they model productivity increments as stochastic process innovations upgrading (if successful) the technology level. Long et. al. (2007) consider instead innovation activity with firm interactions in an oligopolistic market.

Finally, Baldwin and Nicoud (2006) and Gustafsson and Segerstrom (2006) have shown, focusing on product innovation, that the dynamic positive effect of trade liberalization on aggregate productivity growth relies on specific technological spillover. Our model instead suggests that when firms perform vertical innovation, the selection effect could generate productivity growth by forcing the least efficient firms out of the market, even if no technological spillover occurs. Higher market shares incentive process-innovation leading to productivity growth.

The paper is organized as follows. Section 2 presents the model in the closed economy to be compared with the open economy in Section 3. This comparison is illustrative of the effects of trade on the firm´s choice of technology adoption and on the industry-productivity growth. The last section concludes.

2 The Closed Economy

In this section we extend Melitz (2003) to incorporate technology adoption.

Preference

Our economy is populated by a continuum of households of measure L, whose preferences are represented by the standard C.E.S. utility function:

it. The *learning by exporting hypothesis* emphasizes the possibility that exporters become more productive because of the exposure to foreign knowledge and to a more competitive environment. In particular, all studies but Delgado find evidence of learning by exporting when controlling for self selection.

$$U = \left[\int_{\omega \in \Omega} [q(\omega)]^{\rho} d\omega \right]^{1/\rho}$$

where the measure of the set Ω represents the mass of available goods, $0 < \rho < 1$. Households are endowed with one unit of labour (inelastically supplied at the given wage w) and maximize their utility subject to the total expenditure $R = \int_{\omega \in \Omega} p(\omega)q(\omega)d\omega$, so that the demand function for variety ω is:

$$q(\omega) = \frac{R}{P^{1-\sigma}} [p(\omega)]^{-\sigma} \tag{1}$$

where $P = \left[\int_{\omega \in \Omega} [p(\omega)]^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}}$ is the price index of the economy and $\sigma = 1/(1-\rho) > 1$ is the elasticity of substitution across varieties.

Technology

Each variety is produced by a single firm according to a technology for which the only input is labour. The total amount of labour required to produce the quantity $q(\omega)$ of variety ω is given by

$$l(\omega) = f_D + cq(\omega) \tag{2}$$

where f_D is the fixed labour requirement and $c \in [0, \overline{c}]$ the firm-specific marginal labour requirement[5].

Entry - Exit

There is a large (unbounded) pool of prospective entrants into the industry and prior to entry, all firms are identical. To enter the industry, a firm must make an initial investment, modelled as a fixed cost of entry $f_E > 0$ measured in labour units, which is thereafter sunk. An entrant then draws a labour-per-unit-output coefficient c from a known and exogenous distribution with cdf $G(c)$ and density function $g(c)$ on the support $[0, \overline{c}]$. Upon observing this draw, a firm has three options. Like in Melitz (2003), it may decide to exit or to produce. If the firm does not exit and/or produces, it bears the fixed overhead labour costs f_D. Additionally to Melitz (2003), by investing f_I units of labour, it can opt for adopting a more productive technology and produce at a lower cost γc ($\gamma < 1$). Ultimately, it is a choice among a well established "*baseline*" technology - characterized by low "implementation" costs, normalized to 0, and variable costs of production c - and, an *innovative one* - featuring lower variable costs (γc), but higher fixed cost of adoption

[5] Clearly, this technology exhibits increasing return to scale. f_D can be thought as all those activities like marketing or setting up a sales network which are independent of the scale of production. Then, it can be seen as the fixed cost of serving the domestic market. The inverse of c is a measure of a firm's productivity in the production process.

(f_I). The trade-off being between *efficiency-implementation costs*, much like of the *proximity-concentration* trade off for horizontal FDI in HMY (2004).

We are assuming that technological uncertainty and heterogeneity of the Melitz-type relates to what we have called a "*baseline*" technology, reflecting that firms have to learn about their market and their productivity before they can plan to improve it. Having found out about their idiosyncratic productivity, all firms face the option of adopting an alternative technology, what we have referred to as the "*innovative*" one. While the extra fixed cost is the same for each firm, the reduction in variable cost is proportional to the firm's idiosyncratic "marginal cost draw" given from its own entry. Since the Melitz-type entry leads to heterogeneity in variable cost, the technological option results also differently attractive for different firms, relative to their "*baseline*" technologies. This could be rationalized as some firms being more successful than others in implementing the new technology. Indeed, technology-implementation requires an active engagement of the adopter - namely a series of investments undertaken by the adopter - beyond the selection of which technology to adopt. These investments are often label "technology implementation process" which are in the data the main source of site-to-site variations in the success (productivity) of the adopter, better implementation makes new technologies more productive.[6]

The consumers may benefit from this form of innovation in the form of a reduction of good prices. We shall refer sometimes to this reduction of costs in the production stage with an abuse of terminology as *process* or *vertical innovation* .

Finally, as in Melitz (2003) every incumbent faces a constant (across productivity levels) probability δ in every period of a bad shock that would force it to exit.

Prices and Profits

A producer of variety ω with labour-output coefficient c faces the demand function (1) and charges the profit maximizing price:

$$p(\omega) = \frac{\sigma}{\sigma - 1} wc \equiv p_D(c) \tag{3}$$

where $\frac{\sigma}{\sigma-1}$ is the constant markup factor and w is the common wage rate, hereafter taken as the numeraire ($w = 1$). The effective price (3) charged to consumers by non-innovator is higher than the price $p_I(c) = \gamma p_D(c)$ charged by an innovator. Substituting (3) in (1), the output of a non-innovator is:

$$q(\omega) = A \left[\frac{\sigma}{\sigma - 1} c \right]^{-\sigma} \equiv q_D(c) \tag{4}$$

[6] See Comin (2007) and Bikson et. al. (1987).

and likewise, $q_I(c) = \gamma^{-\sigma} q_D(c)$ for an innovator. Therefore, the profit of firm type D (producer with a "traditional" technology) and firm type I (firm with innovative technology) are:

$$\pi_D(c) = \frac{r_D(c)}{\sigma} - f_D = Bc^{1-\sigma} - f_D \tag{5}$$

$$\pi_I(c) = \frac{r_I(c)}{\sigma} - f_D - \delta f_I = B(\gamma c)^{1-\sigma} - f_D - \delta f_I \tag{6}$$

where $r_s(c) = p_s(c)q_s(c),\ s = D, I$ is the revenue of firm type s and $B = (1/\sigma)\frac{R}{P^{1-\sigma}}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}$ is taken as a constant by a single producer and it represents the level of demand in the country. The innovation cost f_I into the profit function is weighted by the exogenous probability of exiting, because the innovation decision occurs after firms learn about their productivity c and since there is no additional uncertainty or time discounting other than the exogenous probability of exiting, firms are indifferent between paying the one time investment cost f_I or the per-period amortized cost δf_I. We shall adopt the latter notation for analytical convenience.

For illustrative purpose, let us consider in figure 1 the profit profiles associated to the two possible technology choice. From the prospect of a single firm, (5) and (6) are linear in $c^{1-\sigma}$ which can be interpreted as a firm's productivity index: the higher it is, the greater the productivity of a firm.[7] Given the fix overhead cost of innovation and that the profit of an innovator is always steeper than a non-innovator's one, technology adoption will be profitable only for high-productivity firms. Firms with draws below $(c_o)^{1-\sigma}$make negative profit and have to exit, while firms with productivity index above $(c_o)^{1-\sigma}$ entry successfully. Only a fraction of these firms ($c^{1-\sigma} \geq (c_I)^{1-\sigma}$), perform also process-innovation.

Using (4) and (3), we have the ratio of any two firms's output and revenues only depend on the ratio of their productivity levels:

$$\frac{q(c_1)}{q(c_2)} = \left[\frac{c_1}{c_2}\right]^{-\sigma}, \quad \frac{r(c_1)}{r(c_2)} = \left[\frac{c_1}{c_2}\right]^{1-\sigma} \tag{7}$$

(7) has some interesting implications. First, dividing numerator and denominator of the quantity ratio by Q and the numerator and the denominator of the revenue ratio by R, we can conclude that relative market shares of the firms depends only on the cost ratio and is independent of aggregate variables. Second, $r_I(c)/r_D(c) > 1$, that is rent increases more than proportionally following the introduction of process innovations.[8]

[7] B is an endogenous variable of the model and it is a non linear function of c. However, from a single firm's prospect, B is taken as given and therefore, it can be treated as a constant. This graph can not be used for comparative statistic or to pin down equilibrium values, but it is useful to understand the behavior of a firm with a productivity draw c.

[8] Note that $r_I(c)/r_D(c) = \gamma^{1-\sigma} r_D(c)/r_D(c) = \gamma^{1-\sigma} > 1$, since $\sigma > 1$ and $\gamma < 1$.

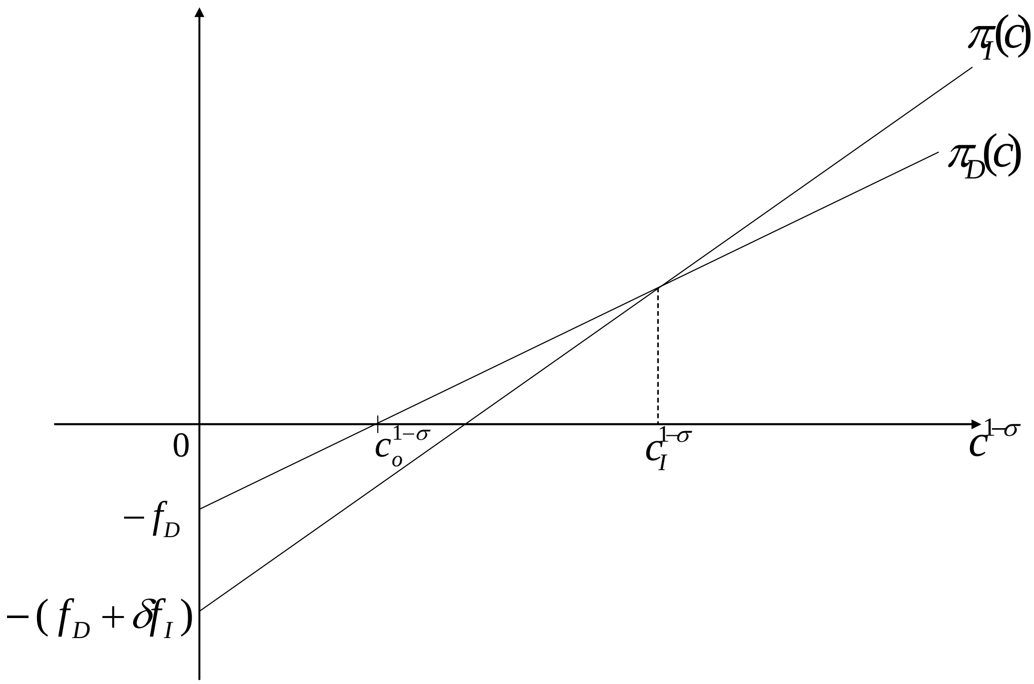

Figure 1: Profits from producing and innovating on the domestic market.

2.1 Equilibrium in a closed economy

We are interested in a stationary equilibrium where the aggregate variables must also remain constant over time. As in Melitz (2003), this requires a mass M_e of new entrants in every period, such that the mass of successful entrants, $M_eG(c_o)$, exactly replaces the mass δM of incumbents who are hit by the bad shock and exit, .

The equilibrium entry cost-cutoff c_o and innovation cost-cutoff c_I must satisfy:

$$\pi_D(c_o) = 0 \Longleftrightarrow B\,(c_o)^{1-\sigma} = f_D \tag{8}$$

$$\pi_I(c_I) = \pi_D(c_I) \Longleftrightarrow (\gamma^{1-\sigma} - 1)B\,(c_I)^{1-\sigma} = \delta f_I \tag{9}$$

Since their productivity is unrevealed upon entry, firms will compare the expected profit in the industry with the entry cost, taking into account the possibility of being hit by a bad shock. Free entry ensures the following equality :

$$\sum_{t=0}^{\infty}(1-\delta)^t \left[\int_0^{c_I}\pi_I(c)dG(c) + \int_{c_I}^{c_o}\pi_D(c)dG(c)\right] = f_E$$

or:

$$\delta f_E = \int_0^{c_I}\pi_I(c)dG(c) + \int_{c_I}^{c_o}\pi_D(c)dG(c) = \overline{\pi}G(c_o) \tag{10}$$

which states that firms equate the per-period expected profit from entering and the equivalent amortized per-period entry cost. The last equality is derived in the appendix with $\overline{\pi}$ denoting the average profit in the industry and shows that following an increase in the per-period entry cost δf_E, firms are willing to enter if they can expect either a higher per period average profit or greater chances of entry (higher c_o).

(8) to (10) characterize the equilibrium cost-cutoffs c_o and c_I as well as B.

Combining (8) with (9) we have the relation between the innovation and the entry cutoff:

$$(c_I)^{1-\sigma} = \frac{\delta f_I}{\gamma^{1-\sigma}-1}\frac{1}{f_D}(c_o)^{1-\sigma} = \Psi (c_o)^{1-\sigma} \tag{11}$$

where $\frac{\delta f_I}{\gamma^{1-\sigma}-1}$ is the cost to benefit ratio of innovation. The numerator is the per-period cost of innovation while the denominator represents the revenue differential of innovation per unit of revenue initially earned. It follows that a necessary and sufficient condition to have selection into the innovation status is $\Psi > 1$, which is assumed to hold throughout since the empirical evidence suggests that only a subset of more productive firms undertakes process innovations[9].

Given (11), (10) is a function of only c_o. The equilibrium is depicted in figure 2, where the flat line δf_E crosses the LHS of (10) which is monotonically increasing from 0 to infinity in c, as proved in the appendix. The graph clearly highlights that c_o has to rise when the fixed cost of entry increases, as discussed above.

More interesting is an increase of f_D - the degree of increasing return to scale - or, alternatively, conceivable as the cost of staying in the industry. This thought experiment has strong analogies to the effects of trade liberalization in our open economy analyzed next, as both exercises have in common that they make survival of domestic firms harder (selection effect). More specifically, a greater f_D lowers Ψ, but it also shifts up the LHS curve in fig. 2, so that it reduces the entry cost-cutoff to $c_o^{'}$ (see(35) in the appendix). Overall, the effect of an increase in f_D on the innovation productivity cutoff $(c_I)^{1-\sigma}$ is ambiguous since Ψ is lower, but $(c_o)^{1-\sigma}$ is larger. This ambiguity is a specific-feature of a general equilibrium model, whereas in partial equilibrium the effect of f_D would be well determined and would affect the economy only through Ψ. The intuition comes from inspecting (5) and (6). A larger f_D reduces the profits of all firm types in the economy for any given c, forcing the least productive firms out of the market given that they are unable to recoup the increased fixed cost of operation. Selection reduces the mass of firms followed by a reduction in the price index P, making possible for incumbent firms to expand their output and, consequently, increase their innovation profits (higher B). This is the pro-innovation effect

[9] See for instance Parisi et. al. (2005) for evidence on Italian firms and Baldwin et al. (2004) for evidence on Canada.

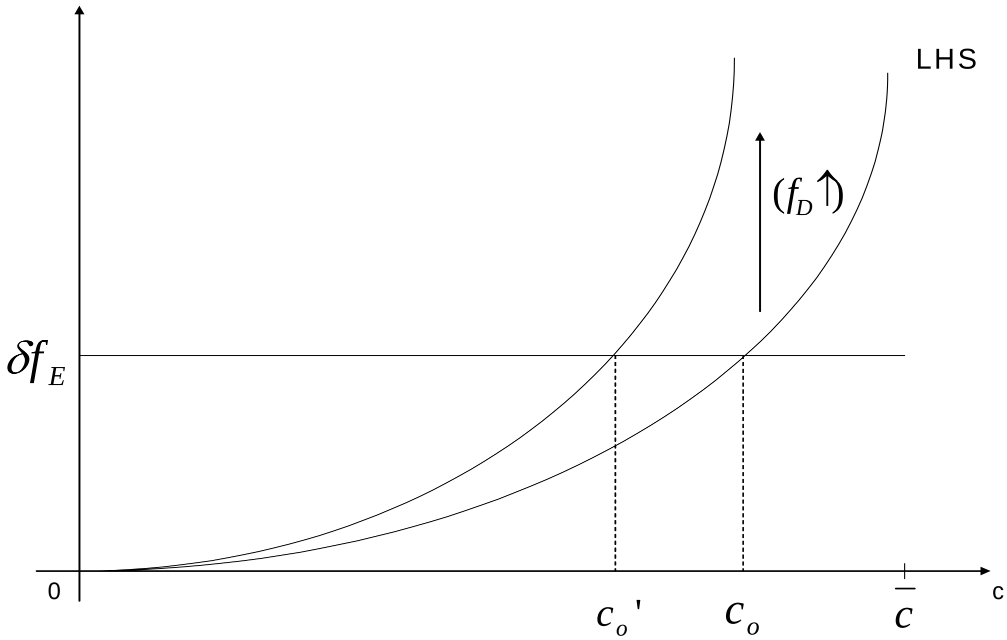

Figure 2: Determination of the equilibrium entry cost cutoff as given by the Free Entry Condition

through selection behind the reduction of Ψ. However, labour demand by innovating firms and potential entrants raises, putting upward pressure on the labour-factor market, leading to a higher real wage $(1/P)$. As a result, profits are reduced (through the B). This is the general equilibrium effect via the factor market behind the rise in $c_o^{1-\sigma}$ and it would be absent in partial equilibrium since the equilibrium wages are unchanged.

The net effect will depend on the relative strength of the two sides of selection. These two offsetting forces on the innovation activity will also be at play in the more complex scenario of an open economy which undergoes through trade liberalization.

Note that the entry productivity cutoff level is higher in our economy than in Melitz (2003).[10] The possibility to innovate allows the most efficient firms that perform process innovation to "steal" market shares to the least efficient firms for which is harder to survive into the market. Consequently, our economy is more efficient, because some varieties are produced at a lower cost, but less varied because some varieties have disappeared. This trade-off has been well emphasized in the growth literature (see Peretto (1998) and more recently Gustafsson and Segerstrom (2006)).

[10] The proof of this result has been left to the appendix.

3 The Open Economy

Let us assume that the economy under study can trade with other $n \geq 1$ symmetric countries. We will assume that trade is not free, but it involves both fixed and variable costs. One can think of the fixed cost associated to trade as the cost of customizing its own variety to the regulations and tastes of foreign countries as well as of creating sale-networks. The variable trade costs are trade or legal barriers such as transportation costs imposed or tariffs. We follow a long tradition in the trade literature and model these variable costs in the iceberg formulation: $\tau > 1$ units of a good must be shipped in order for 1 unit to arrive at destination.

Finally, the symmetry of countries is required to ensure that factor price equalization holds and countries have indeed a common wage which can be still taken as the numeraire.[11] The symmetry assumptions also ensures that all countries share the same aggregate variables.

Prices,Profits and Firm-Types

The imported products are more expensive than domestically produced goods due to transportation costs. As a result, the effective consumer price for imported products from any of the n countries is $p_X(c) = \tau p_D(c)$, while an exporter who has opted for process innovation charges $p_{XI}(c) = \gamma p_X(c)$. The profits of an exporter and an innovator-exporter in a foreign market are:

$$\pi_X(c) = \tau^{1-\sigma} B c^{1-\sigma} - \delta f_X \tag{12}$$

$$\pi_{XI}(c) = (\gamma\tau)^{1-\sigma} B c^{1-\sigma} - \delta f_X \tag{13}$$

where δf_X is the amortized per-period fixed cost of the overhead fixed cost f_X that firms have to pay (in units of labour) to export to foreign markets.[12]

No firm will ever export and not also produce for its domestic market. Indeed, any firm would earn strictly higher profits by also producing for its domestic market since the associated variable profit $r_D(c)/\sigma$ is always positive and the overhead production cost f_D is already incurred. Moreover, since the export cost is assumed equal across countries, a firm will either export to all n countries in every period or never export.

The empirical evidence suggests that exporting and innovation are performed by the most productive firms (lowest cost levels), while domestic producers are typically smaller, less innovative and less productive. Accordingly, we shall focus on the selections with the exporters or the

[11] Alternatively, a freely traded homogenous good produced under constant return to scale could be introduced to pin down its price and thus the wage to unit in all countries.

[12] Note we account for the entire overhead production cost in the domestic profit (see (5) and (6)). This choice is uninfluential for the equilibrium as all firms (domestic producers and exporters) will produce also for the domestic market and incur f_D upon staying into the industry.

innovators being the most productive types. In selection BW in figure 3, exporting is relatively cheaper than innovating and therefore only the most productive exporters can undertake vertical innovation: an innovating firm is necessarily an exporter (XI-type), but there are exporters that are not innovators (X-type).[13] Indeed, from (12) and (13) it is easy to check that if the X-type is making positive profit from exporting, then also the XI-type does necessarily so. However, no innovator would produce and innovate just for the domestic market (no I-type) because given her high productivity she would give up positive profits from not meeting the foreign demand.

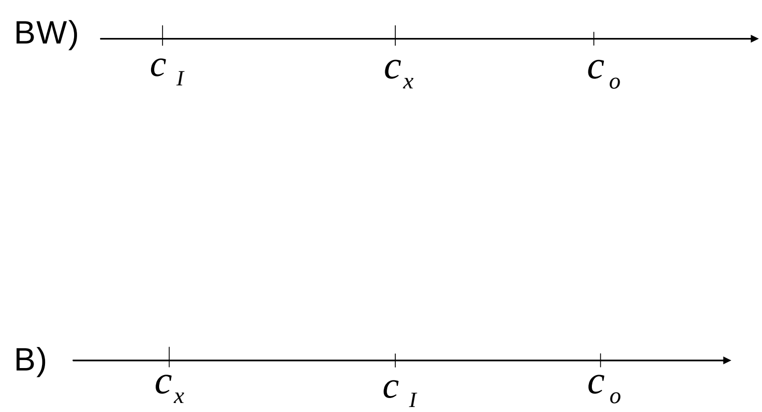

Figure 3: Plausible selections

On the contrary, in selection B only a fraction of incumbents innovate (I-type) and only a subset of innovators become exporters (XI-type). No firm will ever export without innovating (no X- type). Indeed, firms that can take advantage of profit opportunity abroad are already innovating on the domestic market. Therefore they will exploit their innovative technology to serve the foreign market as well.

BW is interesting because the marginal innovating firm is an exporter and trade will likely affect its innovation decision. B represents the other side of the same coin: the marginal innovating firm is a domestic producer and therefore, innovation is mostly determined by domestic factors and will less likely respond to trade liberalization.

Given the aim of the paper, we focus closely on selection BW where trade induces within-

[13] This is different from Yeaple (2005) where the firm type adopting the innovative technology is also necessary an exporter. In other words, the exporting firms coincides with the innovative types and therefore, no selection on the basis of innovation status is possible.

plant productivity changes besides allocative effects of market shares. Then, we turn to discuss briefly selection B and highlight why trade is not influential on plants' innovation activity. In this equilibrium, trade affects productivity only through allocative effects.

3.1 Selection BW

We are again interested only in a stationary equilibrium where all aggregate variables are constant over time, i.e. $\delta M = M_e G(c_o)$. Note that the equilibrium value of the aggregate variable Q, R, and therefore A and B as well as of the entry cutoff c_o is different in this equilibrium from the closed economy one. Nevertheless we stick to same notation as they are defined in the same way.

Cutoffs in **equilibrium BW** must satisfy the following conditions:

$$\pi_D(c_o) = 0 \Leftrightarrow \frac{r_D(c_o)}{\sigma} = B\,(c_o)^{1-\sigma} = f_D \tag{14}$$

$$\pi_X(c_X) = 0 \Leftrightarrow \frac{r_D(c_x)}{\sigma} = Bc_X^{1-\sigma} = \frac{\delta f_X}{\tau^{1-\sigma}} \tag{15}$$

$$\pi_I(c_I) + n\pi_{XI}(c_I) = \pi_D(c_I) + n\pi_X(c_I) \Leftrightarrow \frac{r_D(c_I)}{\sigma} = B\,(c_I)^{1-\sigma} = \frac{\delta f_I}{(\gamma^{1-\sigma}-1)(1+n\tau^{1-\sigma})} \tag{16}$$

Thus the parameter restriction that sustains this equilibrium ($c_I \le c_X \le c_o$) where only exporters perform process innovation must satisfy:

$$\frac{\delta f_I}{(\gamma^{1-\sigma}-1)}\frac{1}{(1+n\tau^{1-\sigma})} \ge \delta f_X \tau^{\sigma-1} \ge f_D \tag{17}$$

This condition requires innovating being relatively more expensive than exporting. That is, foreign markets should be fairly accessible, otherwise serving them would result extremely costly and it could be afforded exclusively by innovators.

$\frac{\delta f_I}{(\gamma^{1-\sigma}-1)}$ is equivalent to the cutoff for innovation for the closed economy: the same assumptions that guarantees selection on the basis of innovation status in the closed economy (i.e., $\Psi \ge 1$) ensures that this term is positive and bounded away from zero in the open economy. Recall that this term represents the cost to benefit ratio of innovation. Importantly, in the open economy we have an extra term given by $\frac{1}{(1+n\tau^{1-\sigma})}$ which is unity in the closed economy (set $n = 0$ or $\tau \to \infty$). The denominator represents precisely the further revenue differential associated to innovation on each of the foreign markets that become available with trade.

We like to think of n as the number of countries into the trading network sharing a common code of rules as it could be for the WTO members. Then, it represents a measure of the world's openness to trade, as for a low n very few countries have trading relations. $\phi = \tau^{1-\sigma} \in [0, 1]$ is commonly referred in the literature as an index of the freeness of trade with values closer to 1 indexing freer trade.

Clearly, trade liberalization that come in the form of either freer trade (greater ϕ) or greater world openness (larger n) can affect process innovation weighing upon the return of innovation.

(14) to (16) give a system of 3 equations in 4 unknowns (c_o,c_X,c_I,B). The FE condition:

$$\int_{c_X}^{c_o} \pi_D(c)dG(c) + \int_{c_I}^{c_X} (\pi_D(c) + n\pi_X(c))dG(c) + \int_{0}^{c_I} (\pi_I(c) + n\pi_{XI}(c))dG(c) = \delta f_E \tag{18}$$

closes this system and the cost cutoffs can be uniquely determined. Combining appropriately the three conditions for the cutoff points ((14) to (16)), the relation between the cutoffs can be written explicitly as:

$$(c_I)^{1-\sigma} = \frac{\delta f_I}{(\gamma^{1-\sigma} - 1)(1 + n\tau^{1-\sigma})} \frac{1}{f_D} (c_o)^{1-\sigma} = \Psi^f (c_o)^{1-\sigma} \tag{19}$$

$$(c_I)^{1-\sigma} = \frac{\delta f_I}{(\gamma^{1-\sigma} - 1)(1 + n\tau^{1-\sigma})} \frac{1}{\delta f_X \tau^{\sigma-1}} c_X^{1-\sigma} = (\Psi_X^f) c_X^{1-\sigma} \tag{20}$$

$$c_X^{1-\sigma} = \frac{\delta f_X \tau^{\sigma-1}}{f_D} (c_o)^{1-\sigma} \tag{21}$$

Note that $\Psi = \Psi^f(1 + n\tau^{1-\sigma})$ and $\Psi_X^f = \Psi^f f_D/\delta f_X \tau^{\sigma-1}$. $\Psi \geq \Psi^f$ - namely, the cost to benefit ratio is smaller in the trading equilibrium than in autarky - reflects that trade and vertical innovation are related: new market opportunities abroad induce exporters to expand their scale of operation, so that the benefits of cost-reducing innovation are spread on a greater number of units, while the up-front cost of innovation is unchanged. Comparing (19) with (11) shows trade (for positive n and non-prohibitive transportation cost τ) reduces, *ceteris paribus,* the innovation productivity cutoff $(c_I)^{1-\sigma}$and therefore it boosts *within-plant innovation.* This is the partial equilibrium effect described also in Bustos (2005).[14]

However, this is not enough for concluding the proportion of incumbents undertaking productivity innovation will be larger after trade. In general equilibrium, trade affects also the entry productivity cutoff $(c_o)^{1-\sigma}$ which results higher in the trading equilibrium than in autarky (*selection effect*), as it is shown in the appendix.

As discussed above , two forces are affecting the innovation cost cutoff when the economy opens to trade:

i) the selection effect and, the asymmetric access to exporting markets, together increase exporters' total market shares, rising the benefit of cost-reducing innovation. Thus, some incumbent will start performing vertical innovation - $\Psi^f < \Psi$.

[14] This situation would describe an industry within the economy which is small enough to affect the equilibrium wages of the economy, and where no entry and exit takes place.

ii) Exporters, innovators and potential entrants, exacerbate the competition for the scarce labour input and push up the real wage. Survival becomes tougher ($c_o^{1-\sigma}$ increases), and exporting and innovating more costly.

The latter effect occurs through the input-factor market and, therefore, only in a general equilibrium setting. It would be necessarily absent in a partial equilibrium approach since the equilibrium wage in the industry is unaffected.
The overall effect of trade on innovation is ambiguous and depends on the relative strength of these pushing and deterring factors of process innovation, similarly to the effect of an increase in f_D above. Although the proportion of incumbents is reduced (lower c_o), the proportion of innovating firms among them will raise (higher c_I) if *i)* dominates *ii)*, namely if the adjustments through the extensive margin of innovation dominate those through the extensive margin of trade.

In order to shed some light on which effect dominates, we use a specific parametrization for $G(c)$. We shall show that the net outcome of these two offsetting forces is a higher proportion of firms performing process innovation with freer trade.

Assuming that the productivity draws ($1/c$) are distributed according to a Pareto distribution with low productivity bound ($1/\bar{c}$) and $k \geq 1$, the c.d.f of cost draws c is given by:

$$G(c) = \left(\frac{c}{\bar{c}}\right)^k, \quad k > \sigma - 1, \quad k > 2. \tag{22}$$

This formulation has been used widely in many extensions of Melitz (2003) because it allows to derive closed form solutions for the cutoff levels.[15] k is a shape parameter indexing the dispersion of cost draws. $k = 1$, corresponds to the uniform distribution. As k increases, the distribution is more concentrated at higher cost level and firms' heterogeneity is reduced. $k > 2$ ensures that the second moment of the distribution is well defined, while $k > \sigma - 1$ ensures the first moment of the truncated distribution ((25) and (26) in the Appendix) exists and is well defined. With this assumption, we are able to prove trade liberalization favours technology adoption by some exporters, as established in the following proposition.

Proposition 1 *Denote with c_I^A (c_I^f) the equilibrium innovation cost cutoff in autarky (in the open economy). If (22) and (17) hold, then the innovation cost cutoff in the open economy is larger than in autarky (i.e $c_I^A < c_I^f$)*

Proof. *See appendix.* ■

[15] See for example Melitz and Ottaviano (2005).

Interestingly, selection into exporting is playing a key role and is related to f_X. In absence of it and with CES preferences, trade liberalization does not have an impact on c_I. Without selection to export markets ($f_x = 0$), all firms exports and perfectly compensates for the loss in the domestic market shares with gains in foreign market shares, since the increase in each firm's market size after trade is exactly offset by the rise in the number of competitors. This can be easily checked inspecting the equilibrium conditions. With $f_x = 0$, (14) becomes $(1 + n\tau^{1-\sigma})Bc_o^{1-\sigma} = f_D$ which together with (16) and (18) characterize the equilibrium and determines (c_o, c_I, B). It is easy to show that such equilibrium is equivalent to the autarky one described by (8)-(10), so that no new firm innovates after engaging in trade. However, when $f_X > 0$, there is selection on the export-status with only some firms engaging in exporting, while the least productive ones serve only the domestic market. This means that, following trade liberalization, the increase in market size for the exporting firms is no longer perfectly offset by the raised number of competitors because the increase in the mass of exporters is lower. As opposed to $f_x = 0$, some domestic exporters are enjoying a larger slice of both the domestic and foreign market, as they are not facing the competition from the actual domestic producers (previously also exporting) and, at the same time, (by symmetry) are confronted with less foreign competitors on the national market. This is the basic economic intuition behind *i)* above and it is strictly related to the existence of fixed trade costs.

Despite the general equilibrium effect, trade translates into net gains for the most productive non-innovating exporting firms, inducing them to implement the innovative technology, as we can conclude from showing that *i* is dominating *ii.* As low productive domestic firms exit, their market shares are reallocated to the most productive surviving incumbents, and thus, also to some domestic exporters (*extensive margin effect* or *selection effect*). This effect adds up to the *intensive-margin effect* or *scale effect* - that following trade liberalization, some exporters have increased their market share abroad. As a result, their combined market share (the sum of the domestic and foreign market shares) enlarges. Since a larger scale of operation is associated to a greater return of the "technological option", a larger fraction of them finds profitable to implement the innovative equipment. In other words, trade affects the extensive margin of innovation inducing exporting firms that are not as productive as former innovators, to adopt more productive technologies.

We would expect that the reduction of transportation costs which lead to trade creation in this model have similar effects on innovation, consistently with the evidence in Bernard et. al. (2006). This is established in the following Lemma.

Lemma 2 *Assume (22) and (17) hold,* $dc_I/d\tau \leq 0$*.*

Proof. *See in the appendix* ■

Trade liberalization taking the form of partial tariff reform, as often it is in practice, induce similar positive effect on process innovation, according to our model. For instance, we can evaluate the effects of Canada-US FTA (CUSFTA) on within firm performances. τ in (19) is the transportation cost faced by Canadian manufacturing firms exporting to US. The model predicts US tariff concessions granted to Canada - a reduction of τ - after the FTA would induce some Canadian exporters to innovate, as they can take advantage of a lower cost to benefit ratio. This is consistent with the evidence shown in Trefler (2004).

Interestingly, firms adopting the innovative technology are the high productive non-innovating exporters, while some less productive exporters keep the "traditional" technology even after trade liberalization, consistently with the evidence shown in Bustos (2005) and Fryges and Wagner (2007).[16]

Summing up, by increasing the scale of production of some of the exporters, trade increases what Cohen and Klepper (1996) call the "ex ante" output - the firm's output when it conducts process innovation. This, in turn, raises firms' incentive to innovate and triggers process-innovation, productivity increments and market share growth at firm level (see (7)). This is consistent with Baldwin and Gu (2003) and Trefler (2004) who find that within-firm productivity increments have occurred mostly among exporters. Moreover, Baldwin (2004) finds empirical support for such casual link: vertical innovation is a main determinant of productivity growth and productivity growth induces market share growth[17].

Finally, the reduction of transportation costs has contrasting effect on c_X too. A reduction of trade barriers have a direct effect and lowers the exporting productivity cutoff $c_X^{1-\sigma}$ (see (21)), but also an indirect effect through $(c_o)^{1-\sigma}$ which rises this threshold. The following lemma shows that the direct effect dominates the indirect one, going in the same direction as in Melitz (2003).

Lemma 3 *Assume (22) holds,* $dc_X/d\tau \leq 0$*.*

Proof. *See the appendix* ■

[16] Also in Yeaple (2005), lower transportation costs induce a greater adoption of the innovative technology. However, no exporters retain the old technology as found in Bustos (2005).

[17] Baldwin (2004) finds Canadian process-innovators had productivity growth that was 3.6 percentage points higher than Canadian non-process innovators (table 9). Moreover, a within-firm productivity increment of 10% relative to the industry average translate into almost 2% gain in the firm's market share (table 12).

In the context of CUSFTA, this lemma predicts that some Canadian manufacturing firms which are not as productive as established exporters, will also start to serve the US market in virtue of the American preferential tariff reform. Interestingly, Baldwin et al. (2003) find evidence of this.

3.2 Selection B

We shall just show that trade in this equilibria can not affect the extensive margin of innovation as for selection BW. The non-innovating firms are only the D-type, while the innovating firms are the I-type and the XI-type, but only the latter are present on international market. There is no X-type.

The cutoff conditions for **equilibrium B** are:

$$\pi_D(c_o) = 0 \tag{23}$$

$$\pi_I(c_I) = \pi_D(c_I) \tag{24}$$

$$\pi_{XI}(c_X) = 0 \Leftrightarrow Bc_X^{1-\sigma} = (\tau\gamma)^{\sigma-1}\delta f_X$$

which imply that the necessary and sufficient condition for $c_X \leq c_I \leq c_o$ is:

$$\delta f_X \tau^{\sigma-1} \geq \frac{\delta f_I}{(\gamma^{1-\sigma}-1)}\gamma^{1-\sigma} \geq f_D\gamma^{1-\sigma}$$

This equilibrium is characterized by a trading cost relatively higher than the innovating one. High variable and fixed cost of exporting make trading a very expensive activity performed only by the most productive firms.

Note also that (23) and (24) imply the same relation among the innovation and the entry cutoff as in the closed economy given by (11). Indeed, the marginal innovating firm is not an exporter and the transition from autarky to trade leaves the cost to benefit ratio of innovation unchanged. That is, trade liberalization can not affect and stimulate firms' innovation investments because it has no impact on Ψ. In other words, the extensive margin of innovation responds to lower trade barriers uniquely through the selection effect (*ii*, above); consequently, a raise in $c_o^{1-\sigma}$ raises $c_I^{1-\sigma}$ as well and depresses vertical innovation.

3.3 Final Remarks

The model has implications on the aggregate productivity level. As in Melitz (2003), the industry average productivity will be rising in the long run by means of the selection effect which expels the least efficient firms out of the market - *between effect* . Moreover, in our model trade will rise the average industry productivity through a further channel, namely the *within effect* (Proposition 1 and Lemma 2). Following trade liberalization, some of the exporters opt for implementing a more efficient technology, improving their productivity level.

This is relevant also for the second moment of the industry productivity distribution. The dispersion of productivity levels among innovators and non-innovators increases, implying a higher variance. Depending on the strength of this effect, the standard prediction in the literature of a smaller variance due to the selection effect of trade could be overturned.

More generally, a greater openness in the trading relations can justify the finding of the great importance of the within component for the industry productivity growth, as recently documented in Bartelsman et. al. (2004).

Finally the model suggests that trade liberalization and the geography of a country can interact each other: the same trade liberalization may induce different innovation outcomes depending on the location of a country.

Moving from B to BW, the cost of exporting relative to the cost of innovating decreases. This means that the effect trade has on the process innovation will be differentiated according to the level of transportation cost. We shall interpret high transportation cost as a proxy for the remoteness of the Home economy from the main exporting markets or, more generally, as the level of trade barriers faced by the Home country.

If in the transition from autarky to trade, the country is fairly remote and faces selection B, then process innovation performed will be reduced, as discussed above. On the contrary, if the country is close to the exporting markets and selection BW is possible, process innovation increases.

This result is close to what Long et. al. (2006) find for an oligopolistic market structure. In their model, a reduction of transportation cost for an initial low level of it, increases the firm´s R&D spending for productivity improvements, whereas for a high level of initial transportation cost, the reverse holds true, namely R&D spending is reduced following trade liberalization.

4 Conclusion

The paper introduces process innovation into the Melitz (2003) framework. As in Melitz (2003), trade has a selection effect on firms forcing the least productive ones out of the market and reallocating market shares to the most productive ones. Although this contributes to the aggregate productivity growth, it is not exhaustive of the effects of trade on productivity. We showed that the same selection effect of trade can favour the adoption of an innovative technology, especially among exporters.

One could think that fiercer competition implied by trade can reduce the incentive for innovation. This is certainly true for low productive domestic firms whose survival possibilities have decreased together with their market shares. Instead, due also to selection, the exporters compensate the loss of market shares in the domestic market with gains in market shares in foreign markets. Selection expand their scale of production, their incentive for process innovation strengthens and some of them introduce a more productive technology.

In productivity studies, this is the so called *within* effect - some of the incumbent firms update their productivity - and it is a main source of labour productivity growth in industrialized countries. This is the new insight of the model: trade contributes to the industry productivity growth through the *within* effect besides through the *between* effect. More generally, a greater openness in the trading relations can justify the finding of the great importance of the within component for the industry productivity growth, as recently documented.

We have shown that the technology adoption response of firms to trade is the net outcome of two different effects: one favouring innovation and related to one side of trade liberalization, namely the opportunity of market expansion; the other one, deterring innovation and related to the other side of the coin, namely a tougher competition on the good market and in the input markets. In particular, it was highlighted that the second effect is specific to general equilibrium as it comes through the interactions with the input-factor market.

Finally, geography plays an important role. Trade liberalization can depress vertical innovation (equilibrium B) for remote countries, while it can boost process-innovation (equilibrium BW) for countries closely located to the core of the exporting markets.

5 Appendix

Note that we shall use a superscript A to denote the equilibrium variables in the closed economy and f for the the equilibrium variables in the open economy whenever we have to compare quantities from the two equilibrium.

5.1 Appendix A - Closed Economy

Cost distribution and productivity indexes

Let us denote by $\mu_D(c)$ and $\mu_I(c)$ respectively, the cost distribution of domestic producers and active innovator prior to innovation.

$$\mu_D(c) = \begin{array}{ccc} \frac{g(c)}{G(c_o)-G(c_I)} & , & c_I < c < c_o \\ o & & otherwise \end{array} \tag{25}$$

$$\mu_I(c) = \begin{cases} \frac{g(c)}{G(c_I)} & 0 < c < c_I \\ o & otherwise \end{cases} \tag{26}$$

$$\widetilde{c_D}^{1-\sigma} = \int_{c_I}^{c_o} c\mu_D(c)dc \tag{27}$$

$$\widetilde{c_I}^{1-\sigma} = \frac{1}{G(c_I)} \int_0^{c_I} c^{1-\sigma}\mu_I(c)dc \tag{28}$$

$$\widetilde{c}^{1-\sigma} = \frac{1}{M}\left[M_I(\gamma\widetilde{c_I})^{1-\sigma} + M_D\widetilde{c_D}^{1-\sigma}\right] \tag{29}$$

$\mu_I(c)$ and $\mu_D(c)$ are not affected by the simultaneous entry and exit since the successful entrants and failing incumbents draw their productivity level from a common distribution and δ is independent of the innovation status. These distributions depend exclusively on the cutoffs points for entry and innovation.

Aggregate variables

Denote by M_I and M_D respectively the mass of active innovator and domestic (non-innovator) producers, where

$$M_I = \frac{G(c_I)}{G(c_o)} M \tag{30}$$

$$M_D = \frac{G(c_o) - G(c_I)}{G(c_o)} M \tag{31}$$

and M is the mass of incumbent firms in the economy. It can be shown that:

$$P^{1-\sigma} = \int_0^{c_I} M_I[p_I(c)]^{1-\sigma}\mu_I(c)dc + \int_{c_I}^{c_o} M_D\left[p_D(c)\right]^{1-\sigma}\mu_D(c)dc = M\left[p_D(\widetilde{c})\right]^{1-\sigma}$$

$$R = \int_0^{c_I} M_I r_I(c)\mu_I(c)dc + \int_{c_I}^{c_o} M_D r_D(c)\mu_D(c)dc = M r_D(\tilde{c}) = M\overline{r}$$

$$\Pi = \int_0^{c_I} M_I \pi_I(c)\mu_I(c)dc + \int_{c_I}^{c_o} M_D \pi_D(c)\mu_D(c)dc = M\pi_D(\tilde{c}) = M\overline{\pi} \tag{32}$$

where $\overline{r}$ and $\overline{\pi}$ are the average revenue and profit in the economy. Moreover, using the labour market condition in equilibrium it can be shown that:

$$M = \frac{R}{\overline{r}} = \frac{L}{\sigma(\overline{\pi} + f_D + \frac{G(c_I)}{G(c_o)}\delta f_I)} \tag{33}$$

Note we can use the first line of (32) together with (30), (31), (25) and (26) to rewrite (10) as:

$$\int_0^{c_I} \pi_I(c)dG(c) + \int_{c_I}^{c_o} \pi_D(c)dG(c) = G(c_o)\overline{\pi} \tag{34}$$

which is (10).

5.1.1 Determination of the equilibrium

Using (32) together with (30) and (31), it is possible to express (10) as (34), which can be further refined and express in terms of solely c_o. Insert (8) and (9) into (10), replace $\delta f_I = \Psi(\gamma^{1-\sigma}-1)f_D$ and rearrange terms to get:

$$\begin{aligned}\delta f_E &= G(c_I)\gamma^{1-\sigma}\left(\frac{\widetilde{c_I}}{c_o}\right)^{1-\sigma} f_D - G(c_I)\left(\frac{\widetilde{c_D}}{c_o}\right)^{1-\sigma} f_D - G(c_I)\Psi(\gamma^{1-\sigma}-1)f_D + \\ &\quad + G(c_o)\left(\frac{\widetilde{c_D}}{c_o}\right)^{1-\sigma} f_D - G(c_o)f_D \\ &= f_D\left[j_D(c_o) + \gamma^{1-\sigma} j_I(c_o)\right]\end{aligned} \tag{35}$$

where

$$j_D(c_o) = G(c_o)\left[\left(\frac{\widetilde{c_D}}{c_o}\right)^{1-\sigma} - 1\right] - G(c_I)\left[\left(\frac{\widetilde{c_D}}{c_o}\right)^{1-\sigma} - \Psi\right] \tag{36}$$

$$j_I(c_o) = G(c_I)\left[\left(\frac{\widetilde{c_I}}{c_o}\right)^{1-\sigma} - \Psi\right] \tag{37}$$

5.1.2 Existence and Uniqueness of the equilibrium in the closed economy

Proposition 4 *Under autarky, the equilibrium exists and is unique.*

Proof. *We shall prove that the RHS of (35) is monotonically increasing in c_o on the domain $[0,\overline{c}]$, so that c_o is uniquely determined by the intersection of the latter curve with the flat line δf_e in the $[0,\overline{c}]$ space. Recall that $\widetilde{c_I}$ is a function of c_I (see (28)), which, in turn, is a function of c_o by (11). Let us define $\Lambda = \Psi^{1/1-\sigma}$. First, note that (11) implies $\frac{\partial c_I}{\partial c_o} = \Psi^{1/1-\sigma} = \Lambda$ and (28) implies $\frac{\partial}{\partial c_o}\left(\frac{\widetilde{c_I}^{1-\sigma}}{c_o^{1-\sigma}}\right) = \Lambda\frac{g(c_I)}{G(c_I)}\left[\Psi - \left(\frac{\widetilde{c_I}}{c_o}\right)^{1-\sigma}\right] - \left(\frac{\widetilde{c_I}}{c_o}\right)^{1-\sigma}\frac{1-\sigma}{c_o}$. It follows:*

$$\frac{\partial j_I(c_o)}{\partial c_o} = -\frac{1-\sigma}{c_o}G(c_I)\left(\frac{\widetilde{c_I}}{c_o}\right)^{1-\sigma} \geq 0 \tag{38}$$

Using (27) and following similar steps we get:

$$\frac{\partial j_D(c_o)}{\partial c_o} = -\frac{1-\sigma}{c_o}\left[G(c_o) - G(c_I)\right]\left(\frac{\widetilde{c_D}}{c_o}\right)^{1-\sigma} \geq 0 \tag{39}$$

(38) and (39) ensure that the RHS of (35) is an increasing function of c_o. Furthermore, $\lim_{c_o\to\overline{c}} j_I(c_o) = \infty$, and $\lim_{c_o\to\overline{c}} j_D(c_o) = a < \infty$, so that $\lim_{c_o\to\overline{c}}\left[j_D(c_o) + \gamma^{1-\sigma}j_I(c_o)\right] = \infty$. In order to show that the RHS of (35) goes to 0 as c_o goes to 0, I will follow Melitz (2003) and show that the elasticities of $j_I(c_o)$ and $j_D(c_o)$ are positive and $j_I(c_o)$ is always bounded away from 0.

$$\frac{\partial j_I(c_o)}{\partial c_o}\frac{c_o}{j_I(c_o)} = -(1-\sigma)\left[1 + \frac{\Lambda}{j_I(c_o)}\right] \geq -(1-\sigma)$$

$$\frac{\partial j_D(c_o)}{\partial c_o}\frac{c_o}{j_D(c_o)} = -(1-\sigma)\left[\frac{(G(c_o) - G(c_I))\left(\frac{\widetilde{c_D}}{c_o}\right)^{1-\sigma}}{j_D(c_o)}\right] \geq 0$$

Therefore the RHS of (35) is monotonically increasing in the space $(0, \overline{c})$ *and it must cross the horizontal curve* δf_E *only once. The equilibrium* c_o *exists and it is unique.* ■

Once the unique c_o is determined, (25) and (26) can be determined as well as (27) to (29). By (11) follows c_I, while by (34) follows $\overline{\pi}$.

5.2 Appendix B - Comparison of our entry cutoff with Melitz's (2003) in the closed economy

Proposition 5 *Let denote* c_M^* *as the cutoff level of marginal cost found in Melitz (2003) for the closed economy. Then we have that:*

$c_0 < c_M^*$

Proof. *Since (8) and* $R = L$ *are common to both models, the ratio of the entry cost-cutoff is given by:*

$$\frac{c_M^*}{c_0} = \frac{P_M^*}{P}$$

where

$$P_M^* = \left(\int_0^{c_I} (p(c))^{1-\sigma} g(c)dc + \int_{c_I}^{c_M^*} (p(c))^{1-\sigma} g(c)dc \right)^{\frac{1}{1-\sigma}}$$

$$P = \left(\int_0^{c_I} (\gamma p(c))^{1-\sigma} g(c)dc + \int_{c_I}^{c_0} (p(c))^{1-\sigma} g(c)dc \right)^{\frac{1}{1-\sigma}}$$

Assume that:

$c_0 > c_M^*$

This implies that :

$$\int_0^{c_I} (p(c))^{1-\sigma} g(c)dc + \int_{c_I}^{c_M^*} (p(c))^{1-\sigma} g(c)dc > \int_0^{c_I} (\gamma p(c))^{1-\sigma} g(c)dc + \int_{c_I}^{c_0} (p(c))^{1-\sigma} g(c)dc.$$

and, rearranging terms, we have:

$$(1 - \gamma^{1-\sigma}) \int_0^{c_I} (p(c))^{1-\sigma} g(c)dc > \int_{c_I}^{c_0} (p(c))^{1-\sigma} g(c)dc. - \int_{c_I}^{c_M^*} (p(c))^{1-\sigma} g(c)dc.$$

which is not possible since, $\gamma < 1, \sigma > 1, c_0 > c_M^*$.

Q.E.D ■

5.3 Appendix C - Open economy - selection BW

5.3.1 Aggregation

Cost Distributions and productivity indexes

Let $\mu_D(c) = g(c)/[G(c_o) - G(c_X)]$, $\mu_X(c) = g(c)/[G(c_X) - G(c_I)]$, $\mu_{XI}(c) = g(c)/[G(c_I)]$ denote the distribution of cost level in each subgroup prior to innovation. Let $\widetilde{c_X}^{1-\sigma} = \int_{c_I}^{c_X} c^{1-\sigma}\mu_X(c)dc$ and $M_D\widetilde{c_D}^{1-\sigma} + M_X\widetilde{c_X}^{1-\sigma} = M_{NI}\widetilde{c_{NI}}^{1-\sigma}$.

Aggregate variables

$$P^{1-\sigma} = \frac{M_T}{\rho^{1-\sigma}} \underbrace{\left\{ \frac{1}{M_T} \left[M_{NI}\widetilde{c_{NI}}^{1-\sigma} + M_{XI}\gamma^{1-\sigma}\widetilde{c_I}^{1-\sigma} + n\tau^{1-\sigma}(M_X\widetilde{c_X}^{1-\sigma} + M_{XI}\gamma^{1-\sigma}\widetilde{c_I}^{1-\sigma}) \right] \right\}}_{\widetilde{c}^{1-\sigma}} \tag{40}$$

where $\widetilde{c}^{1-\sigma}$ is again the weighted average productivity index of the economy. As in the closed economy it can be shown that

$$R = M\bar{r} = M_T r_D(\widetilde{c})$$

$$\bar{\pi} = \frac{\bar{r}}{\sigma} - f_D - \frac{G(c_I)}{G(c_o)}\delta f_I - \frac{G(c_X)}{G(c_o)} n\delta f_X. \tag{41}$$

5.3.2 Existence and Uniqueness of the trading equilibrium

(14) to (16) as well as (19) and (20) allow us to rearrange the FE conveniently for the characterizing the equilibrium as a function of only c_o and c_X:

$$\begin{aligned} \frac{\delta f_E}{G(c_o)} &= \left\{ (1 - p_{rXI}) \left[\frac{\widetilde{c_{NI}}}{c_o} \right]^{1-\sigma} + p_{rXI}\gamma^{1-\sigma} \left[\frac{\widetilde{c_I}}{c_o} \right]^{1-\sigma} - 1 \right\} f_D - \delta f_I p_{rXI} + \\ &+ \left\{ \frac{p_{rX}}{p_{rEXP}} \left[\frac{\widetilde{c_X}}{c_X} \right]^{1-\sigma} + \frac{p_{rXI}}{p_{rEXP}}\gamma^{1-\sigma} \left[\frac{\widetilde{c_I}}{c_X} \right]^{1-\sigma} - 1 \right\} p_{rEXP} n\delta f_X \\ \delta f_E &= \left[l_{NI}(c_o) + \gamma^{1-\sigma} l_I(c_o) \right] f_D + \left[l_{NI}(c_X) + \gamma^{1-\sigma} l_I(c_X) \right] n\delta f_X \end{aligned} \tag{42}$$

where $p_{rEXP} = G(c_X)/G(c_o)$ and

$$l_{NI}(c_o) = G(c_o) \left[\left[\frac{\widetilde{c_{NI}}}{c_o} \right]^{1-\sigma} - 1 \right] - G(c_I) \left[\left[\frac{\widetilde{c_{NI}}}{c_o} \right]^{1-\sigma} - \Psi^f \right]$$

$$l_I(c_o) = G(c_I) \left[\left[\frac{\widetilde{c_I}}{c_o} \right]^{1-\sigma} - \Psi^f \right]$$

$$l_{NI}(c_X) = G(c_X) \left[\left[\frac{\widetilde{c_X}}{c_X} \right]^{1-\sigma} - 1 \right] - G(c_I) \left[\left[\frac{\widetilde{c_X}}{c_X} \right]^{1-\sigma} - \Psi_X^f \right]$$

$$l_I(c_X) = G(c_I) \left[\left[\frac{\widetilde{c_I}}{c_X} \right]^{1-\sigma} - \Psi_X^f \right]$$

Proposition 6 *Assume (17) holds. In the open economy, the equilibrium arising under selection BW exists and is unique.*

Proof. We proceed similarly as in the proof for the closed economy and we shall prove that the RHS of (42) is monotonically increasing in c_o on the interval $[0, \overline{c}]$. By (38), $l_I(c_o)$ is monotonically increasing in c_o and $l_I(c_X)$ is monotonically increasing in c_X from zero to infinity on $c \in [0, \overline{c}]$. In turn, c_X is increasing in c_o from (21). Similarly by (39), $l_{NI}(c_o)$ and $l_{NI}(c_X)$ are monotonically increasing from 0 to infinity respectively in c_o and c_X belonging to $[0, \overline{c}]$. Hence, the RHS of (42) is a monotonic increasing function from 0 to ∞ in the $[0, \overline{c}]$ space, while the LHS is a flat line. The equilibrium cost-cutoff level c_o must then be unique. ■

5.3.3 Comparison of the entry cost-cutoff in autarky and in trade

To compare the equilibrium entry cost-cutoff of autarky c_o^A with the one arising in the BW-equilibrium c_o^f, it is useful to re-arrange (42) in a more convenient way as:

$$\delta f_E = \left[j_D(c_o^f) + \gamma^{1-\sigma} j_I(c_o^f) \right] f_D + \Gamma \tag{43}$$

where

$$\Gamma = \left\{ \left[\frac{\widetilde{c_X}}{c_X} \right]^{1-\sigma} - \frac{G(c_I^f)}{G(c_X)} \left[\frac{\widetilde{c_X}}{c_X} \right]^{1-\sigma} + \gamma^{1-\sigma} \frac{G(c_I^f)}{G(c_X)} \left[\frac{\widetilde{c_I}}{c_X} \right]^{1-\sigma} - 1 \right\} G(c_X) n \delta f_X \geq 0$$

The first term of the RHS in (43) is exactly the same as in the closed economy. If Γ were 0, (35) and (43) would yield the same solution, i.e. $c_o^f = c_o^A$. Since Γ is positive the curve representing the RHS of (43) must lie above the curve representing the RHS of (35), implying a lower entry cost-cutoff in the trading equilibrium than in the autarky equilibrium. That is, $c_o^f \leq c_o^A$.

5.3.4 Proposition 1 - In *BW*, trade increases the proportion of firms performing process-innovation

Proposition *1. If (22) and (17) hold, then the innovation cutoff in the open economy is lower than in autarky (i.e $c_I^f < c_I^A$).*

Proof. Use (11) and (19) to get:

$$\left(\frac{c_I^A}{c_I^f} \right)^k = (1 + n\tau^{1-\sigma})^{\frac{k}{1-\sigma}} \left(\frac{\overline{\pi}^f}{\overline{\pi}^A} \right)$$

which depends on the ratio of both profits. Using the expressions for $\mu_D, \mu_X, \mu_{XI}, p_{rX}, p_{rXI}$ we rewrite (18) as:

$$\overline{\pi}^f = \frac{\delta f_E}{G(c_o^f)} \tag{44}$$

where $\bar{\pi}^f$ is (41).

and Using (10) and (44) combined with (22) we get:

$$\frac{\bar{\pi}^f}{\bar{\pi}^A} = \left(\frac{c_o^A}{c_o^f}\right)^k$$

Let us define some useful transformations: i.e.: $\Lambda = \Psi^{\frac{1}{1-\sigma}}$, $\Lambda^* = \Psi^{f\,\frac{1}{1-\sigma}}$,and $\Lambda^* = \alpha\beta$ where:

$$\alpha = \left(\frac{\tau^{1-\sigma} f_I}{(\gamma^{1-\sigma}-1)(1+n\tau^{1-\sigma})f_X}\right)^{\frac{1}{1-\sigma}}$$

$$\beta = \left(\frac{\delta f_X}{f_D}\tau^{\sigma-1}\right)^{\frac{1}{1-\sigma}} \tag{45}$$

(42) can then be expressed as a function of the parameters of the model:

$$\begin{aligned}\bar{\pi}^f \quad = \quad & \left[\frac{k}{k+1-\sigma}\left[(1-\Lambda^{k+1-\sigma}) + \gamma^{1-\sigma}\Lambda^{k+1-\sigma}\right] - 1\right] f_D - \delta f_I \Lambda^k + \\ & \left[\frac{k}{k+1-\sigma}\left[(1-\alpha^{k+1-\sigma}) + \gamma^{1-\sigma}\alpha^{k+1-\sigma}\right] - 1\right] \beta^k n \delta f_X\end{aligned}$$

Using the definition of Λ,(45) and the fact that $\Lambda^* = (1+n\tau^{1-\sigma})^{\frac{1}{\sigma-1}}\Lambda$ and rearranging terms:

$$\begin{aligned}\bar{\pi}^f \quad = \quad & \left[\frac{k}{k+1-\sigma}\left[\Lambda^{1-\sigma}(\gamma^{1-\sigma}-1)\right] f_D - \delta f_I\right] \Lambda^{*k} + \frac{\sigma-1}{k+1-\sigma} f_D \\ & + \frac{\sigma-1}{k+1-\sigma}\beta^k n \delta f_X\end{aligned} \tag{46}$$

and expanding (35):

$$\begin{aligned}\bar{\pi}^A \quad = \quad & \left[\frac{k}{k+1-\sigma}\left[\Lambda^{1-\sigma}(\gamma^{1-\sigma}-1)\right] f_D - \delta f_I\right] \Lambda^k + \\ & \frac{\sigma-1}{k+1-\sigma} f_D\end{aligned}$$

Then,

$$\left(\frac{c_I^A}{c_I^f}\right)^k = \frac{(1+n\tau^{1-\sigma})^{\frac{k}{\sigma-1}} A + B + C}{(1+n\tau^{1-\sigma})^{\frac{k}{\sigma-1}} A + (1+n\tau^{1-\sigma})^{\frac{k}{\sigma-1}} B} \tag{47}$$

where

$$A = [\frac{k}{k+1-\sigma}\left[\Lambda^{1-\sigma}(\gamma^{1-\sigma}-1)\right] f_D - \delta f_I \Lambda^k \tag{48}$$

$$B = \frac{\sigma-1}{k+1-\sigma} f_D \tag{49}$$

$$C = \frac{\sigma-1}{k+1-\sigma}\beta^k n \delta f_X \tag{50}$$

We have to show that :

$$\frac{c_I^A}{c_I^f} < 1 \Rightarrow ((1+n\tau^{1-\sigma})^{\frac{k}{\sigma-1}} - 1)B > C$$

Substituting (49),(50), the inequality becomes:

$$(1+n\tau^{1-\sigma})^{\frac{k}{\sigma-1}} > 1+\left(\frac{\delta f_X}{f_D}\right)^{\frac{k+1-\sigma}{1-\sigma}}\tau^{-k}n$$

To show that this inequality holds true, note that $\beta < 1$ implies:

$$\left(\frac{\delta f_X}{f_D}\right)^{\frac{k+1-\sigma}{1-\sigma}}\tau^{-k}n < n\tau^{1-\sigma} \Rightarrow 1+\left(\frac{\delta f_X}{f_D}\right)^{\frac{k+1-\sigma}{1-\sigma}}\tau^{-k}n < 1+n\tau^{1-\sigma}$$

It follows:

$$(1+n\tau^{1-\sigma})^{\frac{k}{\sigma-1}} > (1+n\tau^{1-\sigma}) > 1+\left(\frac{\delta f_X}{f_D}\right)^{\frac{k+1-\sigma}{1-\sigma}}\tau^{-k}n$$

since $k > \sigma - 1$ is assumed. ■

5.3.5 Lemma 2

Lemma *2. Assume (22) and (17) hold. Trade liberalization will have positive effects in innovation, i.e.* $dc_I/d\tau \leq 0$.

Proof. Combining (19) with (22), we get that:

$$G(c_I) = \Psi^{f\,\frac{k}{1-\sigma}} G(c_o^f)$$

Substitute (44) and the value of $\Psi^{f\,\frac{k}{1-\sigma}}$ into this expression to get:

$$(G(c_I))^{-1} = f;\; f = (1+n\tau^{1-\sigma})^{\frac{k}{1-\sigma}}\bar{\pi}^f\Theta$$

where Θ is a constant independent of τ, so that from now on we shall ignore it because it does not affect the derivative. Totally differentiating both sides of this expression w.r.t. τ, we obtain the following:

$$\frac{dc_I}{d\tau} = \frac{\frac{df}{d\tau}}{\frac{d(G(c_I))^{-1}}{dc_I}}$$

Since the denominator is negative, it is enough to show $\frac{df}{d\tau} > 0$ for $\frac{dc_I}{d\tau} < 0$. Use (46), (48) to (50) and recall $\Lambda^* = (1+n\tau^{1-\sigma})^{\frac{1}{\sigma-1}}\Lambda$ to expand f in the following way:

$$f = A + \frac{B}{(1+n\tau^{1-\sigma})^{\frac{k}{\sigma-1}}} + \frac{C}{(1+n\tau^{1-\sigma})^{\frac{k}{\sigma-1}}}$$

where A, B, C are defined as in (48) to (50) and A is independent of τ. Using (45) and (50), it is convenient to express $C = \lambda\phi^{\frac{k}{\sigma-1}}$, with $\phi \equiv \tau^{1-\sigma}$, so that:

$$\frac{df}{d\phi} = \frac{\lambda\phi^{\frac{k+1-\sigma}{\sigma-1}}(1+n\phi)^{\frac{k}{\sigma-1}} - (1+n\phi)^{\frac{k+1-\sigma}{\sigma-1}}\phi^{\frac{k}{\sigma-1}}\lambda n - Bn(1+n\phi)^{\frac{k+1-\sigma}{\sigma-1}}}{(1+n\phi)^{\frac{2k}{\sigma-1}}}$$

Rearranging terms:

$$\frac{df}{d\phi} = \frac{\left[\lambda\phi^{\frac{k}{\sigma-1}}\frac{1}{\phi(1+n\phi)} - B\frac{n}{1+n\phi}\right]}{(1+n\phi)^{\frac{k}{\sigma-1}}}$$

Since we are deriving f with respect to ϕ (instead of τ) and $\sigma > 1$, the numerator is negative (i.e. $\frac{df}{d\tau} > 0$) iff:

$$\phi^{\frac{k+1-\sigma}{\sigma-1}} < \frac{B}{\lambda}n$$

and substituting for the values of B and λ, we get:

$$\phi = \frac{f_D}{\delta f_X}$$

and:

$$\tau \leq \left(\frac{\delta f_X}{f_D}\right)^{\frac{1}{1-\sigma}}$$

which satisfies our parameter restrictions (17). ■

5.3.6 Lemma 3

Lemma *3. Assume (22) holds.* c_x *is monotonically decreasing in* τ *and* f_x*.*

Proof. Combining (21) with (22) gives the following equality:

$$G(c_X) = \beta^k G(c_o)$$

Substitute (44) and (45) into this expression to get:

$$(G(c_X))^{-1} = \zeta\tau^k\bar{\pi}^f = g \tag{51}$$

where $\zeta = \left(\frac{\delta f_X}{f_D}\right)^{\frac{k}{\sigma-1}}$ is constant with respect to tariffs.

Proceeding similarly to the proof above, we take the total differential of both sides of (51) w.r.t. τ, so that the response of the exporting cost cutoff to changes in the transportation costs is given by:

$$\frac{dc_X}{d\tau} = \frac{\frac{dg}{d\tau}}{\frac{d(G(c_X))^{-1}}{dc_X}}$$

Since the denominator is negative, we need to prove $\frac{dg}{d\tau} > 0$ for $\frac{dc_X}{d\tau} < 0$. Substituting (46),(48),(49),(50) into (51), g is a function given by:

$$g = \zeta\tau^k(1 + n\tau^{1-\sigma})^{\frac{k}{\sigma-1}}A + \zeta\tau^k B + \zeta\tau^k C$$

or, substituting for the value of C, g can be conveniently expanded as:

$$g = \zeta(\tau^{k(\sigma-1)} + n\tau^{(k-1)(\sigma-1)})^{\frac{k}{\sigma-1}}A + \zeta\tau^k B + \Phi$$

where $\Phi = \frac{(\sigma-1)n}{k+1-\sigma}(\delta f_X)$. It follows $\frac{dg}{d\tau} > 0$.

To prove that $dc_X/df_X \leq 0$ we totally differentiate both sides of (51) w.r.t. f_X and obtain the following:

$$\frac{dc_X}{df_X} = \frac{\frac{dg}{df_X}}{\frac{d(G(c_X))^{-1}}{dc_X}}$$

Note that $\frac{dg}{df_X} > 0$ as $\frac{d\zeta}{df_X} > 0, \frac{d\omega}{df_X} > 0$ and A, B are independent of f_X. Recalling that the denominator is negative, it follows that $\frac{dc_X}{df_X} \leq 0$ - Q.E.D. ■

References

[1] Alvarez, Roberto and Lopez, Ricardo. (2005). Exporting and Performance: Evidence from Chilean Plants. *Canadian Journal of Economics* 38(4): 1384-1400.

[2] Atkeson, Andrew and Burstein, Ariel. (2007). Innovation, Firm Dynamics, and International Trade. *NBER Working Paper* 13326.

[3] Baldwin, J.R. (1995). *The Dynamics of Industrial Competition.* Cambridge: University Press.

[4] Baldwin, John R. and Gu, Wulong. (2003). Participation on Export Markets and Productivity Performance in Canadian Manufacturing. *Canadian Journal of Economics*, 36(3): 634-657.

[5] Baldwin, John R. and Gu, Wulong. (2004). Innovation, Survival and Performance of Canadian Manufacturing Plants. Analytical Studies Research Paper Series 11F0027MIE Analytical Studies Branch Ottawa: Statistics Canada.

[6] Baldwin, Richard, and Nicoud, Frédéric, R. (2006). Trade and Growth with Heterogenous Firms. *Journal of International Economics* (forthcoming).

[7] Bartelsman, Eric J., Haltiwanger, John and Scarpetta, Stefano. (2004). Microeconomic Evidence of Creative Destruction in Industrial and Developing Countries. *Tinbergen Institute Discussion Paper* 114/3.

[8] Bartelsman, Eric and Doms, Mark. (2000). Understanding Productivity: Lessons from Longitudinal Microdata. *Journal of Economic Literature*: 38(3), 569-594.

[9] Bernard, Andrew, Eaton Janathan, Jensen, Bradford and Kortum, Samuel. (2003). Plants and Productivity in International Trade. *American Economic Review* 93(4): 1268-1290.

[10] Bernard, Andrew, Jensen, Bradford J. and Schott, Peter K. (2006). Trade costs, firms and productivity. *Journal of Monetary Economics* 53: 917-937.

[11] Bernard, Andrew, Redding, Stephen J. and Schott, Peter K. (2006). Multi-Product Firms and Trade Liberalization. mimeo (Tuck School of Business at Dartmouth).

[12] Bernard, Andrew. (2006). Firms in International Trade. *NBER Reporter*: Research Summary Fall 2006.

[13] Bikson, Tora K., Don Mankin, Barbara A. Gutek. (1987). Implementing Computerized Procedures on Office Settings: Influences and Outcome. *Rand Report*.

[14] Blundell, R.W., Griffith, R. and Van Reenen, J. (1995). Dynamic Count Data Models of Technological Innovation. *The Economic Journal*: 105, 333-344.

[15] Bustos, Paula. (2005). The Impact of Trade on Technology and Skill Upgrading Evidence from Argentina. *Mimeo*, CREI - Universitat Pompeu Fabra.

[16] Cohen, Wesley and Klepper, Steven. (1996a). Firm Size and the Nature of Innovation within Industries: The case of Process and Product R&D. *Review of Economics and Statistics*: 78, 232-243.

[17] Cohen, Wesley and Klepper, Steven. (1996b). A reprise of size and R&D. *Economic Journal*: 106, 925-951.

[18] Comin, Diego and Hobijin, Bart. (2007). Implementing Technology. *Mimeo*, New York University.

[19] Costantini, James, and Melitz, Marc. (2007). The Dynamics of Firm-Level Adjustment to Trade Liberalization, mimeo.

[20] De Loecker, J. (2006). Do Exports Generate Higher Productivity? Evidence from Slovenia. mimeo, New York University

[21] Delgado, Miguel A., Farinas Jose C., and Ruano, Sonia. (2002). Firm productivity and export markets: a non-parametric approach. *Journal of International Economics* 57: 397–422

[22] Ewers, Hans-Jurgen, Becker, Carsten and Fritsch Michael. (1990). The Nature of Employment Effects of New Technology in Egon Matzner and Michael Wagner (eds.), *The Employment Impact of New Technology - The Case of West Germany*. Aldershot 1990: Avebury/Gower, 23-41.

[23] Feenstra, Robert C. (2004). *Advanced International Trade: Theory and Evidence*. Princeton University Press.

[24] Fritsch, Michael and Meschede, Monika. (1998). Product Innovation, process innovation and size. *Freiberg Working Papers*. Freiberger Arbeitspapier. 98/13.

[25] Fryges, Helmut and Wagner, Joachim. (2007). Exports and Productivity Growth. First Evidence from a Continous Treatment Approach. *University of Luenemburg Working Paper* No. 49.

[26] Foster, Lucia, Haltiwanger, John and Krizan C. J. (2001). Aggregate Productivity Growth: Lessons from Microeconomic Evidence. In: Edward Dean, Michael Harper and Charles Hulten (eds). *New Developments in Productivity Analysis*. Chicago: University of Chicago Press.

[27] Helpman, Elhanan, Melitz, Marc J., Yeaple, Stephen R. (2004). Export versus FDI with heterogenous firms. *American Economic Review*, 94(1): 300-316.

[28] Girma, Sourafel, Greenaway, David and Kneller, Richard. (2004). Does Exporting Increase Productivity? A Microeconometric Analysis of Matched Firms. *Review of International Economics*, 12(5): 855–866.

[29] Gustafsson, Peter and Segerstrom, Paul. (2006). Trade liberalization and productivity growth. *Mimeo* Stockholm School of Economics.

[30] Long, Ngo Van, Raff, Horst and Stähler, Frank. (2007). The Effects of Trade Liberalization on Productivity and Welfare: The Role of Firm Heterogeneity, R&D and Market Structure. *Mimeo* (University of Kiel)

[31] Martinez-Ros, Ester. (1998). Explaining the decisions to carry out product and process innovations: the Spanish case. WP 98-98. *Business Economics Series 22.* Universidad Carlos III de Madrid.

[32] Melitz, Marc J. (2003). The Impact of Trade on Intra-Industry Reallocations and Aggreate Industry Productivity. Econometrica, 71: 1695-1725.

[33] OECD. (1992). *OECD Proposed Guidelines for Collecting and Interpreting Technological Innovation Data*. Paris: OECD (General Distribution (92)26).

[34] Melitz, Marc and Ottaviano, Gianmarco. (2005). Market Size, Trade, and Productivity. *Mimeo*, Harvard University

[35] Parisi, Maria Laura, Schiantarelli, Fabio and Sembenelli, Alessandro. (2006). Productivity, Innovation and R&D: Micro Evidence for Italy. European Economic Review 8

[36] Reinganum, J. (1989). The timing of innovation. In Schmalensee and Willig (eds), *The Handbook of Industrial Organization*, Vol. I.

[37] Topalova, Petia. (2004). Trade Liberalization and Firm Productivity: The Case of India. *IMF Working Paper* WP/04/28.

[38] Trefler, Daniel. (2004). The Long and Short of the Canada-U.S. Free Trade Agreement. *American Economic Review*, 94(4): 870-895.

[39] Trefler, Daniel. (2005). Successful Economies, Failed Economics: What the CAnada-US Free Trade Agreement Teaches Us about International Economics. *In The Macdonald Commission Report 20 Years On* edited by David Laidler and Bill Robson. Toronto: C.D. Howe Institute, 2005, pages 111-120.

[40] Tybout, James R. (2000). Manufacturing Firms in Developing Countries: How Well Do They Do, and Why?. *Journal of Economic Literature* 38(1): 11-44.

[41] Yeaple, Stephen R. (2005). A simple model of firm heterogeneity, international trade, and wages. *Journal of International Economics* 65: 1-20.