Kiel

Working Papers

Kiel Institute
for the World Economy

Technology Choice and International Trade

by Gabriela Schmidt

No. 1600| March 2010

Kiel Institute for the World Economy, Hindenburgufer 66, 24105 Kiel, Germany

Kiel Working Paper No. 1600| March 2010

Technology Choice and International Trade*

Gabriela Schmidt

Abstract:
This paper develops two extensions of the dynamic model presented in Melitz (2003). The first extension consists in the introduction of technology choice between three alternative production technologies: L, M and H. L is assumed to be the same as Melitz's single production technology, while M and H are assumed to be superior production technologies, stemming this superiority from the fact these technologies substitute the more primitive capital goods used in technology L with newer, updated versions which embody technological advances, and also from the fact that M and H are more skill-intensive than L. Technologies M and H are equally skill-intensive, but H still is superior to M because it incorporates world-technology-frontier capital goods, while the capital goods used in M are below such frontier. The second extension consists in the introduction of two different exporting profiles: "Low-Commitment Exporters" –who make the minimum possible investment required to penetrate export markets- and "High-Commitment Exporters" –who are ready to make additional trade-related investments in order to gain additional export sales-.

Under certain restrictions the model reaches an equilibrium both in the closed and open economy settings, which share with Melitz's the dependence of the number of incumbent firms on the size of the economy and on the number of trading partners, as well as the independence from them of the rest of the key variables describing the equilibriums. So long it is assumed that the most primitive production technology in this model coincides with Melitz's single production technology, the productivity threshold to enter the industry as well as the average productivity of all incumbent firms "at the factory gate" are also the same in both models, in both settings. However, average revenue and profits are always higher in the model with technology choice.

On other grounds, an interesting feature that emerges in the model with technology choice –and was precluded by construction in the Melitz (2003) model- is that in equilibrium a redistribution of resources takes place, from the two superior production technologies toward the most primitive production technology, both in autarky and in the open economy. Finally, the present model shares Melitz's result that when the economy opens up to trade increased competition reallocates market shares towards firms with higher idiosyncratic productivity, forcing the least productive ones out of the market, with the consequence that the productivity threshold to enter the industry rises and therefore so does average productivity "at the factory gate". However, other factors influencing static welfare –variety, additional trade-related investments, transport costs and the impact of technology choice on average variable production cost- lead to an ambiguous outcome, which is another difference with the Melitz (2003) model, in which static welfare undoubtedly increased. The present model also allows for the evaluation of the impact of trade on dynamic welfare, but yields an indefinite result in this respect unless additional assumptions are made regarding the distribution of idiosyncratic productivities and the value of parameters. When it comes to individual firms' performance, the more efficient ones respond better to trade than their less efficient competitors both in terms of the change in their market share and profits, unless the new market conditions force them to downgrade technology, putting them at a disadvantage compared to those who have not.

It is worth noting that despite the model presented in this paper does not require that the superior technologies employ imported capital goods –it is only required that the quality of the capital goods they employ be superior-, if we think of it in terms of the empirics it is natural to arrive to the conclusion that the country of origin of the intermediate capital goods is determinant of their quality –being this higher the shorter the distance between the technology frontier belonging to the country where the capital good in question was produced and the world-technology-frontier-. This highlights the crucial influence that a country's choice of its trading partners may exert over the productivity it will be able to achieve, and consequently over its growth trajectory.

Keywords: technology choice – heterogeneous firms – export profiles – embodied technology– resources' redistribution– monopolistic competition

JEL classification: O14, O33

Gabriela Schmidt
Kiel Institute for the World Economy
Universidad Nacional del Sur
Economics Department
Bahía Blanca, Argentina
E-mail: gschmidt@uns.edu.ar

* I am grateful to Dr. Fernando Tohmé for helpful comments and fruitful discussions. I also wish to thank Dr. Carlos Dabús for useful comments and suggestions. All remaining errors are mine.

1. Introduction

Recent empirical studies on the subjects of growth and convergence have reached the conclusion that nowadays most of the world's technical progress originates in a handful of rich leading countries: the United States, Germany, France, Japan and Great Britain[1]. Thus, for the great majority of countries foreign sources of technology account for most of the increase in domestic productivity[2], being its contribution estimated in 90% of the total increase or more[3]. All this reveals that the path of technical change at world-wide level is determined to a great extent by international technology diffusion.

However, despite technical progress diffuses rapidly from the countries where it originates towards the rest of the world through different channels[4], it is not immediately absorbed. This observation has given rise to an abundant literature which intends to explain what causes the different levels and speeds of absorption of technical progress shown by potential receptors, both at the macroeconomic and microeconomic levels. This literature has coined the term "barriers to technology adoption" to reflect the concept that technology transfer is a process which takes place between a source and a receptor and whose intensity and speed are determined not only by the transmissibility of technological progress itself –which used to be the focus of the first studies on the subject-, but also by the characteristics of both the source and the receptor of the technology flow. These barriers can be modeled in many ways and taking different approaches, but nevertheless the basic underlying idea remains that the potential receptor must possess certain characteristics to be in grade of taking advantage from such innovations.

Getting to individualize which are these key characteristics is a crucial step towards identifying the specific mechanisms through which international technology transfer actually occurs and towards uncovering the reasons why different potential receptors benefit so unevenly from it. In particular, one of the most important questions posed is why are there so many low and medium income countries in the world which are permanently lagging in technology, while others satisfactorily follow up the rhythm of expansion of the world-technology-frontier and remain as a consequence on the technology lead, even if they are getting most of their technological progress from foreign sources[5].

Technology adoption barriers can be modeled in many different ways. One option which has received considerable attention in the literature relates this concept with a problem which may emerge when it is allowed that different alternative production technologies coexist[6]. The basic idea behind this approach is that the technology choice compatible with achieving static efficiency –such that resources are efficiently allocated in the short run– may not coincide with the technology choice that would lead to dynamic efficiency –the highest achievable growth–. As a consequence of this, short run objectives would be in conflict with long run objectives, causing an inefficient equilibrium to materialize. This suboptimal situation would tend to worsen as time passes and the world-technology-frontier continues its expansion, widening the gap between itself and the technologically lagging country. This hypothesis has been explored in the literature both from macroeconomic –country level studies- and

[1] Eaton and Kortum (1995b). Keller (2001) also include Italy and Canada in this group, so long they are counted among the seven major R&D producers in the world.

[2] Keller (2000, 2004), Eaton and Kortum (1995a, 1995b, 1997), among others.

[3] Keller (2004), Eaton and Kortum (1995b).

[4] One of the most important technology diffusion channels mentioned in the literature is international trade, particularly trade in capital goods, whose relevance has been confirmed by various empirical studies, such as Eaton and Kortum (1997, 2001) and Coe, Helpman and Hoffmaister (1995). The underlying idea when considering trade as a vehicle for the transmission of technical progress is that goods embody the best technology available in the place and time of their production, which in turn determines that goods produced in countries whose national technology frontier is closer to the world-technology-frontier be superior in quality (compared to goods produced in countries whose national technology frontier is farther from the world-technology-frontier). When referring to intermediate capital goods in particular, superior quality is usually interpreted as greater efficiency when used in production.

[5] Eaton and Kortum (1995a, 1995b) find that, except for the United States, all OECD countries derive almost all of their productivity growth from foreign sources of technical progress. According to their estimations, even the United States, which is the world's main R&D producer, derives more than 40% of its productivity growth from innovations occurred abroad.

[6] This leads us into questioning a basic assumption of early studies on growth and convergence, namely the existence of identical production functions across countries or firms (according to the study's level of aggregation).

microeconomic –firm level studies- perspectives and some contributions include Caselli and Coleman (2000), Basu and Weil (1998), Restuccia (2004) and Zeira (1998).

The monopolistic competition model presented in Melitz (2003) –which will be used as a departing point for the construction of the present model-, is not itself a model "of appropriate technology" as it assumes the existence of a single production technology common to all firms. Nevertheless, it provides an innovative element to approach the concept of barriers to technology adoption: the idiosyncratic productivity of every firm. In Melitz's model all firms use the same production technology but are heterogeneous in terms of their idiosyncratic productivity, being this heterogeneity modeled through an exogenous productivity distribution, of which every individual idiosyncratic productivity parameter is a realization. As a consequence of this heterogeneity, both in the closed as well as in the open economy settings, the model reaches an equilibrium in which differently productive firms obtain different results, corresponding in both cases higher market shares and profits to more productive firms. The concept of heterogeneity in the idiosyncratic productivity taken from Melitz (2003) will be key to modeling the choice between alternative production technologies and the barriers to the absorption of technical progress in the present model. It will also be central to modeling firms' market strategy choice.

An important thing to consider in more detail on reaching this point is the role of human capital and the specific ways in which it is incorporated into models with technology choice and barriers to technology adoption. The idea of new technologies being complementary with human capital has been extensively explored in the literature[7], and has had an impact on the approach to thinking and modeling human capital in the present context, growing farther from the quantification and analysis of the impact of human capital in itself –attempting to isolate it-, and paying increasing attention to the interaction between human capital and technical progress. Bustos (2005) incorporates this concept into a model of monopolistic competition with firms that are heterogeneous in their idiosyncratic productivities à la Melitz. In her model firms must choose between two alternative production technologies: a modern technology –which uses updated capital goods and is intensive in skilled labor- and a traditional technology –which uses more primitive capital goods and is intensive in unskilled labor-. Firms also have to decide whether to export or serve only the domestic market. Working with data from Argentinean industrial firms during the trade and capital account liberalization process undertaken by the country in the early 1990s, she finds empirical support for the hypothesis that technical change is skewed towards technologies that are complementary with human capital.

2. Basic Assumptions of the Model[8]

2.1 Demand

It is assumed that the demand side is characterized by a representative consumer with CES preferences over a continuum of varieties of good q:

$$U = \left[\int_0^N q(i)^\rho di\right]^{\frac{1}{\rho}} \tag{1}$$

where N is the number of available varieties indexed by i. These varieties of good q are substitutes, implying $0 < \rho < 1$ and an elasticity of substitution between any two goods of $\sigma = \frac{1}{(1-\rho)} > 1$.

Using the well known derivation by Dixit and Stiglitz (1977), the set of available varieties is modeled as an aggregate good $Q \equiv U$ whose aggregate price is:

[7] Bartel and Source (1987), Acemoglu (1998, 2003) and Krusell et. al. (2000) among others.
[8] This model builds on Melitz (2003) and also incorporates some key elements from Bustos (2005).

$$P = \left[\int_0^N p(i)^{1-\sigma} di\right]^{\frac{1}{1-\sigma}} \quad (2)$$

As usual, consumers maximize their utility subject to the budget constraint:

$$\int_0^N p(i)q(i)di = E \quad (3)$$

where $p(i)$ is the price of variety i and E is total expenditure in good q. This process yields the demand for each variety:

$$q(i) = \frac{E}{P}\left(\frac{p(i)}{P}\right)^{-\sigma} \quad (4)$$

Optimal consumption and expenditure decisions for individual varieties are then given by:

$$q(i) = Q\left(\frac{p(i)}{P}\right)^{-\sigma} \quad (5)$$

$$r(i) = R\left(\frac{p(i)}{P}\right)^{1-\sigma} \quad (6)$$

where $R = PQ = \int_0^N r(i)di$ denotes aggregate expenditure.

2.2 Production

The market structure is Monopolistic Competition, with a free entry condition and à la Melitz (2003) heterogeneous firms[9], each of whom produce a different variety. Technology choice is modeled following the approach in Bustos (2005), but here the set of alternatives is extended to include three distinct options, with the purpose of making it possible to evaluate the impact of different-quality technologies while holding skill-intensity constant. Each technology features a constant marginal cost (c), which reflects the payments to two types of labor used in fixed proportions, skilled (S) and unskilled (U), and a fixed cost (f), which in turn reflects the cost of the machinery needed for production.

Entering production with technology L involves the lowest fixed cost because it implies the usage of an inferior (older, more primitive) technology, embodied in machines that are assumed to be therefore cheaper than the higher-quality machines used in the other two technologies, M and H. On the other hand, using technology L implies facing a higher marginal cost than those corresponding to technologies M and H. The reason is that technology L employs the highest proportion of unskilled labor, which despite earning a lower salary than skilled labor, is also less productive, which brings about the overall result of a higher marginal cost in this technology relative to technologies M and H.

Adopting technology M involves facing a fixed cost which is higher than that needed to begin production with technology L, but lower than the fixed cost needed to acquire technology H, as the machines it uses for production embody an intermediate-quality technology, not as primitive as the one employed in L, nor as advanced as the one required by H[10]. Technology M is more skill-intensive than technology L, which means that it has a lower associated marginal cost.

Finally, adopting technology H implies paying the highest fixed cost, as this technology employs machines which embody world-technology-frontier technology, which are assumed to be the most

[9] Melitz's heterogeneity can be interpreted either in terms of "quantitative differences" –producing a symmetric variety at lower marginal cost- or in terms of "qualitative differences" –producing a higher quality variety at equal cost-.

[10] The underlying idea is that technology M employs updated capital goods, but procedent from countries which are below the world-technology-frontier.

efficient and expensive. Regarding the marginal cost, technology H features a novelty: despite having the same degree of skill-intensity as technology M, it still achieves a lower marginal cost due to a "productivity enhancing effect" brought about by the superiority of the machines used. Put in other words, equally skilled workers exhibit higher efficiency when working with H-type machines (compared to M-type machines), because these allow for a more efficient use of labor in general.

With a minor modification, Bustos (2005) Total Cost function allows to accommodate the three above outlined technologies:

$$TC_T(\varphi) = f_T + c_T \frac{q}{\varphi} \quad , \qquad T = L, M, H \tag{7}$$

where:

- $\varphi > 0$ indexes idyosincratic productivity
- $f_L < f_M < f_H$
- $c_L > c_M > c_H$
- $c_L = a_{LU} + \frac{w_s}{w_u} a_{LS}$
  where w_u is the salary paid to unskilled workers and w_s is the salary paid to skilled workers.
- $c_M = a_{MU} + \frac{w_s}{w_u} a_{MS}$
  being $\frac{a_{MS}}{a_{MU}} > \frac{a_{LS}}{a_{LU}}$ as technology M is more skill-intensive than technology L.
- $c_H = \left[a_{HU} + \frac{w_s}{w_u} a_{HS}\right](1 - \alpha_H) = \left[a_{MU} + \frac{w_s}{w_u} a_{MS}\right](1 - \alpha_H)$
  because $a_{HU} = a_{MU}$ and $a_{HS} = a_{MS}$. That is, technologies M and H are equally skill-intensive, remaining the only difference between them the "productivity enhancing effect" $0 < \alpha_H < 1$, which stems from the superior quality of the technology embodied in H-type machines and has an homogeneous enhancing effect on the productivity of both skilled and unskilled labor[11]. This results in c_H being lower than c_M.

3. Firm Profit Maximization in the Closed Economy

The assumption of CES preferences leads to all firms facing residual demand curves with constant elasticity σ and consequently choosing the same profit maximizing constant markup $\boldsymbol{\frac{\sigma}{\sigma-1} = \frac{1}{\rho}}$ over marginal cost. This results in the following exprssions for technology-specific price, quantity sold, revenue and profits[12]:

$$p_d^T(\varphi) = \frac{1}{\rho} \frac{c_T}{\varphi} \tag{8}$$

$$q_d^T(\varphi) = EP^{\sigma-1} \left(\rho \frac{\varphi}{c_T}\right)^{\sigma} = EP^{\sigma-1} \left(\frac{1}{p_d^T(\varphi)}\right)^{\sigma} \tag{9}$$

$$r_d^T(\varphi) = p_d^T(\varphi) q_d^T(\varphi) = E \left(P\rho \frac{\varphi}{c_T}\right)^{\sigma-1} \tag{10}$$

$$\pi_d^T(\varphi) = \frac{1}{\sigma} r_d^T(\varphi) - f_T = \frac{1}{\sigma} E \left(P\rho \frac{\varphi}{c_T}\right)^{\sigma-1} - f_T \tag{11}$$

It is important to note that the ratios of any two firms' outputs and revenues depend both on their respective idiosyncratic productivities and on the production technology used by each:

[11] If the "productivity enhancing effect" is zero then there is no difference between technologies M and H and thus the model reduces to Bustos' case, with only two distinct technologies. If the "productivity enhancing effect" is one then then it is so strong that drives the variable cost in technology H to zero.
[12] The subindex "d" stands for "domestic market".

$$\frac{q_d^T(\varphi_1)}{q_d^{T'}(\varphi_2)} = \left(\frac{\frac{\varphi_1}{c_T}}{\frac{\varphi_2}{c_{T'}}}\right)^{\sigma} \qquad \text{and} \qquad \frac{r_d^T(\varphi_1)}{r_d^{T'}(\varphi_2)} = \left(\frac{\frac{\varphi_1}{c_T}}{\frac{\varphi_2}{c_{T'}}}\right)^{\sigma-1} \tag{12}$$

The following conclusions are readily obtained from the above expression:

- For any two firms producing with the same technology ($T = T'$), the most productive one will charge a lower price, consequently achieve larger output and revenues, and earn higher profits than the other, less productive firm[13].

- For any two equally productive firms ($\varphi_1 = \varphi_2$), the one using a superior technology will charge a lower price and thus achieve larger output and revenues than the other, less productive firm.

3.1 Firm Entry and Exit in the Closed Economy

Prospective entrants to the industry are required to make an initial fixed investment $f_e^T > 0$ in order to learn what their idiosyncratic productivity is. This is modeled like in Melitz (2003) as firms drawing an exogenous productivity parameter φ from a common distribution $g(\varphi)$ which has positive support over $(0, \infty)$ and has a continuous cumulative distribution $G(\varphi)$. Entry sunk costs are technology specific, that is, a firm must pay f_e^T to begin production with technology T, being $f_e^L < f_e^M < f_e^H$. However, firms do not know their productivity parameter by the time they have to pay the entry cost, and so they do not know which of these entry costs will correspond to them, not even if they will successfully enter any of the three available technologies at all. Nevertheless, even though they do have to pay "an" entry cost in order to be able to learn what their idiosyncratic productivity is, they are allowed to pay "any" entry cost, so long when they finally discover which technology they will effectively enter, they will pay up the amount needed to cover any resulting cost gap if such technology happens to have a higher entry cost than that already paid by the firm. Thus, the rational thing to do on the part of any prospective entrant is to sink the lowest possible entry cost (f_e^L), because if it does not enter the industry, it suffers the minimum possible loss, and at the same time, if it becomes a successful entrant, it does not risk ending up paying a greater entry cost than necessary[14]. Unsuccessful entrants are those whose idiosyncratic productivity is too low to be compatible with their making nonnegative profits, and consequently they will immediately exit without ever producing. On the other hand, successful entrants will face from the moment they start production a technology specific (though constant across productivity levels within the same technology) probability δ_T in every period of being hit with a bad shock which will put them out of the market. Although these probabilities δ_T need not coincide across technologies, for the time being we will consider they do. Summing up, a firm will either exit immediately upon entry or otherwise produce and earn $\pi_d^T(\varphi) > 0$ in every period until it is hit with the bad shock and forced out of the market, which yields the following firm's value function:

[13] This conclusion is shared with Melitz (2003).

[14] For example, if the firm decided to sink f_e^M, it not only risks a greater loss if it never successfully enters the industry at all, but also risks paying $(f_e^M - f_e^L)$ extra if enters technology L. The same reasoning is valid (and intensified) if the firm decided to sink f_e^H. Therefore, if the firm decides to take the chance to try to enter the industry, it will always sink f_e^L. However, the "real" entry cost it will pay if it turns to be a successful entrant is $f_e = f_e^L + p_{in}^T(f_e^T - f_e^L)$ because once the firm has entered the market and drawn its productivity parameter from the distribution $g(\varphi)$, it will *immediately* decide one course of action out of four:

- Exit immediately and never produce (if $\varphi < \varphi_L^*$), in which case it loses the amount f_e^L it had already paid.
- Start production with technology L (if $\varphi_L^* < \varphi < \varphi_M^*$), in which case the fixed (entry) cost remains the already paid amount f_e^L.
- Switch immediately to technology M (if $\varphi_M^* < \varphi < \varphi_H^*$), in which case the fixed (entry) cost escalates from f_e^L to f_e^M (the firm must add up to its initial payment the amount $f_e^M - f_e^L$).
- Switch immediately to technology H (if $\varphi > \varphi_M^*$), in which case the fixed (entry) cost escalates from f_e^L to f_e^H(the firm must add up to its initial payment the amount $f_e^H - f_e^L$).

$$v_d^T(\varphi) = max\{0\ ,\sum_{t=0}^{\infty}(1-\delta_T)^t\ \pi_d^T(\varphi)\} = max\left\{0\ ,\frac{1}{\delta_T}\pi_d^T(\varphi)\right\} \quad (13)$$

The threshold $\varphi_T^{**} = inf\{\varphi : v_d^T(\varphi) > 0\}$ identifies the lowest productivity level (Melitz's "zero cutoff productivity level") firms need to have in order to make nonnegative profits when producing with technology T. It is also possible to define some $\varphi_T^* \geq \varphi_T^{**}$ which stands for the minimum productivity level for which it is convenient for the firm (in terms of profitability) to use technology T. Therefore, φ_T^* is the lowest productivity level of firms actually using technology T (the "effective cutoff productivity level"). Note that for T=L we have $\varphi_T^* = \varphi_T^{**}$. Because the only exit process affecting the equilibrium productivity distribution $\mu(\varphi)$ is that occurring immediately upon entry, such distribution $\mu(\varphi)$ is just the original distribution $g(\varphi)$ conditional on successful entry:

$$\mu(\varphi) = \begin{cases} \frac{g(\varphi)}{1-G(\varphi_L^*)}\ if\ \varphi \geq \varphi_L^* \\ 0 \qquad if\ \varphi < \varphi_L^* \end{cases} \quad (14)$$

The ex ante probability of successful entry to the industry –that is, entry into technology L "or superior"[15]- is denoted $p_{in}^{L+M+H} \equiv 1 - G(\varphi_L^*)$ and defines the industry average productivity level $\tilde{\varphi} = \tilde{\varphi}^L$ (the mean productivity of all producing firms, no matter if they are using technology L, M or H) as a function of the cutoff level φ_L^* :

$$\tilde{\varphi} = \tilde{\varphi}^L(\varphi_L^*) = \left[\frac{1}{1-G(\varphi_L^*)}\int_{\varphi_L^*}^{\infty}\varphi^{\sigma-1}g(\varphi)d\varphi\right]^{\frac{1}{\sigma-1}} \quad (15)^{16}$$

Analogously, it is possible to determine the mean productivity of the group of firms using technology "M or superior" (that is, M or H), denoted by $\tilde{\varphi}^M$, as a function of the productivity threshold for the adoption of technology M, φ_M^*, as well as the mean productivity of the group of firms using technology "H or superior" (that is, H), denoted by $\tilde{\varphi}^H$, as a function of the productivity threshold for the adoption of technology H, φ_H^*:

$$\tilde{\varphi}^M(\varphi_M^*) = \left[\frac{1}{1-G(\varphi_L^*)}\int_{\varphi_M^*}^{\infty}\varphi^{\sigma-1}g(\varphi)d\varphi\right]^{\frac{1}{\sigma-1}} \quad (16)$$

And

$$\tilde{\varphi}^H(\varphi_H^*) = \left[\frac{1}{1-G(\varphi_L^*)}\int_{\varphi_H^*}^{\infty}\varphi^{\sigma-1}g(\varphi)d\varphi\right]^{\frac{1}{\sigma-1}} \quad (17)$$

Calculation of the average productivity level corresponding to each technology T requires taking into account both the productivity threshold for the profitability of the adoption of such technology as well

[15] This stems from the assumption that technology L is equivalent to the single production technology specified in Melitz (2003). This means that this model preserves that technological option, while it introduces two additional options, technologies M and H, which are "more advanced" and require higher entry productivity levels. As a consequence of this, a firm which is unable to produce profitably using technology L, will be equally unable to produce profitably using technologies M or H as well, while the converse is not true: a firm that can produce profitably using technology H will also be able to produce profitably using either technology M or L, and a firm that can produce profitably using technology M will also be able to produce profitably using technology L, while we cannot assure that it will be equally able to produce profitably using technology H (it may or may not be able to produce profitably using technology H).
Therefore, we can affirm that $p_{in}^{L+M+H} \equiv 1 - G(\varphi_L^*)$ is the probability of successful entry into production with one of the available production technologies: either L or M or H, and thus it is the probability of successful entry to the industry. This p_{in}^{L+M+H} is conceptually equivalent to the probability of successful entry in Melitz (2003).

[16] Exactly as it happens in the Melitz (2003) model, the assumption of a finite $\tilde{\varphi}$ imposes certain restrictions on the size of the upper tail of the distribution $g(\varphi)$: the $(\sigma-1)$th uncentered moment of the upper tail must be finite.

as the productivity threshold for the profitability of the adoption of the immediately superior technology:

$$\tilde{\varphi}_L(\varphi_L^*, \varphi_M^*) = \left[\frac{1}{1-G(\varphi_L^*)}\int_{\varphi_L^*}^{\varphi_M^*} \varphi^{\sigma-1} g(\varphi) d\varphi\right]^{\frac{1}{\sigma-1}} \quad (18)$$

$$\tilde{\varphi}_M(\varphi_M^*, \varphi_H^*) = \left[\frac{1}{1-G(\varphi_L^*)}\int_{\varphi_M^*}^{\varphi_H^*} \varphi^{\sigma-1} g(\varphi) d\varphi\right]^{\frac{1}{\sigma-1}} \quad (19)$$

$$\tilde{\varphi}_H(\varphi_H^*) = \tilde{\varphi}^H(\varphi_H^*) = \left[\frac{1}{1-G(\varphi_L^*)}\int_{\varphi_H^*}^{\infty} \varphi^{\sigma-1} g(\varphi) d\varphi\right]^{\frac{1}{\sigma-1}} \quad (20)$$

The ex ante probabilites of successful and profitable entry to technologies L, M and H are respectively $p_{in}^L \equiv G(\varphi_M^*) - G(\varphi_L^*)$, $p_{in}^M \equiv G(\varphi_H^*) - G(\varphi_M^*)$ and $p_{in}^H \equiv 1 - G(\varphi_H^*)$.[17]

In order for the thresholds for adopting each of the three available production technologies to lie in the desired order ($\varphi_L^* < \varphi_M^* < \varphi_H^*$), it is required that the gain obtained by a firm with a given productivity level φ when switching to a superior technology be smaller "in proportion" to the increase in the fixed cost it simultaneously faces, so that an increase in φ is needed to compensate for this drawback and make the upgrading of technology profitable.

Since each of these average productivity levels $\tilde{\varphi}_T$ is completely determined by the minimum productivity level for which it is convenient for the firm (in terms of profitability) to use technology T (φ_T^*) and that corresponding to the profitability of adoption of the immediate superior technology (φ_{T+1}^*)[18], then the average profit and revenue levels corresponding to each production technology are also linked to these thresholds:

$$\bar{r}_d^T = r_d^T(\tilde{\varphi}_T) = \left(\frac{\tilde{\varphi}_T(\varphi_T^*, \varphi_{T+1}^*)}{\varphi_T^*}\right)^{\sigma-1} r_d^T(\varphi_T^*) \qquad T = L, M, H \quad (21)$$

$$\bar{\pi}_d^T = \pi_d^T(\tilde{\varphi}_T) = \left(\frac{\tilde{\varphi}_T(\varphi_T^*, \varphi_{T+1}^*)}{\varphi_T^*}\right)^{\sigma-1} \frac{r_d^T(\varphi_T^*)}{\sigma} - f_T \qquad T = L, M, H \quad (22)$$[19]

But these thresholds φ_T^* are in turn linked to the cutoff productivity levels corresponding to technology T (φ_T^{**}):

$$\varphi_T^* = \begin{cases} \varphi_T^{**} & if\ T = L \\ \varphi_T^{**} + \varepsilon & if\ T = M, H \end{cases} \qquad \varepsilon > 0$$

This allows a generalization of a central relation in Melitz (2003) to also hold in the technology choice framework, namely that the "Effective Cutoff overall Profit condition for technology T" (ECP^T) – which in the autarky setting coincides with the "Effective Cutoff domestic Profit condition for technology T" (ECP_d^T)- pins down the revenue gained by each technology's effective cutoff firm[20] and

[17] Note that $\tilde{\varphi}_T(\varphi_T^*, \varphi_{T+1}^*) = \tilde{\varphi}^T(\varphi_T^*)$ only when T=H, while the same is not true for technologies L and M. The reason is that H is the best technology available (there is not a technology "superior" to H, that is, when T=H there is not a T+1 technology, and consequently we assume in that case $G(\varphi_{T+1}^*) = 1$, meaning we have reached the upper tail of the productivity distribution. Also note that these ex-ante probabilities of successful entry to each technology ($p_{in}^T,\ T = L, M, H$) are calculated directly from the original distribution$g(\varphi)$ instead of the modified distribution $\mu(\varphi)$ because at this stage (attempt of entry to the industry) all firms (including those who will eventually not succeed) are taken into account. Thus, for the sake of calculating these probabilities the relevant distribution is $g(\varphi)$, not $\mu(\varphi)$.

[18] If T=L then T+1=M, if T=M then T+1=H, if T=H there is no T+1 technology available (H is the best available technology).

[19] For easier derivation of equation (22) recall equation (11): $\pi_d^T(\varphi) = \frac{1}{\sigma} r_d^T(\varphi) - f_T$.

[20] The "effective cutoff firm" for technology T is the least productive firm actually using technology T.

consequently implies a relationship between the average profit per firm using technology T and the cutoff productivity level for the adoption of technology T:

$$\pi_d^T(\varphi_T^*) = A_d^T \quad \leftrightarrow \quad r_d^T(\varphi_T^*) = \sigma\left(A_d^T + f_T\right) \quad \leftrightarrow \quad \bar{\pi}_d^T = A_d^T h_d^T(\varphi_T^*) + f_T k_d^T(\varphi_T^*) \tag{23}$$

where $h_d^T = \left[\frac{\tilde{\varphi}_T(\varphi_T^*,\varphi_{T+1}^*)}{\varphi_T^*}\right]^{\sigma-1}$, $k_d^T(\varphi_T^*) = \left[\frac{\tilde{\varphi}_T(\varphi_T^*,\varphi_{T+1}^*)}{\varphi_T^*}\right]^{\sigma-1} - 1$ and $A_d^T > 0$ is the profit gained by the least idiosyncratically productive firm using technology T (a constant).[21] Note that when T=L, then $\varphi_T^* = \varphi_T^{**}$ and so $\pi_d^T(\varphi_T^*) = 0$ (that is: $A_d^T = 0$). Consequently in such case $r_d^T(\varphi_T^*) = \sigma f_T$ and $\bar{\pi}_d^T = f_T k_d^T(\varphi_T^*)$.

The other Melitz (2003) central relation, the "Free Entry condition" is also generalized to the technology choice framework taking as departing point the present value of the average profit flow of the firm using technology T in the closed economy conditional on successful entry –which is also the average value of firms using technology T in the closed economy:

$$\bar{v}_d^T = \sum_{t=0}^{\infty}(1-\delta_T)^t\, \bar{\pi}_d^T = \frac{1}{\delta_T}\bar{\pi}_d^T \tag{24}$$

The net value of entry to production with technology T is then:

$$v_e^T = p_{in}^T\left[\bar{v}_d^T - (f_e^T - f_e^L)\right] - f_e^L \tag{25}$$

where $p_{in}^T \equiv G(\varphi_{T+1}^*) - G(\varphi_T^*)$ is the probability of successful entry to production with technology T. If this value were negative, no firm would want to produce using technology T.

3.2 Aggregation Conditions in the Closed Economy

Assuming the industry is comprised of Z firms, there will be a proportion of $\frac{L}{Z}$ firms using technology L, a proportion of $\frac{M}{Z}$ using technology M and a proportion of $\frac{H}{Z}$ firms using technology H. $L + M + H = Z$, meaning all incumbent firms in the industry must use one –and one only- of the three available production technologies. Industry average productivity $\tilde{\varphi}$ is a weighted average of the firms' productivity levels –with firms' output shares as weights- and is independent both from total firm population Z and from the proportions of firms using each of the three available technologies, though it will be useful to disaggregate the integral into three smaller ones, according to the thresholds for upgrading technology[22]:

$$\tilde{\varphi}^{\sigma-1} = \int_0^{\infty}\varphi^{\sigma-1}\mu(\varphi)d\varphi = \frac{L}{Z}\int_{\varphi_L^*}^{\varphi_M^*}\varphi^{\sigma-1}\mu(\varphi)d\varphi + \frac{M}{Z}\int_{\varphi_M^*}^{\varphi_H^*}\varphi^{\sigma-1}\mu(\varphi)d\varphi + \frac{H}{Z}\int_{\varphi_H^*}^{\infty}\varphi^{\sigma-1}\mu(\varphi)d\varphi =$$
$$= \frac{L}{Z}\tilde{\varphi}_L^{\ \sigma-1} + \frac{M}{Z}\tilde{\varphi}_M^{\ \sigma-1} + \frac{H}{Z}\tilde{\varphi}_H^{\ \sigma-1} \tag{26}$$

[21] Since $\varphi_T^* > \varphi_T^{**}$ and $\pi_d^T(\varphi_T^{**}) = 0$, then we know $\pi_d^T(\varphi_T^{**}) > 0$. We already know as well that $\bar{\pi}_d^T = \pi_d^T(\tilde{\varphi}_T) = \left(\frac{\tilde{\varphi}_T(\varphi_T^*,\varphi_{T+1}^*)}{\varphi_T^*}\right)^{\sigma-1}\frac{r_d^T(\varphi_T^*)}{\sigma} - f_T$. Replacing $r_d^T(\varphi_T^*) = \sigma\left(A_d^T + f_T\right)$ in this equation we obtain $\bar{\pi}_d^T = \pi_d^T(\tilde{\varphi}_T) = A_d^T\left(\frac{\tilde{\varphi}_T(\varphi_T^*,\varphi_{T+1}^*)}{\varphi_T^*}\right)^{\sigma-1} + f_T\left(\frac{\tilde{\varphi}_T(\varphi_T^*,\varphi_{T+1}^*)}{\varphi_T^*}\right)^{\sigma-1} - f_T =$
$= A_d^T\left(\frac{\tilde{\varphi}_T(\varphi_T^*,\varphi_{T+1}^*)}{\varphi_T^*}\right)^{\sigma-1} + f_T\left[\left(\frac{\tilde{\varphi}_T(\varphi_T^*,\varphi_{T+1}^*)}{\varphi_T^*}\right)^{\sigma-1} - 1\right] = A_d^T h_d^T(\varphi_T^*) + f_T k^T(\varphi_T^*)$.

[22] Recall that knowing these proportions is not a necessary condition for the calculation of $\tilde{\varphi}$, which had already been obtained solely from $g(\varphi)$ in combination with φ_L^*.

where φ_L^* is the productivity threshold upon which it becomes profitable for the firm to have positive production with technology L, φ_M^* is the productivity threshold upon which it becomes profitable for the firm to drop technology L and adopt technology M instead, and φ_H^* is the productivity threshold upon which it becomes profitable for the firm to drop technology M and adopt technology H instead.

In such autarkic equilibrium, the aggregate price, quantity, revenue and profits can be re expressed as (proof in Appendix A):

$$P = \left[Lp_d^L(\tilde{\varphi}_L)^{1-\sigma} + Mp_d^M(\tilde{\varphi}_M)^{1-\sigma} + Hp_d^H(\tilde{\varphi}_H)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \quad (27)$$

$$Q = \left[Lq_d^L(\tilde{\varphi}_L)^{\rho} + Mq_d^M(\tilde{\varphi}_M)^{\rho} + Hq_d^H(\tilde{\varphi}_H)^{\rho}\right]^{\frac{1}{\rho}} \quad (28)$$

$$R = Lr_d^L(\tilde{\varphi}_L) + Mr_d^M(\tilde{\varphi}_M) + Hr_d^H(\tilde{\varphi}_H) = R_L + R_M + R_H \quad (29)$$

$$\Pi = L\pi_d^L(\tilde{\varphi}_L) + M\pi_d^M(\tilde{\varphi}_M) + H\pi_d^H(\tilde{\varphi}_H) = \Pi_L + \Pi_M + \Pi_H \quad (30)$$

The average price, quantity, revenue and profits in this industry in the closed economy setting are obtained as a weighted average of the price, quantity, revenue and profits of each technological group, where the weights are given by the proportion of firms belonging to each group in the total number of firms in the industry, Z[23]:

$$\bar{p}_d = \frac{P}{Z^{\frac{1}{1-\sigma}}} = \left[\frac{L}{Z}p_d^L(\tilde{\varphi}_L)^{1-\sigma} + \frac{M}{Z}p_d^M(\tilde{\varphi}_M)^{1-\sigma} + \frac{H}{Z}p_d^H(\tilde{\varphi}_H)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \quad (31)$$

$$\bar{q}_d = \frac{Q}{Z^{\frac{1}{\rho}}} = \left[\frac{L}{Z}q_d^L(\tilde{\varphi}_L)^{\rho} + \frac{M}{Z}q_d^M(\tilde{\varphi}_M)^{\rho} + \frac{H}{Z}q_d^H(\tilde{\varphi}_H)^{\rho}\right]^{\frac{1}{\rho}} \quad (32)$$

$$\bar{r}_d = \frac{R}{Z} = \frac{L}{Z}r_d^L(\tilde{\varphi}_L) + \frac{M}{Z}r_d^M(\tilde{\varphi}_M) + \frac{H}{Z}r_d^H(\tilde{\varphi}_H) \quad (33)$$

$$\bar{\pi}_d = \frac{\Pi}{Z} = \frac{L}{Z}\pi_d^L(\tilde{\varphi}_L) + \frac{M}{Z}\pi_d^M(\tilde{\varphi}_M) + \frac{H}{Z}\pi_d^H(\tilde{\varphi}_H) \quad (34)$$

3.3 Determination of the Equilibrium in the Closed Economy

The technology-specific Free Entry ($\mathrm{FE^T}$) and Effective Cutoff Crofit ($\mathrm{ECP^T}$) conditions each link the average profit level $\bar{\pi}_d^T$ and the cutoff productivity level φ_T^* corresponding to the group of firms producing with technology T. From equations (23) and (25) it is obtained:

$$\bar{\pi}_d^T = A_d^T h_d^T(\varphi_T^*) + f_T k_d^T(\varphi_T^*) \qquad (\mathrm{ECP^T})$$

$$\bar{\pi}_d^T = \frac{\delta_T f_e^L}{G(\varphi_{T+1}^*) - G(\varphi_T^*)} + \delta_T(f_e^T - f_e^L) \qquad (\mathrm{FE^T}) \quad (35)$$

For each technology T, both functions have an interpretation in terms of the model in the interval of the domain delimited by the thresholds for the adoption of the immediate inferior and the immediate superior production technologies. As shown in Appendix B, under certain parameter restrictions each $\mathrm{FE^T}$ curve will intersect with the corresponding $\mathrm{ECP^T}$ curve and will do it in only one point, ensuring the existence and uniqueness of the equilibrium φ_T^* and $\bar{\pi}_d^T$ for every production technology T. The equilibriums for each production technology are illustrated in Figure 1:

[23] These "theoretical" averages are calculated just in order to provide a rough measure of the industry's "per firm performance". They need not coincide with the price, quantity, revenue and profits of any particular firm.

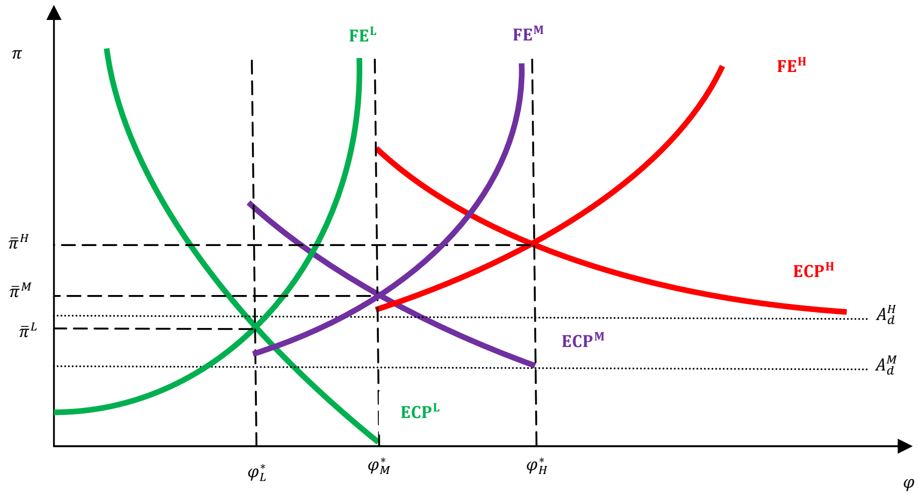


Figure 1

If the gain obtained by a firm with a given productivity level φ when switching to a superior technology is smaller "in proportion" to the increase in the fixed cost it simultaneously faces, then we know $\varphi_L^* < \varphi_M^* < \varphi_H^*$, and thus the ordering of the average profit levels corresponding to each technology must be $\bar{\pi}_d^L < \bar{\pi}_d^M < \bar{\pi}_d^H$. An important remark to make here is that the lowest value of the FE^{T} and the highest value of the $\mathrm{ECP}^{\mathrm{T}}$ need not be as shown in Figure 1: they could be lower or higher. Regarding both curves (for each technology T) we only know that both are continuous in the interval delimited by the thresholds for the adoption of the immediately inferior and superior technologies, and that the former is monotonically strictly increasing while the latter is monotonically strictly decreasing in such interval. However, because the average productivity level is the highest among technology H users, somewhat lower among technology M users, and the lowest among technology L users, such ambiguity regarding the exact geometric position of the FE^{T} and $\mathrm{ECP}^{\mathrm{T}}$ curves does not alter the result that the FE^{H} and $\mathrm{ECP}^{\mathrm{H}}$ curves must intersect not only to the right but also higher than the FE^{M} and $\mathrm{ECP}^{\mathrm{M}}$ curves, and these in turn must intersect to the right and higher than the FE^{L} and $\mathrm{ECP}^{\mathrm{L}}$ curves, as shown in Figure 1.

As we are focusing in steady-state equilibriums, not only the number of successful new entrants $p_{in}^{L+M+H} Z_e$ –where Z_e is the total number of new entrants- must exactly replace the δZ firms who are hit by a bad shock and exit (that is: $p_{in}^{L+M+H} Z_e = \delta Z$), but furthermore, the number of successful new entrants into each technological group need exactly replace the number of failing incumbents amongst the same technological group, so that all aggregate variables remain constant over time:

$$p_{in}^{L} Z_e = \delta_L L \leftrightarrow [G(\varphi_M^*) - G(\varphi_L^*)] Z_e = \delta_L L \tag{36}$$

$$p_{in}^{M} Z_e = \delta_M M \leftrightarrow [G(\varphi_H^*) - G(\varphi_M^*)] Z_e = \delta_M M \tag{37}$$

$$p_{in}^{H} Z_e = \delta_H H \leftrightarrow [1 - G(\varphi_H^*)] Z_e = \delta_H H \tag{38}$$

where $p_{in}^{L} Z_e + p_{in}^{M} Z_e + p_{in}^{H} Z_e = p_{in}^{L+M+H} Z_e$ and $\delta_L L + \delta_M M + \delta_H H = \delta Z$.[24]

Because both the successful entrants and failing incumbents draw their idiosyncratic productivity from the same exogenous distribution $g(\varphi)$, neither the equilibrium distribution $\mu(\varphi)$ nor the proportions of firms belonging to each technological group are affected by this firms' turnover.

[24] So $\delta = \frac{L}{Z}\delta_L + \frac{M}{Z}\delta_M + \frac{H}{Z}\delta_H$.

3.4 Analysis of the Equilibrium in the Closed Economy

The fact that skilled (S) and unskilled (U) labor are used in fixed proportions in each of the three available production technologies makes it possible to relate the size of the industry –indexed by $Z = L + M + H$- to the amount of total labor (skilled and unskilled) used. As a matter of fact, the assumption of fixed proportions in all three production technologies facilitates enormously the analytic treatment of labor because by completely eliminating the possibility that the proportions of S and U employed in any of the technologies may vary, it reduces the difference between a model with homogeneous labor and a model with different qualities of labor to an algebraic matter. Once the fixed proportions in each technology are set, total labor –defined as total skilled plus total unskilled labor- employed in each technology can be treated as a block and called just "labor" without any loss of generality of the results that may emerge.

Total skilled labor employed in the industry is $S = S_L + S_M + S_H$ and total unskilled labor employed in the industry is $U = U_L + U_M + U_H$. Therefore, aggregate labor in the industry is $[S + U] = [(S_L + S_M + S_H) + (U_L + U_M + U_H)] = [(S_L + U_L) + (S_M + U_M) + (S_H + U_H)]$, that is, the sum of the total amount of labor –of any qualification- employed in each of the three available production technologies. In each technology, a fraction of total labor employed –skilled and unskilled- is used for production purposes –by all active firms- and the rest is used for "setting up the bussiness" –by new entrants-:

$$(U_T + S_T) = (U_T + S_T)_p + (U_T + S_T)_e \qquad T = L, M, H \tag{39}$$

where $(U_T + S_T)_p$ and $(U_T + S_T)_e$ represent, respectively, the aggregate labor used in production technology T for regular production (by all incumbents producing with T) and setting up the bussiness (by new entrants to technology T).

Recall that in every period there are δZ firms which are impacted by a bad shock and forced out of the market. We already know from the previous section that the bad shocks δ_T affect equally all firms using the same technology T no matter which their productivity, but need not coincide across the three alternative technologies –although for simplicity we are assuming they do. We also know $\delta_L L + \delta_M M + \delta_H H = \delta Z$ and that in every period there are Z_e entrants, which have the same productivity distribution as the current incumbents. These Z_e firms want to enter the industry, but they ignore their productivity parameter φ and consequently they also ignore if they are going to successfully enter the industry or not, as well as with which production technology they will be producing if they actually do enter successfully (L, M or H). But, as it was already stated in previous sections, there exists a sort of "insurance" for prospective entrants which consists in the possibility, on deciding entrance (a decision made before drawing the productivity parameter) to sink only the lowest fixed entry cost, f_e^L. This is an obvious advantage for the prospective entrant, because in case it results to be an unsuccessful entrant, its loss is reduced to a minimum. If instead the firm would result to be a successful entrant, it will be compelled to pay the full entry cost to the specific production technology it enters. Consequently:

- $f_e^L + p_{in}^L(f_e^L - f_e^L) = f_e^L$ is the sunk cost paid by unsuccessful entrants to the industry and by successful entrants to technology L.
- $f_e^L + p_{in}^M(f_e^M - f_e^L)$ is the sunk cost paid by successful entrants to technology M.
- $f_e^L + p_{in}^H(f_e^H - f_e^L)$ is the sunk cost paid by successful entrants to technology H.

Recall that the probabilities of successful entry into each of the three available technologies are p_{in}^L, p_{in}^M and p_{in}^H. Consequently, the probability of effectively ending up paying $f_e^L + p_{in}^H(f_e^H - f_e^L)$ is p_{in}^H, the probability of effectively ending up paying $f_e^L + p_{in}^M(f_e^M - f_e^L)$ is p_{in}^M and finally, the probability of effectively ending up paying f_e^L is $\left(1 - p_{in}^H - p_{in}^M\right) = \left(1 - p_{in}^H - p_{in}^M - p_{in}^L\right) + p_{in}^L = (1 -$

$p_{in}^{L+M+H}) + p_{in}^{L}$. These probabilities indicate also the proportions of the Z_e entrants that will be effectively paying each entry cost.

The market clearing condition for workers engaged in "regular production" is that aggregate payments to them in each technology T must match the difference between revenue and profit in such technology:

$$(U_T + S_T)_p = R_T - \Pi_T \tag{40}$$

Which in turn determines the aggregate result that payments to production workers as a whole must match the difference between aggregate revenue and aggregate profits in the industry:

$$(U_H + S_H)_p + (U_M + S_M)_p + (U_L + S_L)_p = (U + S)_p = (R_H - \Pi_H) + (R_M - \Pi_M) + (R_L - \Pi_L)$$
$$= (R_H + R_M + R_L) - (\Pi_H + \Pi_M + \Pi_L) = R - \Pi$$

The market clearing condition for workers engaged in "setting up the bussiness" is that aggregate payments to them must be equal to the total amount paid for entry by prospective entrants (successful and unsuccessful). Thus, aggregate payments to "setting up" workers in technology H must match the total entry amount paid by successful entrants into that production technology[25]:

$$(\boldsymbol{U_H} + \boldsymbol{S_H})_{\boldsymbol{e}} = p_{in}^H Z_e\left[f_e^L + p_{in}^H(f_e^H - f_e^L)\right] =$$
$$= p_{in}^H \frac{\delta_H H}{p_{in}^H}\left[f_e^L + p_{in}^H(f_e^H - f_e^L)\right] = H\delta_H\left[f_e^L + p_{in}^H(f_e^H - f_e^L)\right] =$$
$$= H\delta_H f_e^L + H\delta_H p_{in}^H(f_e^H - f_e^L) = Hp_{in}^H\left[\bar{\pi}_d^H - \delta_H(f_e^H - f_e^L)\right] + H\delta_H p_{in}^H(f_e^H - f_e^L) =$$
$$= Hp_{in}^H\bar{\pi}_d^H - Hp_{in}^H\delta_H(f_e^H - f_e^L) + H\delta_H p_{in}^H(f_e^H - f_e^L) = \boldsymbol{p_{in}^H \Pi^H} < \Pi^H \tag{41}$$

In turn, aggregate payments to investment workers in technology M must match the total entry amount paid by successful entrants into that production technology[26]:

$$(\boldsymbol{U_M} + \boldsymbol{S_M})_{\boldsymbol{e}} = p_{in}^M Z_e\left[f_e^L + p_{in}^M(f_e^M - f_e^L)\right] =$$
$$= p_{in}^M \frac{\delta_M M}{p_{in}^M}\left[f_e^L + p_{in}^M(f_e^M - f_e^L)\right] = M\delta_M\left[f_e^L + p_{in}^M(f_e^M - f_e^L)\right] =$$
$$= M\delta_M f_e^L + M\delta_M p_{in}^M(f_e^M - f_e^L) = Mp_{in}^M\left[\bar{\pi}_d^M - \delta_M(f_e^M - f_e^L)\right] + M\delta_M p_{in}^M(f_e^M - f_e^L) =$$
$$= Mp_{in}^M\bar{\pi}_d^M - Mp_{in}^M\delta_M(f_e^M - f_e^L) + M\delta_M p_{in}^M(f_e^M - f_e^L) = \boldsymbol{p_{in}^M \Pi^M} < \Pi^M \tag{42}$$

Finally, aggregate payments to investment workers in technology L must match the total entry amount paid by successful entrants into that production technology and by unsuccessful entrants to the industry[27]:

$$(\boldsymbol{U_L} + \boldsymbol{S_L})_{\boldsymbol{e}} = \left(1 - p_{in}^H - p_{in}^M\right)Z_e f_e^L = \left[\left(1 - p_{in}^H - p_{in}^M - p_{in}^L\right) + p_{in}^M\right]Z_e f_e^L{}_L =$$
$$= \left(1 - p_{in}^{L+M+H}\right)Z_e f_e^L + p_{in}^L Z_e f_e^L =$$
$$= \left(1 - p_{in}^{L+M+H}\right)Z_e f_e^L + p_{in}^L \frac{\delta_L L}{p_{in}^L} f_e^L = \left(1 - p_{in}^{L+M+H}\right)Z_e f_e^L + L\delta_L f_e^L =$$

---

[25] This derivation is obtained using the "Aggregate Stability" condition for technology H $\left(p_{in}^H Z_e = \delta_H H \leftrightarrow Z_e = \frac{\delta_H H}{p_{in}^H}\right)$ and the "Free Entry" condition for technology H $\left(\bar{\pi}_d^H = \frac{\delta_H f_e^L}{p_{in}^H} + \delta_H(f_e^H - f_e^L) \leftrightarrow \delta_H f_e^L = p_{in}^H[\bar{\pi}_d^H - \delta_H(f_e^H - f_e^L])\right)$.

[26] This derivation is obtained using the "Aggregate Stability" condition for technology M $\left(p_{in}^M Z_e = \delta_M M \leftrightarrow Z_e = \frac{\delta_M M}{p_{in}^M}\right)$ and the "Free Entry" condition for technology M $\left(\bar{\pi}_d^M = \frac{\delta_M f_e^L}{p_{in}^M} + \delta_M(f_e^M - f_e^L) \leftrightarrow \delta_M f_e^L = p_{in}^M[\bar{\pi}_d^M - \delta_M(f_e^M - f_e^L])\right)$.

[27] This derivation is obtained using the "Aggregate Stability" condition for technology L $\left(p_{in}^L Z_e = \delta_L L \leftrightarrow Z_e = \frac{\delta_L L}{p_{in}^L}\right)$ and the "Free Entry" condition for technology L $\left(\bar{\pi}_d^L = \frac{\delta_L f_L}{p_{in}^L} \leftrightarrow \delta_L f_L = p_{in}^L \bar{\pi}_d^L\right)$, as well as the identity $p_{in}^{L+M+H} = p_{in}^L + p_{in}^M + p_{in}^H$.

$$= \left(1 - p_{in}^{L+M+H}\right) Z_e f_e^L + L \bar{\pi}_d^L p_{in}^L = \left(1 - p_{in}^{L+M+H}\right) Z_e f_e^L + \Pi^L p_{in}^L =$$
$$= \boldsymbol{\left(1 - p_{in}^L - p_{in}^M - p_{in}^H\right) Z_e f_e^L + p_{in}^L \Pi^L} \quad (43)$$

Consequently, for the aggregate industry the expression for the payment received by "set up" workers is:

$$(U+S)_e = (U_L + S_L)_e + (U_M + S_M)_e + (U_H + S_H)_e = \left(1 - p_{in}^L - p_{in}^M - p_{in}^M\right) Z_e f_e^L + p_{in}^L \Pi^L + p_{in}^M \Pi^M + p_{in}^H \Pi^H \quad (44)$$

In the Melitz setting, with a single production technology and consequently with no possible difference between the exante and ex post entry payments made by all prospective entrants (successful and unsuccessful), it is straightforward that such entry payments must add up to aggregate profits at the industry level[28]. In the present context this result is not as immediat, though bearing in mind that the essence of the stationary equilibrium remains unchanged by the introduction of technology choice, it is nevertheless maintained. Consequently $(U+S)_e = \Pi$, which implies total payments to labor (of any qualification, employed in any technology, both "set up" and "production") will add up to aggregate revenue at industry level: $(U+S) = (U+S)_p + (U+S)_e = R$. However, the existence of differences across technologies in ex post entry costs does add an additional dimension to the characterization of the stationary equilibrium. From equation (44) we have:

$$(U+S)_e = \Pi \leftrightarrow \left(1 - p_{in}^L - p_{in}^M - p_{in}^H\right) Z_e f_e^L + p_{in}^L \Pi^L + p_{in}^M \Pi^M + p_{in}^H \Pi^H = \Pi \leftrightarrow$$
$$\leftrightarrow \left(1 - p_{in}^L - p_{in}^M - p_{in}^H\right) Z_e f_e^L + \left[p_{in}^L \Pi^L + p_{in}^M \Pi^M + p_{in}^H \Pi^H\right] = \Pi \leftrightarrow$$
$$\leftrightarrow \left(1 - p_{in}^L - p_{in}^M - p_{in}^H\right) Z_e f_e^L = \Pi - \left[p_{in}^L \Pi^L + p_{in}^M \Pi^M + p_{in}^H \Pi^H\right] \leftrightarrow$$
$$\leftrightarrow \left(1 - p_{in}^L - p_{in}^M - p_{in}^H\right) Z_e f_e^L = \left[\Pi^L + \Pi^M + \Pi^H\right] - \left[p_{in}^L \Pi^L + p_{in}^M \Pi^M + p_{in}^H \Pi^H\right] \leftrightarrow$$
$$\leftrightarrow \left(1 - p_{in}^L - p_{in}^M - p_{in}^H\right) Z_e f_e^L = \left(\Pi^L - p_{in}^L \Pi^L\right) + \left(\Pi^M - p_{in}^M \Pi^M\right) + \left(\Pi^H - p_{in}^H \Pi^H\right) \leftrightarrow$$
$$\leftrightarrow \left(1 - p_{in}^L - p_{in}^M - p_{in}^H\right) Z_e f_e^L = \left(1 - p_{in}^L\right) \Pi^L + \left(1 - p_{in}^M\right) \Pi^M + \left(1 - p_{in}^H\right) \Pi^H \quad (45)$$

This means that a part of the profits generated by successful entrants into each production technology is absorbed by the "set up" workers employed in them, but not the total amount: a fraction of these profits is used to pay the wages of the "set up" workers hired by unsuccessful entrants[29], who have not generated any profits themselves because they have never produced (recall that unsuccessful entrants leave the industry immediately upon entry). This is intuitive: all workers must receive payment. If some firms do not generate the resources necessary to pay the wages of the "setting-up-the-bussiness" workers they have hired (this is the case of the unsuccessful entrants), then the rest of the firms (that is, all successful entrants, no matter into which production technology) must cede a fraction of theirs in order to have all the "setting-up-the-bussiness" workers paid. Unsuccessful entrants do not ever hire any "regular production" workers, so there is not an equivalent reasoning applying to them: "regular production" workers are always paid with resources generated by the firms hiring them. A particularity of the present model is that the investment workers hired by unsuccessful entrants will always be employed in technology L, because a priori of drawing their productivity parameter all prospective entrants choose to pay the entry (sunk) cost corresponding to this technology, which is the lowest, in order to reduce their loss in case they draw a low productivity parameter and are forced to leave immediately upon entry. As a consequence of this, a redistribution of resources takes place, from the two superior technologies (M and H) toward the inferior technology (L).

On other grounds, welfare per worker is given by: $W = \frac{1}{P} = \frac{1}{Z^{\frac{1}{1-\sigma}} \bar{p}}$. Therefore, it increases the larger the number of incumbent firms –and thus, of available varieties-, and the lower the average price. The average price will be lower the higher aggregate average idiosyncratic productivity and the greater the proportion of firms using the superior production technologies, especially technology H.

[28] See Melitz (2003), page 1704.
[29] This result is already present in the Melitz setting.

Because the distribution of productivity levels $\mu(\varphi)$ remains constant in equilibrium, and for this reason, so do the proportions $\frac{L}{Z}$, $\frac{M}{Z}$ and $\frac{H}{Z}$ of incumbent firms belonging to each technological group, $\bar{r}_d = \frac{R}{Z} = \frac{R^L+R^M+R^H}{Z} = \frac{L}{Z}\bar{r}_d^L + \frac{M}{Z}\bar{r}_d^M + \frac{H}{Z}\bar{r}_d^H$ must also remain unchanged. Thus, the number of incumbent firms (and consequently the number of available varieties) $Z = \frac{R}{\bar{r}_d} = \frac{(U+S)_p+(U+S)_e}{\bar{r}_d}$ increases proportionally with country size, resulting in higher welfare. This is a feature this model has in common with Melitz (2003).

On the other hand, all the remaining key variables are independent from country size, that is: φ_T^*, $\tilde{\varphi}_T$, $\bar{r}_d^L$ and $\bar{\pi}_d^T$ (T=L, M, H), as well as $\tilde{\varphi}$, $\bar{r}_d$ and $\bar{\pi}_d$ do not vary with country size. This result is also shared with Melitz (2003)[30]. Nevertheless, despite the productivity threshold to enter the industry and industry average productivity in the present model will always coincide with those in Melitz's setting, so long it is assumed that both models share the same exogenous productivity distribution $g(\varphi)$ and that technology L in this model is the same as Melitz's single production technology, some differences emerge as well: $\bar{r}_d$ will always be higher in the current model –as a direct consequence of average variable cost being undoubtedly lower here than in Melitz (2003)-, while $\bar{\pi}_d$ in the model with technology choice must also be higher for upgrading technology decisions to make sense –thus, given that in the equilibrium obtained technology upgrading actually occurs, it follows that this result holds-[31].

4. Extension of the Model to the Open Economy Case

Opening the economy to trade implies both modelling exporting behaveiour and taking into account the competition coming from foreign goods sold in the domestic market. The basic traits of the Melitz open economy environment are maintained: the home country can trade with $n \geq 1$ other countries, all of them assumed identical to it so as to ensure they all share the same input costs for each technology T and the same aggregate variables. Exporting firms face two types of trade related costs: a variable "iceberg" cost –capturing mainly fleet and tariff- and a fixed cost –representing the investment needed to penetrate export markets-. The decision regarding export status choice takes place once the firm has already drawn its productivity parameter, and there is no additional uncertainty.

We depart from this benchmark setting by dividing exporting firms into two subgroups according to their "level of commitment" with the export markets. Firms can now choose between three alternative market strategies: they can serve the domestic market only, or they can otherwise self-select into the export markets in two different ways, one "more accessible" and the other "more demanding"[32]. The

[30] Recall that in the Melitz model technologies M and H do not exist, thus neither do φ_M^* and φ_H^* and consequently technology specific average productivities, average revenue and average profits are redundant there.

[31] Recall that in the Melitz (2003) model every incumbent firm –whatever its productivity φ- uses production technology L, obtaining profits $\pi_d^L(\varphi)$. Thus, average profits in such model are given by $\bar{\pi}_{Melitz} = \frac{L}{Z}\pi_d^L(\tilde{\varphi}_L) + \frac{M}{Z}\pi_d^L(\tilde{\varphi}_M) + \frac{H}{Z}\pi_d^L(\tilde{\varphi}_H)$. Instead, in the current model any firm whose productivity surpasses the threshold φ_M^* will find $\pi_d^L(\varphi) < \pi_d^M(\varphi)$and will consequently switch to technology M, while any firm whose productivity surpasses the threshold φ_H^* will find $\pi_d^M(\varphi) < \pi_d^H(\varphi)$ and will consequently switch to technology H. Thus, in equilibrium only those incumbent firms with productivity below φ_M^* (a proportion $\frac{L}{Z}$ of total firm population) will be getting profits $\pi_d^L(\varphi)$, while those for whom $\varphi_M^* \leq \varphi < \varphi_H^*$ (a proportion $\frac{M}{Z}$ of total firm population) will be getting profits $\pi_d^M(\varphi)$, and those with $\varphi \geq \varphi_H^*$ (a proportion $\frac{H}{Z}$ of total firm population) will be getting profits $\pi_d^H(\varphi)$ -bear in mind that the proportions $\frac{L}{Z}$, $\frac{M}{Z}$ and $\frac{H}{Z}$ depend solely on the equilibrium productivity distribution, $\mu(\varphi)$, and the value of parameters-. Consequently, in the current model average profits are given by $\bar{\pi}_{Schmidt} = \frac{L}{Z}\pi_d^L(\tilde{\varphi}_L) + \frac{M}{Z}\pi_d^M(\tilde{\varphi}_M) + \frac{H}{Z}\pi_d^H(\tilde{\varphi}_H)$ which readily yields $\bar{\pi}_{Schmidt} > \bar{\pi}_{Melitz}$.

[32] Due to the assumptions of the model regarding demand formulation (which imply that the individual firm never faces scale limitations for its variety sales in any market –whether domestic or foreign-), strictly speaking it is not to necessary introduce different exporting profiles to achieve compatibility with incentives regarding technology choice decisions. Furthermore, even in a closed economy setting firms still have incentives -the more the higher their idiosyncratic productivity- to upgrade

“accessible” export status is achieved by incurring the minimum fixed cost indispensable for the firm to enter the foreign market. Firms who follow this strategy are called “Low-Commitment Exporters”. Achieving the “demanding” export status involves making an additional investment –beyond the minimum fixed cost indispensable to begin exporting-, in order to gain a greater market share in the foreign market[33]. Firms who follow this strategy are called “High-Commitment Exporters”[34]. The per unit trade iceberg cost captures mainly fleet and tariffs and is the same for both types of exporting firms.

Analytically, the trade costs faced by exporting firms are:

- **“Low-Commitment Exporters”:** the fixed export cost faced by these firms is denoted by $f_{elcx} > 0$, while the per unit export cost is $\tau > 1$.

- **“High-Commitment Exporters”:** the fixed export cost faced by these firms is $f_{ehcx} > f_{elcx}$, while the per unit export cost is once again $\tau > 1$.

Domestic price remains a constant mark-up over marginal cost, and firms pass on the additional variable costs incurred in export sales to foreign consumers. Thus, the firm’s pricing rule for the export markets is given by:

$$p_{ix}^T = \frac{\tau}{\rho}\frac{c_T}{\varphi(1+\beta_i)} = \frac{\tau}{(1+\beta_i)}p_d^T \qquad i = lc, hc \tag{46}$$

where β_i stands for the “effects of the additional trade-related fixed investments” made by type i exporters. Therefore $\beta_{lc} = 0$ –because “Low-Commitment Exporters” do not make any additional investments to foster export sales- and $0 < \beta_{hc} < A$, being A a positive finite number –because “High-Commitment Exporters” do make some additional investments to increase their exports, which are assumed not sterile, but nevertheless neither unlimited-. This means each firm may simultaneously set two different prices:

- Domestic price (p_d^T)

- Export price (p_{ix}^T)

---

their production technology, because by doing so they gain access to an increased market share and this way achieve greater revenue and profits. However, acknowledging that this result is brought about by a simplification which is useful in the modeling process but that is not an empirical feature –that is: in reality, market size limitations do exist-, the two exporting profiles are modeled to give the model greater realism. More precisely, the idea underlying this extension is that the domestic market has limited capacity to absorb the industry’s production, which in turn creates incentives for the firms to penetrate foreign markets in order to avoid reaching a limit in their sales’ expansion. At the same time, because export sales involve additional costs, only the firms whose idiosyncratic productivity is above a certain threshold will be able to become exporters, and among this group, only those with the highest productivity parameters will be in grade of assuming the most aggressive exporting profile and this way reach the highest expansion of total sales –and consequently, the highest total profits-.

[33] This additional investment can be understood in terms of extra advertising expenditure, the creation of better distribution channels, better postsale service, etc.

[34] On reaching this point it will be useful to remember that differences in idiosyncratic productivity can be interpreted either as differences in the costs associated to the production of goods of similar quality, or as differences in the quality of goods produced at the same cost. For convenience in the current context, the second interpretation (quality differences) will be adopted. We will then consider that “High-Commitment Exporters” incur a fixed cost which is superior to the minimum required fixed cost to begin exporting, in order to carry out certain activities in the export market with the purpose to induce potential buyers to choose their variety from among all the available varieties. As in terms of the model, sales –given the price- only increase as product quality increases –which in this context is the same as saying “as firm’s idiosyncratic productivity increases”-, the specific purpose of this additional fixed investment is to make potential buyers in the foreign market perceive the firm’s variety as better quality. Such increase in quality may be real –e.g.: due to better distribution channels or postsale service- or immaginary –e.g.: due to smart advertising-, but its effect in terms of the model is nevertheless “as if” the idiosyncratic productivity of the firm was increased by these additional investments. This way, the firm is able to expand its sales in the foreign market beyond what its true idiosyncratic productivity would determine. Therefore, given its idiosyncratic productivity level, a firm will achieve larger export sales –and thus, larger total sales- if it follows the “High-Commitment Exporter” strategy than if it follows the “Low-Commitment Exporter” strategy. In exchange for such larger sales, the High-Commitment Exporter faces a higher fixed export cost.

It is important to note that since export costs –fixed and variable- for each export profile are assumed equal across countries, then a firm will either export to all countries –and with the same level of "commitment"- in every period or never export at all.

Quantity sold in the domestic market still is $q_d^T(\varphi) = EP^{\sigma-1}\left(\rho\frac{\varphi}{c_T}\right)^{\sigma} = EP^{\sigma-1}\left(\frac{1}{p_d^T(\varphi)}\right)^{\sigma}$ while quantity sold in the foreign markets is $q_{ix}^T(\varphi) = EP^{\sigma-1}\left(\rho\frac{\varphi(1+\beta_i)}{\tau c_T}\right)^{\sigma} = EP^{\sigma-1}\left(\frac{1}{p_{ix}^T(\varphi)}\right)^{\sigma}$ per export destination. Therefore, total quantity sold depends on export status:

$$q^T(\varphi) = \begin{cases} q_d^T(\varphi) & if\ the\ firm\ is\ a\ "Non-Exporter" \\ q_d^T(\varphi) + nq_{lcx}^T(\varphi) = \left[1+n\left(\frac{\tau}{(1+\beta_{lc})}\right)^{-\sigma}\right]q_d^T(\varphi) = [1+n\tau^{-\sigma}]q_d^T(\varphi) \\ \qquad if\ the\ firm\ is\ a\ "Low-Commitment\ Exporter" \\ q_d^T(\varphi) + nq_{hcx}^T(\varphi) = \left[1+n\left(\frac{\tau}{(1+\beta_{hc})}\right)^{-\sigma}\right]q_d^T(\varphi) = \left[1+n\left(\frac{\tau}{(1+\beta_{hc})}\right)^{-\sigma}\right]q_d^T(\varphi) \\ \qquad if\ the\ firm\ is\ a\ "High-Commitment\ Exporter" \end{cases} \quad (47)^{35}$$

The revenue earned by a firm from its domestic sales and from its export sales per export destination (either "Low-Commitment" or "High-Commitment") are:

- $r_d^T(\varphi) = E\left(P\rho\frac{\varphi}{c_T}\right)^{\sigma-1}$ (recall equation (10))
- $r_{lcx}^T(\varphi) = E\left(P\rho\frac{\varphi(1+\beta_{lc})}{\tau c_T}\right)^{\sigma-1} = E\left(P\rho\frac{\varphi}{c_T}\right)^{\sigma-1}\left(\frac{1}{\tau}\right)^{\sigma-1} = \tau^{1-\sigma}E\left(P\rho\frac{\varphi}{c_T}\right)^{\sigma-1} = \tau^{1-\sigma}r_d^T(\varphi)$.
- $r_{hcx}^T(\varphi) = E\left(P\rho\frac{\varphi(1+\beta_{hc})}{\tau c_T}\right)^{\sigma-1} = E\left(P\rho\frac{\varphi}{c_T}\right)^{\sigma-1}\left(\frac{(1+\beta h_c)}{\tau}\right)^{\sigma-1} = \left(\frac{\tau}{(1+\beta_{hc})}\right)^{1-\sigma}E\left(P\rho\frac{\varphi}{c_T}\right)^{\sigma-1} = \left(\frac{\tau}{(1+\beta_{hc})}\right)^{1-\sigma}r_d^T(\varphi)$

Which yields:

$$r^T(\varphi) = \begin{cases} r_d^T(\varphi) \quad if\ the\ firm\ is\ a\ "Non-Exporter" \\ r_d^T(\varphi) + nr_{lcx}^T(\varphi) = [1+n\tau^{1-\sigma}]r_d^T(\varphi) \\ \qquad if\ the\ firm\ is\ a\ "Low-Commitment\ Exporter" \\ r_d^T(\varphi) + nr_{hcx}^T(\varphi) = \left[1+n\left(\frac{\tau}{(1+\beta_{hc})}\right)^{1-\sigma}\right]r_d^T(\varphi) \\ \qquad if\ the\ firm\ is\ a\ "High-Commitment\ Exporter" \end{cases} \quad (48)$$

4.1 Firm Entry, Exit and Market Strategy in the Open Economy

While the general setting of the economy is the same as in autarky –thus entry and exit dynamics remain unchanged-, an additional choice comes by with trade: the necessity that firms choose their export status. As in Meliz (2003), the simplifying assumption of no additional uncertainty concerning the export markets determines isomorphy between modelling the sunk investment cost assotiated to exporting, f_{eix}, as such –thus, paid all at once when the firm begins exporting- or as a fixed cost incurred in every period –equivalent to the amortized per period portion of this cost $f_{ix}^T = \delta_T f_{eix}$-[36].

[35] Total sales for the exporting firm are given by :

$$q^T(\varphi) = q_d^T(\varphi) + nq_{ix}^T(\varphi) = EP^{\sigma-1}\left(\frac{1}{p_d^T(\varphi)}\right)^{\sigma} + nEP^{\sigma-1}\left(\frac{1}{p_{ix}^T(\varphi)}\right)^{\sigma} = EP^{\sigma-1}\left(\rho\frac{\varphi}{c_T}\right)^{\sigma} + nEP^{\sigma-1}\left(\rho\frac{\varphi(1+\beta_i)}{\tau c_T}\right)^{\sigma}$$
$$= EP^{\sigma-1}\left(\rho\frac{\varphi}{c_T}\right)^{\sigma} + nEP^{\sigma-1}\left(\rho\frac{\varphi}{c_T}\right)^{\sigma}\left(\frac{\tau}{(1+\beta_i)}\right)^{-\sigma} = EP^{\sigma-1}\left(\rho\frac{\varphi}{c_T}\right)^{\sigma}\left[1+n\left(\frac{\tau}{(1+\beta_i)}\right)^{-\sigma}\right] = \left[1+n\left(\frac{\tau}{(1+\beta_i)}\right)^{-\sigma}\right]q_d^T(\varphi).$$

[36] The logic of this reasoning is not altered by the introduction of technology choice. Here again, if such cost is modeled as sunk, then only new exporters will pay it and all at once (new Low-Commitment Exporters will pay f_{elcx} , and new High-Commitment Exporters will pay f_{ehcx}). If instead it is modeled as a per period fixed cost, then all exporting firms will spend resources to cover the smaller amortized

Also, because the variable profit from domestic sales $\frac{1}{\sigma}r_d^T(\varphi)$ is always positive, and the fixed production cost f_T is paid on entering production –before choosing export status-, then no firm will ever export and not also produce for its domestic market, which allows separation of total profits according to thir source –domestic or export markets-:

$$\begin{cases} \pi_d^T(\varphi) = \frac{1}{\sigma}r_d^T(\varphi) - f_T \\ \pi_{xi}^T(\varphi) = \frac{1}{\sigma}r_{xi}^T(\varphi) - f_{xi}^T \end{cases} \tag{49}$$

Consequently, total profits for a firm using technology T are given by:

$$\pi^T(\varphi) = \pi_d^T(\varphi) + max\{0, n\pi_{lcx}^T(\varphi), n\pi_{hcx}^T(\varphi)\}$$

Firm value is once again given by $v^T(\varphi) = max\left\{0, \frac{1}{\delta_T}\pi^T(\varphi)\right\}$ and $\varphi^{T*} = inf\{\varphi: v^T(\varphi) > v^{T-1}(\varphi)\}$[37] identifies the cutoff productivity level for profitable entry to production with technology T in the open economy setting. Exporting productivity thresholds are determined similarly: $\varphi_{lcx}^* = inf\{\varphi: \varphi \geq \varphi^{T*} and\ \pi_{lcx}^T(\varphi) > 0\ for\ some\ technology\ T\}$ is the cutoff productivity level for firms to find it profitable to enter the export market as "Low-Commitment Exporters", while $\varphi_{hcx}^* = inf\{\varphi: \varphi \geq \varphi^{T*} and\ \pi_{hcx}^T(\varphi) > \pi_{lcx}^T(\varphi) for\ some\ technology\ T\}$ is the cutoff productivity level for firms to find it profitable to enter the export market as "High-Commitment Exporters".

Productivity Threshold to become a "Low-Commitment Exporter" (φ_{lcx}^*):

If $\varphi_{lcx}^* = \varphi^{T*}$ then all firms using technology T or superior export (either as "Low-Commitment Exporters" or as "High-Commitment Exporters") while no firm using technology T-1 or inferior exports at all. In this case, the effective cutoff exporting firm (with productivity level $\varphi^{T*} = \varphi_{lcx}^*$) earns nonnegative total profit ($\pi^T(\varphi^{T*}) = \pi_d^T(\varphi^{T*}) + \pi_{lcx}^T(\varphi^{T*}) \geq 0$) and nonnegative export profit ($\pi_{lcx}^T(\varphi^{T*}) \geq 0$). If $\varphi_{lcx}^* > \varphi^{T*}$ then some firms using technology T (with productivity levels between φ^{T*} and φ_{lcx}^*) do not export, as well as all firms using technology T-1 or inferior. Meanwhile, some firms using technology T (those with productivity levels equal to or above φ_{lcx}^*) do export, either as "Low-Commitment" or as "High-Commitment"exporters, as well as all firms using technology T+1 or superior[38].

Productivity Threshold to become a "High-Commitment Exporter" (φ_{hcx}^*):

If $\varphi_{hcx}^* = \varphi^{T*}$ then all firms using technology T or superior are "High-Commitment Exporters", while no firm using technology T-1 or inferior is so (firms using technology T-1 or inferior may be exporters, but only of the "Low-Commitment" type). In this case, the effective cutoff "High-Commitment" exporting firm (with idiosyncratic productivity $\varphi^{T*} = \varphi_{hcx}^*$) earns nonnegative total profit ($\pi^T(\varphi^{T*}) = \pi_d^T(\varphi^{T*}) + \pi_{hcx}^T(\varphi^{T*}) \geq 0$) and export profits equal to or greater than those it would earn as a "Low-Commitment Exporter" ($\pi_{hcx}^T(\varphi^{T*}) \geq \pi_{lcx}^T(\varphi^{T*})$). If $\varphi_{hcx}^* > \varphi^{T*}$ then some firms using technology T (with productivity levels between $\varphi^{T*}$and φ_{hcx}^*) are not "High-Commitment Exporters", as well as all firms using technology T-1 or inferior[39]. Meanwhile, some firms using technology T (those with productivity levels equal to or above φ_{hcx}^*) are "High-Commitment Exporters", as well as all firms using technology T+1 or superior.

portion of the corresponding cost $f_{ix}^T = \delta_T f_{eix}$. Because in equilibrium the ratio of new type *i* exporters to all type *i* exporters (*i* = Low-Commitment, High-Commitment) in each technology T is δ_T (see Appendix C), it follows that the same aggregate labor resources are spent in either case.

[37] For T=L there is no T-1 technology, and thus the condition reduces to $\varphi^{L*} = \varphi^{L**} = inf\{\varphi: v^L(\varphi) > 0\}$ –analogously to what happened in the closed economy case-.

[38] Their being "Low-Commitment" or "High-Commitment" exporters depends on whether their intrinsic productivity parameter falls between the thresholds corresponding to each exporting category (in which case the firm is a "Low-Commitment Exporter") or surpasses both (in which case the firm is a "High-Commitment Exporter").

[39] These firms are not "High-Commitment Exporters" because they can have higher profits by being "Low-Commitment Exporters" or "Non-Exporters".

In general:

- $\pi_d^T(\varphi^{T**}) = 0$ and $\pi_d^T(\varphi^{T*}) \geq 0$ for all T (analogously as in the closed economy case)
- $\pi_{lcx}^T(\varphi_{lcx}^*) = 0$ for some T satisfying $\varphi^{T*} \leq \varphi_{lcx}^*$
- $\pi_{hcx}^T(\varphi_{hcx}^*) = \pi_{lcx}^T(\varphi_{hcx}^*)$ for some T satisfying $\varphi^{T*} \leq \varphi_{hcx}^*$

φ_{lcx}^* could be (alternatively) one (and one only) of the following: φ_{lcx}^{L*}, φ_{lcx}^{M*} or φ_{lcx}^{H*}. Which of the technology-specific thresholds is the relevant one is an empirical matter[40]. The same is true for φ_{hcx}^* which can be (alternatively) one (and one only) of the following: φ_{hcx}^{L*}, φ_{hcx}^{M*} or φ_{hcx}^{H*}[41]. For now the following "plausible" situation will be assumed: that in the industry there are both exporters and nonexporters, and that users of all three production technologies are represented among the former. However, "High-Commitment Exporters" can be found only among users of technologies M and H, meaning that any firm using technology L who is an exporter, is necessarily a "Low-Commitment Exporter". If a firm with a certain productivity level finds it profitable to assume a certain export status (eg: "High-Commitment Exporter"), then all firms whose idiosyncratic productivity is above that level will too. Therefore, because there are some "High-Commitment Exporters" who use technology M and the threshold for adopting technology H is above that for adopting technology M, then all users of technology H must be "High-Commitment Exporters" as well. Finally, because there are users of technology L who are exporters, then all users of technology M are so too. We have also said that no firm using technology L is a "High-Commitment Exporters" and that at least some the firms using technology M and all of the firms using technology H are so, thus the threshold for assuming this export status must lie somewhere between the productivity thresholds for adopting technologies M and H (the lowest it could lie is coinciding with the threshold for the the adoption of technology M). Figure 2 captures the ordering of productivity thresholds resulting from these assumptions:

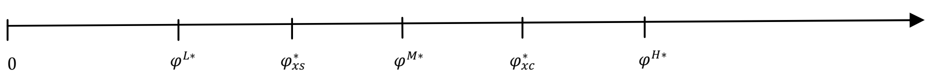


Figure 2

As it was the case in the closed economy, for the assumed order of the five productivity thresholds ($\varphi^{L*} < \varphi_{xs}^* < \varphi^{M*} < \varphi_{xc}^* < \varphi^{H*}$) to hold, it is required that, roughly speaking, the gain obtained by a firm when switching from each category to the immediate superior category (ej: from Non-Exporter who uses technology L to Low-Commitment Exporter who uses technology L) must be smaller "in proportion" to the increase in the fixed cost it simultaneously faces for a given productivity level, so that an increase in φ is needed to make such upgrading profitable.

Because the entry and exit dynamics are unchanged by trade, the equilibrium distribution of productivity levels for incumbent firms continues to be $\mu(\varphi) = \frac{g(\varphi)}{[1-G(\varphi^{L*})]}$ $\forall \varphi \geq \varphi^{L*}$. The ex ante probability that a successful entrant to the industry will become a "Low-Commitment Exporter" is $p_{inlcx}^{L+M+H} = \frac{G(\varphi_{hcx}^*) - G(\varphi_{lcx}^*)}{1-G(\varphi^{L*})}$, while $p_{inhcc}^{L+M+H} = \frac{1-G(\varphi_{hcx}^*)}{1-G(\varphi^{L*})}$ now represents the ex-ante probability that one of these successful entrants will become a "High-Commitment Exporter". These coincide with the ex

[40] For example, if we look at the data and see that some firms that produce with technology L are exporting, then the relevant threshold to become at least a "Low-Commitment Exporter" will be φ_{lcx}^{L*}. On the contrary, if we do not see any firms using technology L and exporting, but some firms using technology M are actually exporting, then we know that such threshold must be located after the threshold for dropping technology L and upgrading to M. In such case, the relevant threshold would be φ_{lcx}^{M*}. And if data show that only firms using technology H export, then the relevant threshold would be φ_{lcx}^{H*}.
[41] The reasoning is in all senses analogous to that explained in the previous footnote.

post fractions of "Low-Commitment" and "High-Commitment" exporters, respectively[42]. We can further define[43]:

- $p_{inlcx}^{L} = \frac{G(\varphi^{M*})-G(\varphi_{lcx}^{*})}{G(\varphi^{M*})-G(\varphi^{L*})}$ represents both the ex-ante probability that one of the successful entrants into technology L will be a "Low-Commitment Exporter" and the ex-post fraction of firms that use technology L and are "Low-Commitment Exporters".

- $p_{inlcx}^{M} = \frac{G(\varphi_{hcx}^{*})-G(\varphi^{M*})}{G(\varphi^{H*})-G(\varphi^{M*})}$ represents both the ex-ante probability that one of the successful entrants into technology M will be a "Low-Commitment Exporter" and the ex-post fraction of firms that use technology M and are "Low-Commitment Exporters".

- $p_{inhcx}^{M} = \frac{G(\varphi^{H*})-G(\varphi_{hcx}^{*})}{G(\varphi^{H*})-G(\varphi^{M*})}$ represents both the ex-ante probability that one of the successful entrants into technology M will be a "High-Commitment Exporter" and the ex-post fraction of firms that use technology M and are "High-Commitment Exporters".

- $p_{inhcx}^{H} = \frac{1-G(\varphi^{H*})}{1-G(\varphi^{H*})}$ represents both the ex-ante probability that one of the successful entrants into technology H will be a "High-Commitment Exporter" and the ex-post fraction of firms that use technology H and are "High-Commitment Exporters".

Denoting the number of incumbent firms in any country by Z_{open}, it is possible to calculate the number of firms belonging to each export satatus: "Low-Commitment Exporters" are $Z_{lcx} = p_{inlcx}^{L+M+H} Z_{open}$, "High-Commitment Exporters" are $Z_{hcx} = p_{inhcx}^{L+M+H} Z_{open}$ and "Non Exporters" are $Z_{nx} = Z_{open} - Z_{lcx} - Z_{hcx}$. To be more specific, $p_{inlcx}^{L} L = \gamma p_{inlcx}^{L+M+H} Z_{open}$ is the mass of firms that use technology L and are "Low-Commitment Exporters", $p_{inlcx}^{M} M = (1-\gamma) p_{inlcx}^{L+M+H} Z_{open}$ is the mass of firms that use technology M and are "Low-Commitment Exporters", $p_{inhcx}^{M} M = \delta p_{inhcx}^{L+M+H} Z_{open}$ is the mass of incumbent firms that use technology M and are "High-Commitment Exporters" and $p_{inhcx}^{H} H = (1-\delta) p_{inhcx}^{L+M+H} Z_{open}$ is the mass of incumbent firms that use technology H and are "High-Commitment Exporters".[44]

Using these definitions it is possible to calculate the total mass of varieties available to consumers in any country –or alternatively, the total mass of firms competing in any country-:

$$\boldsymbol{Z_t} = Z_{open} + n p_{inlcx}^{L+M+H} Z_{open} + n p_{inhcx}^{L+M+H} Z_{open} = Z_{open}\left(1 + n p_{inlcx}^{L+M+H} + n p_{inhcx}^{L+M+H}\right) =$$

---

[42] Note that, unlike the procedure for the calculation of the ex-ante probabilities of successful entry into each production technology ($p_{in}^{T}, T = L, M, H$), here for the calculation of the ex-ante probabilities of entry into each of the exporting categories, the distribution we use is $\mu(\varphi)$, not $g(\varphi)$. This is because the choice of export status occurs after the firm draws its productivity parameter φ, which means only successful entrants must be taken into account.

[43] Continuing with the reasoning in the previous footnote, we know that firms choose their export status after they gain knowledge on their productivity parameter. Thus, only successful entrants to the industry decide whether to become "High-Commitment" or "Low-Commitment" exporters or neither. But firms who face such decision not only already know that they are successful entrants to the industry, but also they know precisely with which production technology: L, M or H. Therefore, the rational thing to do when calculating the probabilities of adopting each exporting profile ("Low-Commitment Exporter", "High-Commitment Exporter") is to take into account all the available information. Because of this, the ex ante probabilities of each firm of becoming each type of exporter are calculated conditional on the production technology they are using.

[44] $\gamma = \frac{G(\varphi^{M*})-G(\varphi_{lcx}^{*})}{G(\varphi_{hcx}^{*})-G(\varphi_{lcx}^{*})}$ is the proportion of "Low-Commitment Exporters" who produce using technology L, $(1-\gamma) = \frac{G(\varphi_{hcx}^{*})-G(\varphi^{M*})}{G(\varphi_{hcx}^{*})-G(\varphi_{lcx}^{*})}$ is the proportion of "Low-Commitment Exporters" who produce using technology M, $\delta = \frac{G(\varphi^{H*})-G(\varphi_{hcx}^{*})}{1-G(\varphi_{hcx}^{*})}$ is the proportion of "High-Commitment Exporters" who produce using technology M and finally $(1-\delta) = \frac{1-G(\varphi^{H*})}{1-G(\varphi_{hcx}^{*})}$ is the proportion of "High-Commitment Exporters" who produce using technology H. We also know $p_{in}^{L+M+H} Z_e = Z$. Using this information together with the definition of p_{inix}^{L+M+H} and p_{inix}^{T} the equivalences stated above can be easily derived.

$$= L_{open} + M_{open} + H_{open} + np_{inlcx}^{L} L_{open} + np_{inlcx}^{M} M_{open} + np_{inhcx}^{M} M_{open} + np_{inhcx}^{H} H_{open} =$$
$$= \boldsymbol{L_{open}(1 + np_{inlcx}^{L}) + M_{open}(1 + np_{inlcx}^{M} + np_{inhcx}^{M}) + H_{open}(1 + np_{inhcx}^{H})} \quad (50)$$

Unless the contrary is explicitly stated, from now on we will refer to Z_{open} simply as Z, L_{open} as L, M_{open} as M and H_{open} as H.

4.2 Aggregation Conditions in the Open Economy

As in autarky, it is possible to calculate the average productivity level across all incumbent firms as a function of the new threshold for entering the industry:

$$\tilde{\varphi} = \tilde{\varphi}^{L}(\varphi^{L*}) = \left[\frac{1}{1-G(\varphi^{L*})}\int_{\varphi^{L*}}^{\infty} \varphi^{\sigma-1} g(\varphi) d\varphi\right]^{\frac{1}{\sigma-1}} \quad (51)$$

The average productivity levels corresponding to each Market Strategy (“Non-Exporter”, “Low-Commitment Exporter”, “High-Commitment Exporter”) are:

$$\tilde{\varphi}_{nx}(\varphi_{L}^{*}, \varphi_{lcx}^{*}) = \left[\frac{1}{1-G(\varphi^{L*})}\int_{\varphi_{L}^{*}}^{\varphi_{lcx}^{*}} \varphi^{\sigma-1} g(\varphi) d\varphi\right]^{\frac{1}{\sigma-1}} \quad (52)$$

$$\tilde{\varphi}_{lcx}(\varphi_{lcx}^{*}, \varphi_{hcx}^{*}) = \left[\frac{1}{1-G(\varphi^{L*})}\int_{\varphi_{lcx}^{*}}^{\varphi_{hcx}^{*}} \varphi^{\sigma-1} g(\varphi) d\varphi\right]^{\frac{1}{\sigma-1}} \quad (53)$$

$$\tilde{\varphi}_{hcx}(\varphi_{hcx}^{*}) = \left[\frac{1}{1-G(\varphi^{L*})}\int_{\varphi_{hcx}^{*}}^{\infty} \varphi^{\sigma-1} g(\varphi) d\varphi\right]^{\frac{1}{\sigma-1}} \quad (54)$$

We can further calculate the productivity average corresponding to each Market Strategy and production technology:

$$\tilde{\varphi}_{Lnx}(\varphi_{L}^{*}, \varphi_{lcx}^{*}) = \left[\frac{1}{1-G(\varphi^{L*})}\int_{\varphi_{L}^{*}}^{\varphi_{lcx}^{*}} \varphi^{\sigma-1} g(\varphi) d\varphi\right]^{\frac{1}{\sigma-1}} \quad (55)$$

$$\tilde{\varphi}_{Llcx}(\varphi_{lcx}^{*}, \varphi^{M*}) = \left[\frac{1}{1-G(\varphi^{L*})}\int_{\varphi_{lcx}^{*}}^{\varphi^{M*}} \varphi^{\sigma-1} g(\varphi) d\varphi\right]^{\frac{1}{\sigma-1}} \quad (56)$$

$$\tilde{\varphi}_{Mlcx}(\varphi^{M*}, \varphi_{hcx}^{*}) = \left[\frac{1}{1-G(\varphi^{L*})}\int_{\varphi^{M*}}^{\varphi_{hcx}^{*}} \varphi^{\sigma-1} g(\varphi) d\varphi\right]^{\frac{1}{\sigma-1}} \quad (57)$$

$$\tilde{\varphi}_{Mhcx}(\varphi_{hcx}^{*}, \varphi^{H*}) = \left[\frac{1}{1-G(\varphi^{L*})}\int_{\varphi_{hcx}^{*}}^{\varphi^{H*}} \varphi^{\sigma-1} g(\varphi) d\varphi\right]^{\frac{1}{\sigma-1}} \quad (58)$$

$$\tilde{\varphi}_{Hhcx}(\varphi^{H*}, \infty) = \left[\frac{1}{1-G(\varphi^{L*})}\int_{\varphi^{H*}}^{\infty} \varphi^{\sigma-1} g(\varphi) d\varphi\right]^{\frac{1}{\sigma-1}} \quad (59)$$

Because all these averages are constructed the in the same way as in the autarky setting, they only take into account domestic market share differences between firms, and ingore the additional sales more productive firms are now gaining in the export markets, as well as the fraction of resources consumed by transportation when selling abroad (and thus no longer available for consumption). In order to provide a measure of average productivity more adequate for the open economy setting, these factors must be incorporated[45]. The comprehensive average productivity measure $\tilde{\varphi}_{t}$ is constructed on the

[45] Because neither the introdutcion of technology choice nor the diversification of market strategies affect this aspect of the original Melitz (2003) model, we stick to its approach for doing so, making only minor amendments when necessary.

basis of the combined market share of all firms, taking into account the transport costs faced by both types of exporters and the export-sales-boosting effect of the additional fixed investments undertaken by High-Commitment Exporters:

$$\tilde{\varphi}_t = \left\{\frac{1}{Z_t}\left[Z\tilde{\varphi}^{\sigma-1} + np_{inlcx}^{L+M+H} Z\left(\frac{\tilde{\varphi}_{lcx}}{\tau}\right)^{\sigma-1} + np_{inhcx}^{L+M+H} Z\left(\frac{\tilde{\varphi}_{hcx}(1+\beta_{hc})}{\tau}\right)^{\sigma-1}\right]\right\}^{\frac{1}{\sigma-1}} \quad (60)$$

Expression (61) is equivalent to:

$$\tilde{\varphi}_t^{\sigma-1} = \frac{1}{Z_t}\left[Z\int_0^\infty \varphi^{\sigma-1}\mu(\varphi)d\varphi + np_{inlcx}^{L+M+H} Z\int_{\varphi_{lcx}^*}^{\varphi_{xc}^*}\left(\frac{\varphi}{\tau}\right)^{\sigma-1}\mu(\varphi)d\varphi + np_{inhcx}^{L+M+H} Z\int_{\varphi_{hcx}^*}^{\infty}\left(\frac{\varphi(1+\beta_{hc})}{\tau}\right)^{\sigma-1}\mu(\varphi)d\varphi\right] \quad (61)$$

Taking explicitly into account the production technology used by every firm (domestic and foreign), comprehensive aggregate productivity $\tilde{\varphi}_t$ can be rewritten as the following (derivation in Appendix D):

$\tilde{\varphi}_t =$
$\left\{\frac{1}{Z_t}\left[L[\tilde{\varphi}_L{}^{\sigma-1} + np_{inlcx}^{L}\frac{1}{\tau^{\sigma-1}}\tilde{\varphi}_{Llcx}{}^{\sigma-1}] + M[\tilde{\varphi}_M{}^{\sigma-1} + np_{inlcx}^{M}\frac{1}{\tau^{\sigma-1}}\tilde{\varphi}_{Mlcx}{}^{\sigma-1} +\right.\right.$
npinhcxM1+βhcτσ−1φMhcxσ−1]+H[φHσ−1+npinhcxH1+βhcτσ−1φHhcxσ−1]1σ−1
(62)

Because of the symmetry assumption, $\tilde{\varphi}_t$ is also the weighted average adjusted productivity of all firms –domestic and foreign- competing in each country.

The aggregate price index P_t, quantity Q_t, expenditure level R_t and profits Π_t in the open economy setting are given by:

$P_t = [Lp_d^L(\tilde{\varphi}_L)^{1-\sigma} + Mp_d^M(\tilde{\varphi}_M)^{1-\sigma} + Hp_d^H(\tilde{\varphi}_H)^{1-\sigma} + np_{inlcx}^L Lp_{lcx}^L(\tilde{\varphi}_{Llcx})^{1-\sigma} + np_{inlcx}^M Mp_{lcx}^M(\tilde{\varphi}_{Mlcx})^{1-\sigma} + np_{inhcx}^M Lp_{hcx}^M(\tilde{\varphi}_{Mhcx})^{1-\sigma} +$
$np_{inhcx}^H Hp_{hcx}^H(\tilde{\varphi}_{Hhcx})^{1-\sigma}]^{\frac{1}{1-\sigma}} =$
$[Lp_d^L(\tilde{\varphi}_L)^{1-\sigma} + Mp_d^M(\tilde{\varphi}_M)^{1-\sigma} + Hp_d^H(\tilde{\varphi}_H)^{1-\sigma} + np_{inlcx}^L Lp_d^L(\tilde{\varphi}_{lcxL})^{1-\sigma} + np_{inlcx}^M Mp_d^M(\tilde{\varphi}_{lcxM})^{1-\sigma} + np_{inhcx}^M p_d^M(\tilde{\varphi}_{hcxM})^{1-\sigma} + np_{inhcx}^H Hp_d^H(\tilde{\varphi}_{hcxH})^{1-\sigma}]^{\frac{1}{1-\sigma}}$
(63)[46]

$Q_t =$
$[Lq_d^L(\tilde{\varphi}_L)^{\rho} + Mq_d^M(\tilde{\varphi}_M)^{\rho} + Hq_d^H(\tilde{\varphi}_H)^{\rho} + np_{inlcx}^L Lq_{lcx}^L(\tilde{\varphi}_{Llcx})^{\rho} + np_{inlcx}^M Mq_{lcx}^M(\tilde{\varphi}_{Mlcx})^{\rho} + np_{inhcx}^M Mq_{hcx}^M(\tilde{\varphi}_{Mhcx})^{\rho} +$
npinhcxHHqhcxHφHhcxρ1ρ=

$= [Lq_d^L(\tilde{\varphi}_L)^{\rho} + Mq_d^M(\tilde{\varphi}_M)^{\rho} + Hq_d^H(\tilde{\varphi}_H)^{\rho} + np_{inlcx}^L Lq_d^L(\tilde{\varphi}_{lcxL})^{\rho} + np_{inlcx}^M Mq_d^M(\tilde{\varphi}_{lcxM})^{\rho} + np_{inhcx}^M Lq_d^M(\tilde{\varphi}_{hcxM})^{\rho} + np_{inhcx}^H Hq_d^H(\tilde{\varphi}_{hcxH})^{\rho}]^{\frac{1}{\rho}}$
(64)[47]

$R_t = Lr_d^L(\tilde{\varphi}_L) + Mr_d^M(\tilde{\varphi}_M) + Hr_d^H(\tilde{\varphi}_H) + np_{inlcx}^L Lr_{lcx}^L(\tilde{\varphi}_{Llcx}) + np_{inlcx}^M Mr_{lcx}^M(\tilde{\varphi}_{Mlcx}) + np_{inhcx}^M Mr_{hcx}^M(\tilde{\varphi}_{Mhcx}) + np_{inhcx}^H Hr_{hcx}^H(\tilde{\varphi}_{Hhcx}) =$
$= R_{Ld} + R_{Md} + R_{Hd} + R_{Llcx} + R_{Mlcx} + R_{Mhcx} + R_{Hhcx} =$
$= Lr_d^L(\tilde{\varphi}_L) + Mr_d^M(\tilde{\varphi}_M) + Hr_d^H(\tilde{\varphi}_H) + np_{inlcx}^L Lr_d^L(\tilde{\varphi}_{lcxL}) + np_{inlcx}^M Mr_d^M(\tilde{\varphi}_{lcxM}) + np_{inhcx}^M Mr_d^M(\tilde{\varphi}_{hcxM}) + np_{inhcx}^H Hr_d^H(\tilde{\varphi}_{hcxH})$ (65)[48]

$\Pi_t =$
$L\pi_d^L(\tilde{\varphi}_L) + M\pi_d^M(\tilde{\varphi}_M) + H\pi_d^H(\tilde{\varphi}_H) + np_{inlcx}^L L\pi_{lcx}^L(\tilde{\varphi}_{Llcx}) + np_{inlcx}^M M\pi_{lcx}^M(\tilde{\varphi}_{Mlcx}) + np_{inhcx}^M M\pi_{hcx}^M(\tilde{\varphi}_{Mhcx}) + np_{inhcx}^H H\pi_{hcx}^H(\tilde{\varphi}_{Hhcx}) =$
$= L\left[\frac{1}{\sigma}r_d^L(\tilde{\varphi}_L) - f_L\right] + M\left[\frac{1}{\sigma}r_d^M(\tilde{\varphi}_M) - f_M\right] + H\left[\frac{1}{\sigma}r_d^H(\tilde{\varphi}_H) - f_H\right] + np_{inlcx}^L L\left[\frac{1}{\sigma}r_{lcx}^L(\tilde{\varphi}_{Llcx}) - f_{lcx}^L\right] + np_{inlcx}^M M\left[\frac{1}{\sigma}r_{lcx}^M(\tilde{\varphi}_{Mlcx}) - f_{lcx}^M\right] +$
$np_{inhcx}^M M\left[\frac{1}{\sigma}r_{hcx}^M(\tilde{\varphi}_{Mhcx}) - f_{hcx}^M\right] + np_{inhcx}^H H\left[\frac{1}{\sigma}r_{hcx}^H(\tilde{\varphi}_{Hhcx}) - f_{hcx}^H\right] =$
$= \Pi_{Ld} + \Pi_{Md} + \Pi_{Hd} + \Pi_{Llcx} + \Pi_{Mlcx} + \Pi_{Mhcx} + \Pi_{Hhcx} =$

---

[46] Recall from expression (47) that $p_{ix}^T(\varphi) = \frac{\tau}{\rho}\frac{c_T}{\varphi(1+\beta_i)} = \frac{\tau}{(1+\beta_i)}p_d^T(\varphi),\ i = lc, hc.$

[47] Recall from expression (48) that $q_{ix}^T(\varphi) = \left(\frac{(1+\beta_i)}{\tau}\right)^{\sigma} q_d^T(\varphi)$. Therefore, $q_{ix}^T(\varphi) = EP^{\sigma-1}\left(\frac{1}{p_{ix}^T(\varphi)}\right)^{\sigma} = EP^{\sigma-1}\left(\frac{(1+\beta_i)}{\tau p_d^T(\varphi)}\right)^{\sigma}$, just as $q_d^T(\varphi) = EP^{\sigma-1}\left(\frac{1}{p_d^T(\varphi)}\right)^{\sigma}$. Also note that $q_{ix}^T(\tilde{\varphi}_{Tix}) = EP^{\sigma-1}\left(\frac{\rho\tilde{\varphi}_{Tix}(1+\beta_i)}{c_T\tau}\right)^{\sigma-1} = EP^{\sigma-1}\left(\frac{\rho\tilde{\varphi}_{ixT}}{c_T}\right)^{\sigma} = q_d^T(\tilde{\varphi}_{ixT})$.

[48] Recall from expression (49) that $r_{xi}^T(\varphi) = E\left(\frac{P\rho\varphi(1+\beta_i)}{c_T\tau}\right)^{\sigma-1} = \left(\frac{(1+\beta_i)}{\tau}\right)^{\sigma-1} r_d^T(\varphi)$. Note that $r_{ix}^T(\tilde{\varphi}_{Tix}) = E\left(\frac{P\rho\tilde{\varphi}_{Tix}(1+\beta_i)}{c_T\tau}\right)^{\sigma-1} = E\left(\frac{P\rho\tilde{\varphi}_{ixT}}{c_T}\right)^{\sigma-1} = r_d^T(\tilde{\varphi}_{ixT})$.

$$= L\left[\frac{1}{\sigma}r_d^L(\tilde{\varphi}_L) - f_L\right] + M\left[\frac{1}{\sigma}r_d^M(\tilde{\varphi}_M) - f_M\right] + H\left[\frac{1}{\sigma}r_d^H(\tilde{\varphi}_H) - f_H\right] + np_{inlcx}^L L\left[\frac{1}{\sigma}r_d^L(\tilde{\varphi}_{lcxL}) - f_{lcx}^L\right] + np_{inlcx}^M M\left[\frac{1}{\sigma}r_d^M(\tilde{\varphi}_{lcxM}) - f_{lcx}^M\right] + np_{inhcx}^M M\left[\frac{1}{\sigma}r_d^M(\tilde{\varphi}_{hcxM}) - f_{hcx}^M\right] + np_{inhcx}^H H\left[\frac{1}{\sigma}r_d^H(\tilde{\varphi}_{hcxH}) - f_{hcx}^H\right] \quad (66)^{49}$$

The average price, quantity, revenue and profits in the industry in the open economy setting are obtained as a weighted average of the price, quantity, revenue and profits of each group of firms, where the weights are the given by the proportion of firms of each group in the total number of firms competing in the country, Z_t[50]:

$$\bar{p}_t = \frac{P_t}{Z_t^{\frac{1}{1-\sigma}}} = \left[\frac{L}{Z_t}p_d^L(\tilde{\varphi}_L)^{1-\sigma} + \frac{M}{Z_t}p_d^M(\tilde{\varphi}_M)^{1-\sigma} + \frac{H}{Z_t}p_d^H(\tilde{\varphi}_H)^{1-\sigma} + \frac{np_{inlcx}^L L}{Z_t}p_d^L(\tilde{\varphi}_{lcxL})^{1-\sigma} + \frac{np_{inlcx}^M M}{Z_t}p_d^M(\tilde{\varphi}_{lcxM})^{1-\sigma} + \frac{np_{inhcx}^M M}{Z_t}p_d^M(\tilde{\varphi}_{hcxM})^{1-\sigma} + \right.$$
npinhcxHHZtpdHφhcxH1−σ=

$$= \left[\frac{L}{Z_t}p_d^L(\tilde{\varphi}_L)^{1-\sigma} + \frac{M}{Z_t}p_d^M(\tilde{\varphi}_M)^{1-\sigma} + \frac{H}{Z_t}p_d^H(\tilde{\varphi}_H)^{1-\sigma} + \frac{np_{inlcx}^L L}{Z_t}p_{lcx}^L(\tilde{\varphi}_{Llcx})^{1-\sigma} + \frac{np_{inlcx}^M M}{Z_t}p_{lcx}^M(\tilde{\varphi}_{Mlcx})^{1-\sigma} + \frac{np_{inhcx}^M M}{Z_t}p_{hcx}^M(\tilde{\varphi}_{Mhcx})^{1-\sigma} + \right.$$
npinhcxHHZtphcxHφHhcx1−σ11−σ
(67)

$$\bar{q}_t = \frac{Q_t}{Z_t^{\rho}} =$$
$$\left[\frac{L}{Z_t}q_d^L(\tilde{\varphi}_L)^{\rho} + \frac{M}{Z_t}q_d^M(\tilde{\varphi}_M)^{\rho} + \frac{H}{Z_t}q_d^H(\tilde{\varphi}_H)^{\rho} + \frac{np_{inlcx}^L L}{Z_t}q_d^L(\tilde{\varphi}_{lcxL})^{\rho} + \frac{np_{inlcx}^M M}{Z_t}q_d^M(\tilde{\varphi}_{lcxM})^{\rho} + \frac{np_{inhcx}^M M}{Z_t}q_d^M(\tilde{\varphi}_{hcxM})^{\rho} + \frac{np_{inhhcx}^H H}{Z_t}q_d^H(\tilde{\varphi}_{hcxH})^{\rho}\right]^{\frac{1}{\rho}} =$$
$$\left[\frac{L}{Z_t}q_d^L(\tilde{\varphi}_L)^{\rho} + \frac{M}{Z_t}q_d^M(\tilde{\varphi}_M)^{\rho} + \frac{H}{Z_t}q_d^H(\tilde{\varphi}_H)^{\rho} + \frac{np_{inlcx}^L L}{Z_t}q_{lcx}^L(\tilde{\varphi}_{Llcx})^{\rho} + \frac{np_{inlcx}^M M}{Z_t}q_{lcx}^M(\tilde{\varphi}_{Mlcx})^{\rho} + \frac{np_{inhcx}^M M}{Z_t}q_{hcx}^M(\tilde{\varphi}_{Mhcx})^{\rho} + \frac{np_{inhcx}^H H}{Z_t}q_{hcx}^H(\tilde{\varphi}_{Hhcx})^{\rho}\right]^{\frac{1}{\rho}} \quad (68)$$

$$\bar{r}_t = \frac{R_t}{Z_t} = \frac{L}{Z_t}r_d^L(\tilde{\varphi}_L) + \frac{M}{Z_t}r_d^M(\tilde{\varphi}_M) + \frac{H}{Z_t}r_d^H(\tilde{\varphi}_H) + \frac{np_{inxs}^L L}{Z_t}r_d^L(\tilde{\varphi}_{lcxL}) + \frac{np_{inxs}^M M}{Z_t}r_d^M(\tilde{\varphi}_{lcxM}) + \frac{np_{inxc}^M M}{Z_t}r_d^M(\tilde{\varphi}_{hcxM}) + \frac{np_{inxc}^H H}{Z_t}r_d^H(\tilde{\varphi}_{hcxH}) =$$
$$\frac{L}{Z_t}r_d^L(\tilde{\varphi}_L) + \frac{M}{Z_t}r_d^M(\tilde{\varphi}_M) + \frac{H}{Z_t}r_d^H(\tilde{\varphi}_H) + \frac{np_{inlcx}^L L}{Z_t}r_{lcx}^L(\tilde{\varphi}_{Llcx}) + \frac{np_{inlcx}^M M}{Z_t}r_{lcx}^M(\tilde{\varphi}_{Mlcx}) + \frac{np_{inhcx}^M M}{Z_t}r_{hcx}^M(\tilde{\varphi}_{Mhcx}) + \frac{np_{inhcx}^H H}{Z_t}r_{hcx}^H(\tilde{\varphi}_{Hhcx}) \quad (69)$$

$$\bar{\pi}_t = \frac{\Pi_t}{Z_t} = \frac{L}{Z_t}\pi_d^L(\tilde{\varphi}_L) + \frac{M}{Z_t}\pi_d^M(\tilde{\varphi}_M) + \frac{H}{Z_t}\pi_d^H(\tilde{\varphi}_H) + \frac{np_{inlcx}^L L}{Z_t}\pi_d^L(\tilde{\varphi}_{lcxL}) + \frac{np_{inlcx}^M M}{Z_t}\pi_d^M(\tilde{\varphi}_{lcxM}) + \frac{np_{inhcx}^M M}{Z_t}\pi_d^M(\tilde{\varphi}_{hcxM}) + \frac{np_{inhcx}^H H}{Z_t}\pi_d^H(\tilde{\varphi}_{hcxH}) =$$
$$= \frac{L}{Z_t}\pi_d^L(\tilde{\varphi}_L) + \frac{M}{Z_t}\pi_d^M(\tilde{\varphi}_M) + \frac{H}{Z_t}\pi_d^H(\tilde{\varphi}_H) + \frac{np_{inlcx}^L L}{Z_t}\pi_{lcx}^L(\tilde{\varphi}_{Llcx}) + \frac{np_{inlcx}^M M}{Z_t}\pi_{lcx}^M(\tilde{\varphi}_{Mlcx}) + \frac{np_{inhcx}^M M}{Z_t}\pi_{hcx}^M(\tilde{\varphi}_{Mhcx}) + \frac{np_{inhcx}^H H}{Z_t}\pi_{hcx}^H(\tilde{\varphi}_{Hhcx}) \quad (70)$$

In each country, firms using technology T get “in average” the following revenue and profits:

$$\bar{r}^L = r_d^L(\tilde{\varphi}_L) + np_{inlcx}^L r_{lcx}^L(\tilde{\varphi}_{Llcx}) \quad (71)$$

$$\bar{r}^M = r_d^M(\tilde{\varphi}_M) + np_{inlcx}^M r_{lcx}^M(\tilde{\varphi}_{Mlcx}) + np_{inhcx}^M r_{hcx}^M(\tilde{\varphi}_{Mhcx}) \quad (72)$$

$$\bar{r}^H = r_d^H(\tilde{\varphi}_H) + np_{inhcx}^H r_{hcx}^H(\tilde{\varphi}_{Hhcx}) \quad (73)$$

$$\bar{\pi}^L = \pi_d^L(\tilde{\varphi}_L) + np_{inlcx}^L \pi_{lcx}^L(\tilde{\varphi}_{Llcx}) \quad (74)$$

$$\bar{\pi}^M = \pi_d^M(\tilde{\varphi}_M) + np_{inlcx}^M \pi_{lcx}^M(\tilde{\varphi}_{Mlcx}) + np_{inhcx}^M \pi_{hcx}^M(\tilde{\varphi}_{Mhcx}) \quad (75)$$

$$\bar{\pi}^H = \pi_d^H(\tilde{\varphi}_H) + np_{inhcx}^H \pi_{hcx}^H(\tilde{\varphi}_{Hhcx}) \quad (76)$$

4.3 Equilibrium Conditions in the Open Economy

The equilibrium in each technology T will still be obtained, as in the closed economy setting, by the intersection of the “Effective Cutoff overall Profit condition for technology T” (ECP^T)” and the “Free Entry condition for technology T”. However, ECP^T is now different because average profit per firm

[49] Recall from expression (50) that $\pi_d^T(\varphi) = \frac{1}{\sigma}r_d^T(\varphi) - f_T$ and $\pi_{ix}^T(\varphi) = \frac{1}{\sigma}r_{ix}^T(\varphi) - f_{ix}^T$.

[50] Once again, as it was the case in the closed economy setting, these “theoretical” averages are calculated just in order to provide a rough measure of the industry’s per firm performance. They need not coincide with the price, quantity, revenue and profits of any particular firm.

using technology T in the open economy setting includes a "domestic profit component" and an "export profit component", which in turn subdivides into two categories: a "Low-Commitment export profit component" and a "High-Commitment export profit component". Thus, in order to construct the "Effective Cutoff overall Profit condition for technology T" (ECP^T) it is necessary to first relate the average profit level for each exporting category to the minimum idiosyncratic productivity level required to enter such category, with which it will be obtained the "Effective Cutoff type *i* export Profit condition for technology T" (ECP^T_{ix}), *i: lc, hc*. That is, a relation must be established between:

- $\bar{\pi}^L_{lcx} = \pi^L_{lcx}(\tilde{\varphi}_{Llcx})$ with φ^*_{lcx}
- $\bar{\pi}^M_{lcx} = \pi^M_{lcx}(\tilde{\varphi}_{Mlcx})$ with φ^{M*}
- $\bar{\pi}^M_{hcx} = \pi^M_{hcx}(\tilde{\varphi}_{Mhcx})$ with φ^*_{hcx}
- $\bar{\pi}^H_{hcx} = \pi^H_{hcx}(\tilde{\varphi}_{Hhcx})$ with φ^{H*}

The expression of the "Effective Cutoff Low-Commitment export Profit condition for technology L" (ECP^L_{lcx}) is:

$$\pi^L_{lcx}(\varphi^*_{lcx}) = 0 \quad \leftrightarrow \quad r^L_{lcx}(\varphi^*_{lcx}) = \sigma f^L_{lcx} \quad \leftrightarrow \quad \bar{\pi}^L_{lcx} = \pi^L_{lcx}(\tilde{\varphi}_{Llcx}) = f^L_{lcx} k^L_{lcx}(\varphi^*_{lcx})$$

where $k^L_{lcx}(\varphi^*_{lcx}) = \left[\frac{\tilde{\varphi}_{Llcx}(\varphi^*_{lcx},\varphi^{M*})}{\varphi^*_{lcx}}\right]^{\sigma-1} - 1$.

The expression of the "Effective Cutoff Low-Commitment export Profit condition for technology M" (ECP^M_{lcx}) is:

$$\pi^M_{lcx}(\varphi^{M*}) = A^M_{lcx} \quad \leftrightarrow \quad r^M_{lcx}(\varphi^{M*}) = \sigma\left(A^M_{lcx} + f^M_{lcx}\right) \quad \leftrightarrow \quad \bar{\pi}^M_{lcx} = \pi^M_{lcx}(\tilde{\varphi}_{Mlcx}) = A^M_{lcx} h^M_{lcx}(\varphi^{M*}) + f^M_{lcx} k^M_{lcx}(\varphi^{M*})$$

where $h^M_{lcx}(\varphi^{M*}) = \left[\frac{\tilde{\varphi}_{Mlcx}(\varphi^{M*},\varphi^*_{hcx})}{\varphi^*_{hcx}}\right]^{\sigma-1}$, $h^M_{lcx}(\varphi^{M*}) = \left[\frac{\tilde{\varphi}_{Mlcx}(\varphi^{M*},\varphi^*_{hcx})}{\varphi^*_{hcx}}\right]^{\sigma-1} - 1$ and $A^M_{lcx} > 0$ is the profit gained in each export destination by the least idiosyncratically productive firm who is a "Low-Commitment Exporter" and uses technology M (a constant).[51]

The expression of the "Effective Cutoff High-Commitment export Profit condition for technology M" (ECP^M_{xc}) is:

$$\pi^M_{hcx}(\varphi^*_{hcx}) = A^M_{hcx} \quad \leftrightarrow \quad r^M_{hcx}(\varphi^*_{hcx}) = \sigma\left(A^M_{hcx} + f^M_{hcx}\right) \quad \leftrightarrow \quad \bar{\pi}^M_{hcx} = \pi^M_{hcx}(\tilde{\varphi}_{Mhcx}) = A^M_{hcx} h^M_{hcx}(\varphi^*_{hcx}) + f^M_{hcx} k^M_{hcx}(\varphi^*_{hcx})$$

where $h^M_{hcx}(\varphi^*_{hcx}) = \left[\frac{\tilde{\varphi}_{Mhcx}(\varphi^*_{hcx},\varphi^{H*})}{\varphi^*_{hcx}}\right]^{\sigma-1}$, $h^M_{hcx}(\varphi^*_{hcx}) = \left[\frac{\tilde{\varphi}_{Mhcx}(\varphi^*_{hcx},\varphi^{H*})}{\varphi^*_{hcx}}\right]^{\sigma-1} - 1$ and $A^M_{hcx} > 0$ is the profit gained in each export destination by the least idiosyncratically productive firm who is a "High-Commitment Exporter" and uses technology M (a constant).[52]

---

[51] We already know that profits in general, and export profits in particular are increasing in φ. Besides, we know that $\pi^L_{lcx}(\varphi^*_{lcx}) = 0$ and $\varphi^{M*} > \varphi^*_{lcx}$. Thus, we know $\pi^L_{lcx}(\varphi^{M*}) > 0$. Finally, we also know that, keeping all other factors constant, using a superior production technology determines higher revenue and consequently higher profits for the firm. As a result, we know $\pi^M_{lcx}(\varphi^{M*}) > \pi^L_{lcx}(\varphi^{M*}) > 0$. We pin down this information by writing $\pi^M_{lcx}(\varphi^{M*}) = A^M_{lcx}$, where A^M_{lcx} is a positive constant. On other grounds, we already know that $\bar{\pi}^M_{lcx} = \pi^M_{lcx}(\tilde{\varphi}_{Mlcx}) = \frac{r^M_{lcx}(\tilde{\varphi}_{Mlcx})}{\sigma} - f^M_{lcx} = \left(\frac{\tilde{\varphi}_{Mlcx}(\varphi^{M*},\varphi^*_{lcx})}{\varphi^{M*}}\right)^{\sigma-1} \frac{r^M_{lcx}(\varphi^{M*})}{\sigma} - f^M_{lcx}$. Replacing $r^M_{lcx}(\varphi^{M*}) = \sigma\left(A^M_{lcx} + f^M_{lcx}\right)$ in this equation we obtain $\bar{\pi}^M_{lcx} = \pi^M_{lcx}(\tilde{\varphi}_{Mlcx}) = A^M_{lcx}\left(\frac{\tilde{\varphi}_{Mlcx}(\varphi^{M*},\varphi^*_{hcx})}{\varphi^{M*}}\right)^{\sigma-1} + f^M_{lcx}\left(\frac{\tilde{\varphi}_{Mlcx}(\varphi^{M*},\varphi^*_{hcx})}{\varphi^{M*}}\right)^{\sigma-1} - f^M_{lcx} =$
$= A^M_{lcx}\left(\frac{\tilde{\varphi}_{Mlcx}(\varphi^{M*},\varphi^*_{hcx})}{\varphi^{M*}}\right)^{\sigma-1} + f^M_{lcx}\left[\left(\frac{\tilde{\varphi}_{Mlcx}(\varphi^{M*},\varphi^*_{hcx})}{\varphi^{M*}}\right)^{\sigma-1} - 1\right] = A^M_{lcx} h^M_{lcx}(\varphi^{M*}) + f^M_{lcx} k^M_{lcx}(\varphi^{M*})$.

The expression of the “Effective Cutoff High-Commitment export Profit condition for technology H” (ECP_{hcx}^{H}) is:

$$\pi_{hcx}^{H}(\varphi^{H*}) = A_{hcx}^{H} \quad \leftrightarrow \quad r_{hcx}^{M}(\varphi^{H*}) = \sigma\left(A_{hcx}^{H} + f_{hcx}^{H}\right) \quad \leftrightarrow$$
$$\bar{\pi}_{hcx}^{H} = \pi_{hcx}^{H}(\tilde{\varphi}_{Hhcx}) = A_{hcx}^{H} h_{hcx}^{H}(\varphi^{H*}) + f_{hcx}^{H} hcx(\varphi^{H*})$$

where $h_{hcx}^{H}(\varphi^{H*}) = \left[\frac{\tilde{\varphi}_{Mhcx}(\varphi^{H*},\infty)}{\varphi^{H*}}\right]^{\sigma-1}$, $h_{hcx}^{H}(\varphi^{H*}) = \left[\frac{\tilde{\varphi}_{Mhcx}(\varphi^{H*},\infty)}{\varphi^{H*}}\right]^{\sigma-1} - 1$ and $A_{hcx}^{H} > 0$ is the profit gained in each export destination by the least idiosyncratically productive firm who is a “High-Commitment Exporter” and uses technology H (a constant).[53]

Now we can finally write down the “Effective Cutoff overall Profit condition for technology T” (ECP^{T}), which implies a relationship between the average overall profit per firm using technology T ($\bar{\pi}^{T}$) and the effective cutoff productivity level for the adoption of technology T (φ^{T*}).

The “Effective Cutoff overall Profit condition for technology L” (ECP^{L}) is:

$$\bar{\boldsymbol{\pi}}^{\boldsymbol{L}} = \pi_{d}^{L}(\tilde{\varphi}_{L}) + p_{inlcx}^{L} n \pi_{lcx}^{L}(\tilde{\varphi}_{Llcx}) = \boldsymbol{f_{L} k_{d}^{L}(\varphi^{L*}) + p_{inlcx}^{L} n f_{lcx}^{L} k_{lcx}^{L}(\varphi_{lcx}^{*})} \qquad (77)^{54}$$

The “Effective Cutoff overall Profit condition for technology M” (ECP^{M}) is:

$$\bar{\boldsymbol{\pi}}^{\boldsymbol{M}} = \pi_{d}^{M}(\tilde{\varphi}_{M}) + p_{inlcx}^{M} n \pi_{lcx}^{M}(\tilde{\varphi}_{Mlcx}) + p_{inhcx}^{M} n \pi_{hcx}^{M}(\tilde{\varphi}_{Mhcx}) =$$
$$= \boldsymbol{\left[A_{d}^{M} h_{d}^{M}(\varphi^{M*}) + f_{M} k_{d}^{M}(\varphi^{M*})\right] + p_{inlcx}^{M} n \left[A_{lcx}^{M} h_{lcx}^{M}(\varphi^{M*}) + f_{lcx}^{M} k_{lcx}^{M}(\varphi^{M*})\right] +}$$
$$\boldsymbol{p_{inhcx}^{M} n \left[A_{hcx}^{M} h_{hcx}^{M}(\varphi_{hcx}^{*}) + f_{hcx}^{M} k_{hcx}^{M}(\varphi_{hcx}^{*})\right]} \qquad (78)^{55}$$

The “Effective Cutoff overall Profit condition for technology H” (ECP^{H}) is:

$$\bar{\boldsymbol{\pi}}^{\boldsymbol{H}} = \pi_{d}^{H}(\tilde{\varphi}_{H}) + p_{inhcx}^{H} n \pi_{hcx}^{H}(\tilde{\varphi}_{Hhcx}) = \boldsymbol{\left[A_{d}^{H} h_{d}^{H}(\varphi^{H*}) + f_{H} k_{d}^{H}(\varphi^{H*})\right] + p_{inhcx}^{H} n \left[A_{hcx}^{H} h_{hcx}^{H}(\varphi^{H*}) + f_{hcx}^{H} f_{hcx}^{H}(\varphi^{H*})\right]} \qquad (79)^{56}$$

The present value of average profits flows for firms using technology T (that is, the value of such firms) remains $\bar{v}^{T} = \sum_{t=0}^{\infty}(1-\delta_{T})^{t}\bar{\pi}^{T} = \frac{\bar{\pi}^{T}}{\delta_{T}}$ and the value of entry to production with technology T continues to be $v_{e}^{T} = p_{in}^{T}[\bar{v}^{T} - (f_{e}^{T} - f_{e}^{L})] - f_{e}^{L}$. The Free Entry condition for each technology T (FE^{T}) thus remains unchanged: $v_{e}^{T} = 0$ if and only if $\bar{\pi}^{T} = \frac{\delta_{T} f_{e}^{L}}{p_{in}^{T}} + \delta_{T}(f_{e}^{T} - f_{e}^{L})$.

4.4 Determination of the Equilibrium in the Open Economy

Like in the closed economy case, the “Free Entry condition for technology T” (FE^{T}) and the new “Effective Cutoff overall Profit condition for technology T” (ECP^{T}) will identify a unique φ^{T*} and $\bar{\pi}^{T}$ if the new ECP^{T} cuts the FE^{T} only once from above. We cannot assure this will happen in the general case outlined above: there could be no intersection between both curves because in the open economy setting the ECP^{T} can be discontinuous. However, the existence (and uniqueness) of equilibrium in each production technology T can still be assured in a particular case: when all firms using the same

[52] The same reasoning as in the previous footnote applies here.

[53] The same reasoning in footnote 51 applies here.

[54] $\varphi_{lcx}^{*} = \varphi^{L*}\tau\left(\frac{f_{lcx}^{L}}{f_{L}}\right)^{\frac{1}{\sigma-1}}$ and thus equation (78) is implicitly a function of φ^{L*}.

[55] $\varphi_{hcx}^{*} = \varphi^{M*}\frac{\tau}{\beta_{hc}}\left(\frac{A_{hcx}^{M}+f_{hcx}^{M}}{A_{d}^{M}+f_{M}}\right)^{\frac{1}{\sigma-1}}$ and thus equation (79) is implicitly a function of φ^{M*}.

[56] $p_{inhcx}^{H} = \frac{1-G(\varphi_{H}^{*})}{1-G(\varphi_{H}^{*})} = 1$ is the ex ante probability that the firm will become a “High-Commitment Exporter” given that it is using production technology H.

production technology T, share as well the same export status, whichever this may be: "Non-Exporter", "Low-Commitment Exporter" or "High-Commitment Exporter"[57] (proff in Appendix E). The equilibrium thresholds for technology adoption φ^{L*}, φ^{M*} and φ^{H*} trivially determine the "Low-Commitment" export productivity cutoff, φ^{*}_{lcx}, and the "High-Commitment" export productivity cutoff, φ^{*}_{hcx}. Thus φ^{L*}, φ^{M*} and φ^{H*} also determine the productivity levels $\tilde{\varphi}$, $\tilde{\varphi}_{lcx}$, $\tilde{\varphi}_{hcx}$ and $\tilde{\varphi}_{t}$ as well as the ex-ante probability of entry to production with each available technology (p^{L}_{in}, p^{M}_{in} and p^{H}_{in}) and the ex ante probability of entry to each export status, conditional on the production technology the firm is using (p^{L}_{inlcx}, p^{M}_{inlcx}, p^{M}_{inhcx} and p^{H}_{inhcx}). Note that in the case for which the existence (and uniqueness) of equilibrium in each technology T can be guaranteed, each of the latter probabilities will be either 1 or 0.

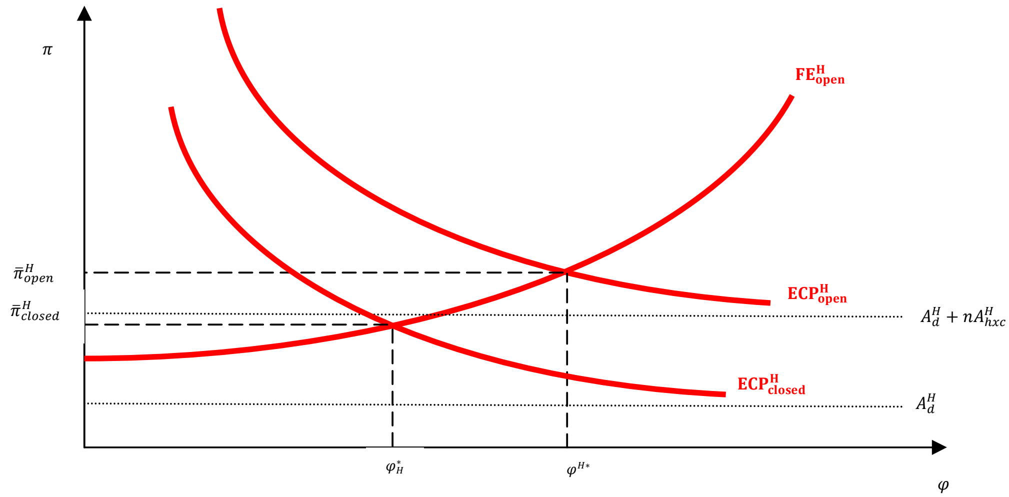
We will focus here in the equilibrium reached when $\varphi^{*}_{lcx} = \varphi^{M*}$ and $\varphi^{*}_{hcx} = \varphi^{H*}$, and consequently $p^{L}_{inlcx} = p^{M}_{inhcx} = 0$ and $p^{M}_{inlcx} = p^{H}_{inhcx} = 1$, as it can be considered a limiting case in which the "plausible" ordering of productivity thresholds referred to in previous sections ($\varphi^{L*} \leq \varphi^{*}_{lcx} \leq \varphi^{M*} \leq \varphi^{*}_{hcx} \leq \varphi^{H*}$) is maintained.

5. Evaluating the Impact of Trade

The present section compares the closed and open economy steady state equilibria, for which some ammendments in notation will be necessary. We have denoted the cutoff productivity levels for each production technology in autarky as φ^{*}_{L}, φ^{*}_{M} and φ^{*}_{H}, and the cutoff productivity levels for each production technology in the open economy setting as φ^{L*}, φ^{M*} and φ^{H*}. Let as well $\tilde{\varphi}^{closed}_{L}$, $\tilde{\varphi}^{closed}_{M}$ and $\tilde{\varphi}^{closed}_{M}$ denote the average productivity levels for each technology in autarky, and $\tilde{\varphi}^{open}_{L}$, $\tilde{\varphi}^{open}_{M}$ and $\tilde{\varphi}^{open}_{M}$ in the open economy.

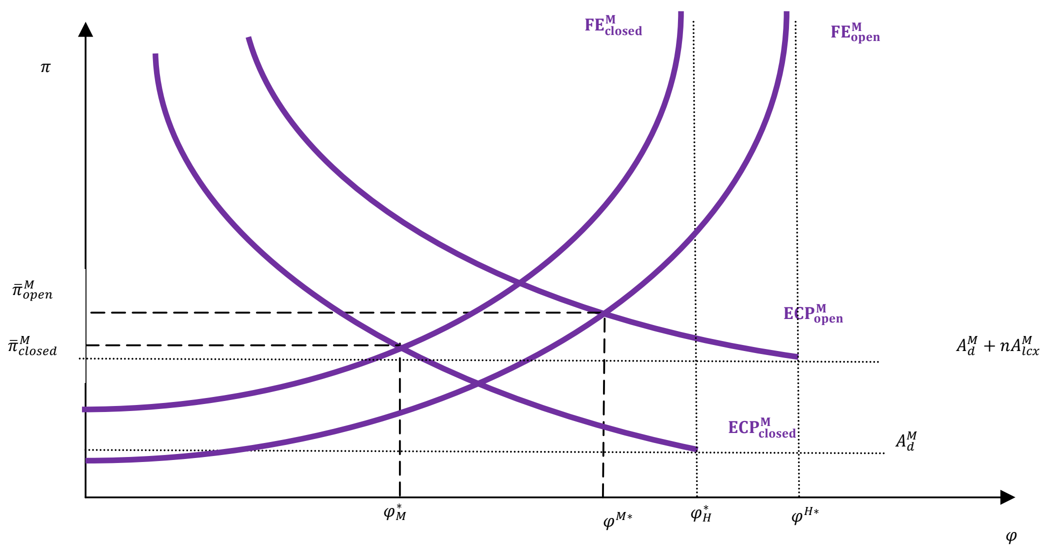
It can be readily noted that in the open economy the ECP^{L}, ECP^{M} and ECP^{H} curves shift up and to the right, relative to their closed economy counterparts. Meanwhile, the FE^{H} curve remains unchanged, but FE^{M} and FE^{H} curves shift down and also to the right. Together these shifts imply, for the three technologies, that the mean productivity increases because de effective cutoff productivity levels to entry each technology are now higher: $\varphi^{T*} > \varphi^{*}_{T}$ and consequently $\tilde{\varphi}^{open}_{T} > \tilde{\varphi}^{closed}_{T}$ for every technology T. Consequently, average profit in each technology must also increase: $\bar{\pi}^{T}_{open} > \bar{\pi}^{T}_{closed}$ for every T. In the case of technology H, the fact that the free entry curve remains unchanged makes this result visually straightforward. The increase in the average profit is not as graphically evident in the case of technologies M and L, because the FE^{M} and FE^{L} curves shift down. Nevertheless, we know for certain that the $\mathrm{FE^{M}}$ and $\mathrm{ECP^{M}}$ curves must intersect not only to the right but also higher than they did in autarky, and the same applies to the intersection of the $\mathrm{FE^{L}}$ and $\mathrm{ECP^{L}}$ curves, as shown in Figure 3. Once again, the higher the profit earned by the cutoff technology T firm, the higher the minimum value the ECP^{T} reaches, and thus the higher $\bar{\pi}^{T}_{open}$. The comparison of the equilibriums for each technology before and after the economy opens up to trade is represented in panels (a)-(c) of Figure 3:

[57] Because $\varphi^{*}_{lcx}$and φ^{*}_{hcx} are defined as functions of some φ^{T*}, the materialization of this special case requires certain parameter restrictions to hold.



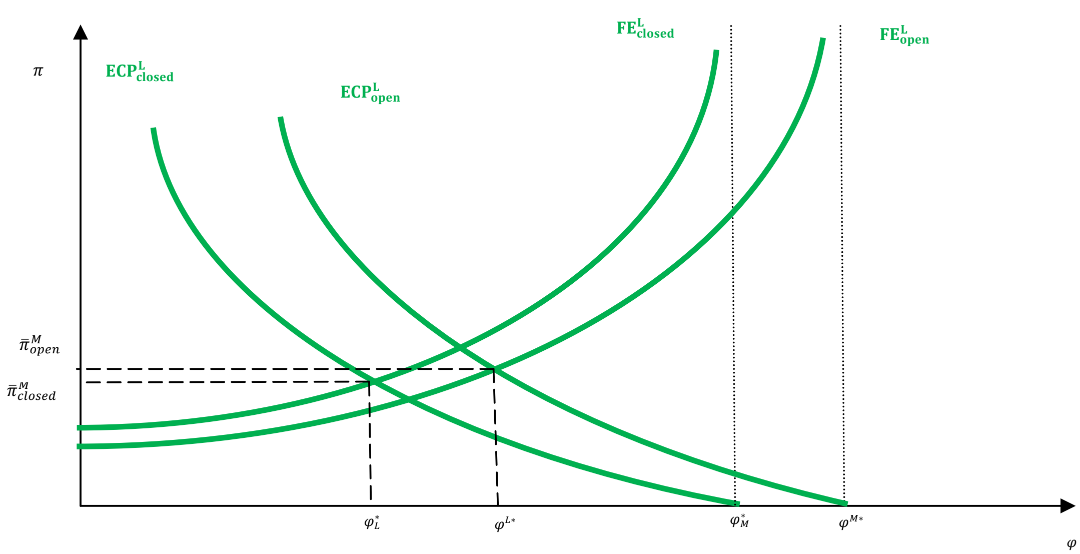
π
FE^H_open
ECP^H_open
ECP^H_closed
π̄^H_open
π̄^H_closed
A^H_d + nA^H_hxc
A^H_d
φ*_H
φ^H*
φ

(a)



π
FE^M_closed
FE^M_open
ECP^M_open
ECP^M_closed
π̄^M_open
π̄^M_closed
A^M_d + nA^M_lcx
A^M_d
φ*_M
φ^M*
φ*_H
φ^H*
φ

(b)



π
ECP^L_closed
ECP^L_open
FE^L_closed
FE^L_open
π̄^M_open
π̄^M_closed
φ*_L
φ^L*
φ*_M
φ^M*
φ

(c)

Figure 3

The logic behind these results is quite intuitive. In the open economy setting, increased competition (coming from the foreign firms who now export to the home country) reallocates market shares towards the more efficient firms, forcing the least productive ones out of the market and contributing to an aggregate productivity gain. The shrinkage of their market share forces some firms to downgrade to an inferior technology, as their sales in the open economy setting are no longer enough to amortize the fixed cost corresponding to the technology they had been using in autarky. So they sell their equipment and buy another less costly in order to continue obtaining nonnegative (and the highest possible) profits[58]. This way, some former users of technology H[59] become users of technology M when the economy opens up to trade, some former users of technology M[60] become users of technology L, and some former users of technology L[61] are forced out of the market, as they can no longer obtain nonnegative profits with any of the available production technologies. This results in an increase in each technology T average productivity, and consequently also in average profits within each production technology. Only firms with productivity levels above φ_{lcx}^{*} and φ_{hcx}^{*} enter the export markets –either as "Low-Commitment" or "High-Commitment" exporters, respectively-, which reinforces the reallocation of market shares towards more efficient firms and thus further contributes to an aggregate productivity gain.

As was the case in the closed economy equilibrium, aggregate payments to workers (employed both for "setting-up-bussiness" and for regular production, of any qualification) must add up to total revenue at the industry level. Thus, aggregate revenue remains exogenously fixed by the size of the labor force:

$$R = R_L + R_M + R_H = (U+S)_e + (U+S)_p = (U_L+S_L)_e + (U_L+S_L)_p + (U_M+S_M)_e + (U_M+S_M)_p + (U_H+S_H)_e + (U_H+S_H)_p$$

The market clearing condition for production workers continues to be that aggregate payments to them must match the difference between aggregate revenue and profit in each technology, which in aggregate terms yields:

$$(U+S)_p = R - \Pi$$

The market clearing condition for "setting-up-bussiness" workers in turn continues to be that aggregate payments to them must match the total amount paid by prospective entrants (both successful and unsuccessful). Together with the free entry and aggregate stability conditions for each technology T and the market clearing conditions, this ensures not only that aggregate payments to the investment workers in the industry $(U+S)_e$ equal the aggregate profit level $\Pi = \Pi_L + \Pi_M + \Pi_H$, but also that at the same time a transference of resources from the superior technologies, M and H, toward the inferior technology, L, takes place[62].

Once again, the average firm revenue for technology T is determined by the ECP^T and the FE^T conditions:

---

[58] Remember no depreciation is assumed.
[59] Those with productivity levels between φ_H^* and φ^{H*}.
[60] Those with productivity levels between φ_M^* and φ^{M*}.
[61] Those productivity levels between φ_L^* and φ^{L*}.
[62] The results $(U_H+S_H)_e = p_{in}^H \Pi_H < \Pi_H$, $(U_M+S_M)_e = p_{in}^M \Pi_M < \Pi_M$ and $(U_L+S_L)_e = (1-p_{in}^L-p_{in}^M-p_{in}^M)Z_e f_L + \Pi_L p_{in}^L$, implying $(1-p_{in}^L-p_{in}^M-p_{in}^H)Z_e f_L = (1-p_{in}^L)\Pi_L + (1-p_{in}^M)\Pi_M + (1-p_{in}^H)\Pi_H$ continue to hold in the open economy equilibrium, meaning that still a part of the profits generated by successful entrants into each production technology is absorbed by the "setting-up" workers employed in them, but not the total amount: a fraction of these profits is here again used to pay the wages of the "setting-up" workers hired by unsuccessful entrants, which have not generated any profits themselves because they have never produced (recall that unsuccessful entrants leave the industry immediately upon entry). This is because, as was explained in more detail in the closed economy section, all prospective entrants benefit from some "sort of insurance", and the fraction of successful entrants' profits that they must "put aside" in order to get the "setting-up" workers hired by unsuccessful entrants paid, can be thought of as the cost of this insurance. As a consequence of this, a redistribution of resources takes place, from the two superior technologies (M and H) toward the inferior technology (L).

$$\bar{r}^L = \sigma(\bar{\pi}^L + f_L) \quad (80)$$

$$\bar{r}^M = \sigma\left(\bar{\pi}^M + f_M + nf_{lcx}^M\right) \quad (81)$$

$$\bar{r}^H = \sigma\left(\bar{\pi}^H + f_H + nf_{hcx}^H\right) \quad (82)$$

So average revenue for all domestic firms is:

$$\bar{r} = \frac{L}{Z}\bar{r}^L + \frac{M}{Z}\bar{r}^M + \frac{H}{Z}\bar{r}^H$$

Because the productivity threshold to enter the industry is higher in the open economy, the number of domestic incumbent firms must decrease. However, we cannot ascertain how this decrease in the total number of domestic firms is distributed among the three available production technologies, because the thresholds for the entry to technologies M and H rise as well. Consequently, we do not know if the proportion of firms using a particular technology T will decrease, increase or stay unchanged. The result regarding this depends on the value of parameters and on the shape of the distribution $g(\varphi)$. Because we are analyzing long run equilibria, it is assumed that labor will be reallocated between technologies as needed to guarantee full employment[63].

5.1 The Impact of Trade on Aggregate Welfare

Welfare per worker is still given by:

$$W = \frac{1}{P} = \frac{1}{Z_t^{\frac{1}{1-\sigma}}\bar{p}_t}$$

Therefore, it once again increases the larger the number of available varieties, but now this result can be achieved not only if country size increases, but also through trade. Even though the number of domestic incumbent firms is lower in the open economy setting than it was in autarky ($Z_{open} < Z_{closed}$), the number of foreign firms who now export to the home country typically overcompensates such reduction in the number of local firms, resulting in increased variety and thus fostering an increase in welfare ($Z_t = Z_{open}\left(1 + np_{inlcx}^{L+M+H} + np_{inhcx}^{L+M+H}\right) > Z_{closed}$)[64]. Besides, the aggregate productivity gain pulls down the average price, thus increasing welfare[65]. Finally, a third factor which exerts an impact on aggregate welfare (and was precluded by construction in the Melitz (2003) model) is the technology-specific variable cost: the greater the proportion of firms using the superior technologies, the lower the average price will tend to be, not only because such firms are idiosyncratically more productive, but also because they have lower variable production costs, and can therefore charge lower prices. However, as was stated before, we cannot anticipate how the

[63] We are considering long run equilibria. Consequently, even though each production technology uses skilled and unskilled workers in fixed proportions, we are focusing in what the outcome will be after the necessary adjustment in the degree of human capital of the labor force takes place. If in the open economy equilibrium the proportion of firms using technology L decreases, this will mean that the excess of unskilled labor will be unemployed in the short run until some of these former unskilled workers acquire the necessary skills to be reallocated in technologies M and H, which are more skill intensive. If, on the contrary, the proportion of firms using technology L increases in the new equilibrium, this will mean that in the short run some former technology M and H skilled workers will be underemployed in technology L, performing tasks for which they are overqualified. In the long run, as the incentives to become qualified are now lower, the proportions of skilled and unskilled workers in the labor force will adjust to fit the new situation (there will be less skilled workers and more unskilled workers).

[64] However the possibility that the number of domestic firms being pushed out of the market be larger than the number of exporting foreign firms entering it is not ruled out, especially if trade costs are high.

[65] This is a likely but not certain result, because even though aggregate productivity "at the factory gate" (that is, before it is corrected to capture transport iceberg costs and the effects of additional trade-related fixed invesments) always increases, once these corrections are made there is a possibility that $\tilde{\varphi}_t < \tilde{\varphi}_{closed}$, if τ is sufficiently large and β_{hc} , f_{lcx}^T and f_{hcx}^T are sufficiently low.

proportions of firms using each of the available technologies will vary among domestic firms in each country –or even if they will vary at all- without making further assumptions regarding technology parameters and the distribution $g(\varphi)$.

In the particular equilibrium in which we are focusing now, with $p^L_{inlcx} = 0$ and $p^M_{inlcx} = p^H_{inhcx} = 1$, it can be readily noted that the proportion of firms using technology L among all the firms (domestic and foreign) competing in the country decreases as the number of trading partners n rises because all the firms exporting to the home country are users of technologies M or H. Consequently, unless the proportion of firms using technology L among surviving domestic firms rises significantly when the economy opens up to trade, then the overall outcome will be a decreased participation of technology L users in the total number of firms (domestic and foreign) competing in each country, thus conducing to a lower average price and higher welfare.

As a result of all this, we cannot assure that welfare per worker, as measured above, will always increase when the economy opens up to trade, which is an important difference with the Melitz (2003) model (see Appendix F). However, what we do know is that if at least one of the three above mentioned factors (variety, aggregate productivity or average variable production cost) is sufficiently "better" in the open economy setting than in autarky (that is, if at least one the first two factors is sufficiently higher, or if the third is sufficiently lower), static welfare per worker will here too increase when trade is allowed.

5.2 The Impact of Trade on the Reallocations of Market Shares and Profits Across Firms

This section examines the effects of trade on firms that employ different production technologies –which may or may not be the same before and after the economy opens up to trade- and have different market strategies and productivity levels. The focus still is in the equilibrium reached when $\varphi^*_{lcx} = \varphi^{M*}$ and $\varphi^*_{hcx} = \varphi^{H*}$, and consequently $p^L_{inlcx} = p^M_{inhcx} = 0$ and $p^M_{inlcx} = p^H_{inhcx} = 1$.

The analysis is carried out by contrasting the performance of a firm with productivity $\varphi \geq \varphi^*_T$ before and after the transition to trade[66]. We denote with $r^T_a(\varphi) > 0$ and $\pi^T_a(\varphi) > 0$ the revenue and profits obtained by a firm with productivity φ who uses technology T in autarky. Because both in the closed and open economy equilibria the aggregate revenue of domestic firms is exogenously fixed by country size, $\frac{r^T_a(\varphi)}{R}$ and $\frac{r^T(\varphi)}{R}$ represent respectively the firm's total market share in autarky and in the open economy (in this last scenario, $\frac{r^T_d(\varphi)}{R}$ represents the firm's share of its domestic market).

The impact of trade on the market share of a firm who uses the same production technology T both in autarky and in the open economy is rather simple and can be evaluated using the following inequality (proof in Appendix G):

$$r^T_d(\varphi) < r^T_a(\varphi) < r^T_d(\varphi) + n r^T_{ix}(\varphi) \qquad , \forall \varphi \geq \varphi^{T*}, \ i = lc, hc \qquad (83)^{67}$$

The left-hand side of the inequality indicates that all firms incur a loss in domestic sales in the open economy, which means all nonexporting firms will incur a total revenue loss as well –which is the case of all firms using technology L, as none of them exports-. The right-hand side of the inequality indicates exporting firms –all M and H users- will make sufficient extra sales abroad to more than compensate for such domestic loss in market share, no matter if they are "Low-Commitment" or "High-Commitment" exporters.

[66] The analysis relies on Melitz's methodology, with the necessary ammendments to allow for the consideration of technology choice and different export profiles.
[67] Assuming σ sufficiently high.

The analysis of the impact of trade on the market share of a firm who used technology T^a in autarky and uses technology T in the open economy (T^a is superior to T)[68] is somewhat more complicated. There are two possible cases here. The first is $T^a = M$ and $T = L$, and the second one is $T^a = H$ and $T = M$.

In the first case the result is straightforward: because no firm using technology L exports, the former user of technology M who downgrades to technology L must suffer a reduction of its total market share, which is furthermore greater in magnitude than the loss suffered by a firm which was already using technology L in autarky[69]. Regarding the second case, because $r_a^M(\varphi) < r_a^H(\varphi)$, it is possible that former users of technology H who downgrade to technology M may experience as well a reduction of their total market share, if $r_a^M(\varphi) < r_d^M(\varphi) + nr_{lcx}^M(\varphi) < r_a^H(\varphi)$ for some φ. This outcome is more likely if φ_H^* is close to φ^{M*}, if the profit obtained by the least productive firm using technology H in autarky is substantially higher than the profit obtained by the least productive firm using technology M in the open economy, when f_H is substantially higher than f_M and when τ is high.[70]

Turning to the analysis of the reallocation of profits, once again we will distinguish between firms who use the same production technology T both in autarky and in the open economy (Cases 1, 3 and 5) and firms who downgrade technology when the economy opens up to trade (Cases 2 and 4).

Case 1: Firms who used technology L in autarky and continue to use technology L in the open economy. The change in the profit earned by a firm in this category who has productivity φ is given by:

$$\Delta\boldsymbol{\pi}^{\boldsymbol{LL}}(\boldsymbol{\varphi}) = \pi^L(\varphi) - \pi_a^L(\varphi) = \frac{\mathbf{1}}{\boldsymbol{\sigma}}\left[\boldsymbol{r}_{\boldsymbol{d}}^{\boldsymbol{L}}(\boldsymbol{\varphi}) - \boldsymbol{r}_{\boldsymbol{a}}^{\boldsymbol{L}}(\boldsymbol{\varphi})\right] \tag{84}$$

Because in the open economy setting no firm using technology L exports, then total revenue is just domestic revenue, which was previously shown to be lower than its autarky counterpart. Then, firms in this category experience a profit loss.

Case 2: Firms who used technology M in autarky and downgrade to technology L in the open economy. The change in the profit earned by a firm in this category who has productivity φ is given by:

$$\Delta\boldsymbol{\pi}^{\boldsymbol{ML}}(\boldsymbol{\varphi}) = \pi^L(\varphi) - \pi_a^M(\varphi) = \left[\frac{1}{\sigma}r_d^L(\varphi) - f_L\right] - \left[\frac{1}{\sigma}r_a^M(\varphi) - f_M\right] = \frac{1}{\sigma}r_d^L(\varphi) - f_L - \frac{1}{\sigma}r_a^M(\varphi) + f_M$$
$$= \frac{1}{\sigma}r_d^L(\varphi) - \frac{1}{\sigma}r_a^M(\varphi) - f_L + f_M = \frac{\mathbf{1}}{\boldsymbol{\sigma}}\left[\boldsymbol{r}_{\boldsymbol{d}}^{\boldsymbol{L}}(\boldsymbol{\varphi}) - \boldsymbol{r}_{\boldsymbol{a}}^{\boldsymbol{M}}(\boldsymbol{\varphi})\right] + [\boldsymbol{f}_{\boldsymbol{M}} - \boldsymbol{f}_{\boldsymbol{L}}] \tag{85}$$

Profits are pulled down because $r_d^L(\varphi) < r_a^L(\varphi) < r_a^M(\varphi)$ and thus the term in the first bracket is negative (and more negative than in Case 1). However, the term in the second bracket is positive, so the overall result on profits for firms in this situation depends on wether the reduction in fixed production costs is enough to compensate for the lower revenue they are getting in the open economy.

Case 3: Firms who used technology M in autarky and continue to use technology M in the open economy. The change in the profit earned by a firm in this category who has productivity φ is given by:

$$\Delta\boldsymbol{\pi}^{\boldsymbol{MM}}(\boldsymbol{\varphi}) = \pi^M(\varphi) - \pi_a^M(\varphi) = \frac{1}{\sigma}\left\{\left[r_d^M(\varphi) + nr_{lcx}^M(\varphi)\right] - r_a^M(\varphi)\right\} - nf_{lcx}^M =$$

[68] Recall that as increased competition shifts upward the thresholds for entry to each production technology, in the open economy firms will either continue to use the same technology as in autarky or downgrade to an inferior technology. For the sake of simplicity it is assumed that firms may downgrade to the immediate inferior technology at the most.
[69] Because $r_d^L(\varphi) < r_a^L(\varphi) < r_a^M(\varphi)$.
[70] This is straightforward from equation (88).

$$= \frac{1}{\sigma}\left\{\left[r_d^M(\varphi)(1+n\tau^{1-\sigma})\right] - r_a^M(\varphi)\right\} - nf_{lcx}^M =$$
$$= \frac{1}{\sigma}\left\{\left(\frac{\varphi}{\varphi^{M*}}\right)^{\sigma-1}\sigma\left(A_d^M + f_M\right)[1+n\tau^{1-\sigma}] - \left(\frac{\varphi}{\varphi_M^*}\right)^{\sigma-1}\sigma\left(A_{da}^M + f_M\right)\right\} - nf_{lcx}^M =$$
$$= \left\{\frac{\varphi^{\sigma-1}}{(\varphi^{M*})^{\sigma-1}}\left(A_d^M + f_M\right) + \frac{\varphi^{\sigma-1}}{(\varphi^{M*})^{\sigma-1}}\left(A_d^M + f_M\right)n\tau^{1-\sigma} - \frac{\varphi^{\sigma-1}}{\left(\varphi_M^*\right)^{\sigma-1}}\left(A_{da}^M + f_M\right)\right\} - nf_{lcx}^M =$$
$$= \varphi^{\sigma-1}\left\{\frac{A_d^M + f_M}{(\varphi^{M*})^{\sigma-1}} + \frac{(A_d^M + f_M)n\tau^{1-\sigma}}{(\varphi^{M*})^{\sigma-1}} - \frac{A_{da}^M + f_M}{\left(\varphi_M^*\right)^{\sigma-1}}\right\} - nf_{lcx}^M =$$
$$= \boldsymbol{\varphi^{\sigma-1}\left\{\frac{(A_d^M + f_M)[1+n\tau^{1-\sigma}]}{(\varphi^{M*})^{\sigma-1}} - \frac{A_{da}^M + f_M}{\left(\varphi_M^*\right)^{\sigma-1}}\right\} - nf_{lcx}^M} \qquad (86)^{71}$$

The term between curly brackets is always positive because $r_d^M(\varphi) + nr_{lcx}^M(\varphi) > r_a^M(\varphi),\quad \forall\varphi \geq \varphi^{M*}$.[72] Consequently the profit change is an increasing function of the firm's productivity level φ. Such profit change must be negative for the cutoff firm (with $\varphi = \varphi^{M*}$) because $\pi_{lcx}^M(\varphi^{M*}) = 0$ and $r_d^M(\varphi^{M*}) < r_a^M(\varphi^{M*})$. Therefore, some firms in this group will undoubtedly lose profits (those with lower values of φ) but there is still the possibility that at least some of the firms in this group can actually experience an increase in their profits (if their productivity φ is high enough).

Case 4: Firms who used technology H in autarky and downgrade to technology M in the open economy. The change in the profit earned by a firm in this category who has productivity φ is given by:

$$\Delta\boldsymbol{\pi^{HM}(\varphi)} = \pi^M(\varphi) - \pi_a^H(\varphi) = \left[\frac{1}{\sigma}r_d^M(\varphi) - f_M + n\frac{1}{\sigma}r_{lcx}^M(\varphi) - nf_{lcx}^M\right] - \left[\frac{1}{\sigma}r_a^H(\varphi) - f_H\right] =$$
$$= \left[\frac{1}{\sigma}r_d^M(\varphi)(1+n\tau^{1-\sigma}) - f_M - nf_{lcx}^M\right] - \left[\frac{1}{\sigma}r_a^H(\varphi) - f_H\right] =$$
$$= \frac{1}{\sigma}r_d^M(\varphi)(1+n\tau^{1-\sigma}) - f_M - nf_{lcx}^M - \frac{1}{\sigma}r_a^H(\varphi) + f_H =$$
$$= \frac{1}{\sigma}\left[r_d^M(\varphi)(1+n\tau^{1-\sigma}) - r_a^H(\varphi)\right] + \left[f_H - f_M - nf_{lcx}^M\right] =$$
$$= \frac{1}{\sigma}\left[\left(\frac{\varphi}{\varphi^{M*}}\right)^{\sigma-1}\sigma\left(A_d^M + f_M\right)[1+n\tau^{1-\sigma}] - \left(\frac{\varphi}{\varphi_H^*}\right)^{\sigma-1}\sigma\left(A_{da}^H + f_H\right)\right] + \left[f_H - f_M - nf_{lcx}^M\right] =$$
$$= \left[\frac{\varphi^{\sigma-1}}{(\varphi^{M*})^{\sigma-1}}\left(A_d^M + f_M\right) + \frac{\varphi^{\sigma-1}}{(\varphi^{M*})^{\sigma-1}}\left(A_d^M + f_M\right)n\tau^{1-\sigma} - \frac{\varphi^{\sigma-1}}{\left(\varphi_H^*\right)^{\sigma-1}}\left(A_{da}^H + f_H\right)\right] + \left[f_H - f_M - nf_{lcx}^M\right] =$$
$$= \varphi^{\sigma-1}\left[\frac{A_d^M + f_M}{(\varphi^{M*})^{\sigma-1}} + \frac{(A_d^M + f_M)n\tau^{1-\sigma}}{(\varphi^{M*})^{\sigma-1}} - \frac{A_{da}^H + f_H}{\left(\varphi_H^*\right)^{\sigma-1}}\right] + \left[f_H - f_M - nf_{lcx}^M\right] =$$
$$= \boldsymbol{\varphi^{\sigma-1}\left[\frac{(A_d^M + f_M)[1+n\tau^{1-\sigma}]}{(\varphi^{M*})^{\sigma-1}} - \frac{A_{da}^H + f_H}{\left(\varphi_H^*\right)^{\sigma-1}}\right] + \left[f_H - f_M - nf_{lcx}^M\right]} \qquad (87)$$

Because firms in this group, unlike those who were already using technology M in autarky, may indeed experience a reduction of their market share, an interesting outcome arises: every firm who experiences a revenue loss, will experience as well a profit loss unless f_H is so high it not only overwhelms the fixed costs associated to the new situation (f_M and nf_{lcx}^M) –which becomes more unlikely the higher the number of export destinations-, but also more than compensates the revenue loss –in all, an extremely unlikely outcome-. For the firms who will experience a revenue loss in the new setting, such loss will be greater the higher the firm's productivity parameter, which can be interpreted as signaling that the shrinkage of their market share is "more painful" for those firms who were doing better in autarky, as they fall to a disadvantageous position from a "higher" place. However, firms in this group who do not experience market share shrinkage will see their profits increase as their productivity φ increases, and may end up with higher profits than they had in autarky, if their φ parameter is high enough.

---

[71] Using $\frac{r_d^T(\varphi_1)}{r_d^{T'}(\varphi_2)} = \left(\frac{\frac{\varphi_1}{c_T}}{\frac{\varphi_2}{c_{T'}}}\right)^{\sigma-1}$ and $r_d^T(\varphi^{T*}) = \sigma\left(A_d^T + f_T\right)$.

[72] Assuming σ sufficiently high.

Case 5: Firms who used technology H in autarky and continue to use technology H in the open economy. The change in the profit earned by a firm in this category who has productivity φ is given by:

$$\Delta\boldsymbol{\pi}^{\boldsymbol{HH}}(\boldsymbol{\varphi}) = \pi^H(\varphi) - \pi_a^H(\varphi) = \frac{1}{\sigma}\left\{\left[r_d^H(\varphi) + nr_{hcx}^H(\varphi)\right] - r_a^H(\varphi)\right\} - nf_{hcx}^H =$$
$$= \frac{1}{\sigma}\left\{\left[r_d^H(\varphi)(1 + n\tau^{1-\sigma})\right] - r_a^H(\varphi)\right\} - nf_{hcx}^H =$$
$$= \frac{1}{\sigma}\left\{\left(\frac{\varphi}{\varphi^{H*}}\right)^{\sigma-1}\sigma\left(A_d^H + f_H\right)\left[1 + n\tau^{1-\sigma}\right] - \left(\frac{\varphi}{\varphi_H^*}\right)^{\sigma-1}\sigma\left(A_{da}^H + f_H\right)\right\} - nf_{hcx}^H =$$
$$= \left\{\frac{\varphi^{\sigma-1}}{(\varphi^{H*})^{\sigma-1}}\left(A_d^H + f_H\right) + \frac{\varphi^{\sigma-1}}{(\varphi^{H*})^{\sigma-1}}\left(A_d^H + f_H\right)n\tau^{1-\sigma} - \frac{\varphi^{\sigma-1}}{(\varphi_H^*)^{\sigma-1}}\left(A_{da}^H + f_H\right)\right\} - nf_{hcx}^H =$$
$$= \varphi^{\sigma-1}\left\{\frac{A_d^H + f_H}{(\varphi^{H*})^{\sigma-1}} + \frac{\left(A_d^H + f_H\right)n\tau^{1-\sigma}}{(\varphi^{H*})^{\sigma-1}} - \frac{A_{da}^H + f_H}{(\varphi_H^*)^{\sigma-1}}\right\} - nf_{hcx}^H =$$
$$= \boldsymbol{\varphi}^{\boldsymbol{\sigma-1}}\left\{\frac{\left(\boldsymbol{A_d^H + f_H}\right)\left[\boldsymbol{1 + n\tau^{1-\sigma}}\right]}{(\boldsymbol{\varphi^{H*}})^{\boldsymbol{\sigma-1}}} - \frac{\boldsymbol{A_{da}^H + f_H}}{(\boldsymbol{\varphi_H^*})^{\boldsymbol{\sigma-1}}}\right\} - \boldsymbol{nf_{hcx}^H} \tag{88}$$

The term between curly brackets is always positive because $r_d^H(\varphi) + nr_{lcx}^H(\varphi) > r_a^H(\varphi), \quad \forall\varphi \geq \varphi^{H*}$.[73] Consequently the profit change is once again an increasing function of the firm's productivity level φ. Because the cutoff firm (with $\varphi = \varphi^{H*}$) earns strictly positive profits in the export market –as $\pi_{hcx}^H(\varphi^{H*}) > \pi_{lcx}^H(\varphi^{H*}) > \pi_{lcx}^M(\varphi^{M*}) = 0$-, it is actually possible that no firm amongst this group experiences a profit loss, if the export profit earned by the cutoff firm is high enough to guarantee $\frac{1}{\sigma}r_d^H(\varphi^{H*}) + n\left[\frac{1}{\sigma}r_{lcx}^H(\varphi^{H*}) - f_{lcx}^H\right] \geq \frac{1}{\sigma}r_a^H(\varphi^{H*})$.[74] If this were not the case, then some firms in this group (those with the lowest values of φ) will lose profits, while the rest (from a certain φ and upward) will see them increase.

Summing up, the firms that in the open economy setting produce with technology L are always worse off than in autarky in terms of market share, and to a greater extent if they were former users of M in autarky. In terms of profits, they are always worse off if they were already using L in autarky, and are likely to be worse off too if they were using M in autarky (unless f_M is substantially higher than f_L, to the point that it more than compensates for the revenue loss). Meanwhile, firms that in the open economy produce with technology M will be better off in terms of market share if they were former users of that same technology in autarky, but may actually lose revenue –and in such case, also profits- if they were former users of technology H. In fact, even though profits may decrease or increase in both cases, in the first case –former users of M who continue using M- the firms more at risk of such profit loss are those with lower productivites among the group, while in the second case –former users of H who have downgraded to M- the profit loss accompanying revenue loss will be bigger for firms with the largest productivities among the group, precisely because they were doing better in autarky –thus, they have more to lose-. Finally, firms using technology H in the open economy not only always see their market share increase, but also are more likely to also see their profits increase, and under certain circumstances[75] it is even possible that all firms in this group will experience an increase in their profits. The bottom line is that among firms who remain in the same technology group they belonged to in autarky, the more efficient ones always do better both in terms of market share and profits, while at the same time firms who have downgraded technology are at a disadvantage compared to those who have not.

6. Final Considerations

The model shows that, given its idiosyncratic productivity distribution $g(\varphi)$, the industry will achieve a more favorable aggregate result –in terms of higher aggregate and average revenue and profits and

[73] Assuming σ sufficiently high.
[74] It is straightforward that the higher n is, the more likely this will be the outcome.
[75] Depending on the value of parameters and the shape of the distribution $g(\varphi)$.

also in terms of welfare per worker- the higher the number of firms in it whose idiosyncratic productivity surpasses the thresholds for the adoption of technologies M and H, beyond what can be attributed to the increase in industry average productivity. The reason is that to be in grade of taking advantage from the technical progress embodied in the higher quality intermediate capital goods used in technologies M and H and from the higher relative efficiency of the labor factor employed in them, the individual firm needs first to adopt such technologies, which will only be able to do if it possesses a high enough idiosyncratic productivity φ. Consequently, if there are in the industry many firms whose productivity φ lies above the thresholds for the adoption of the superior production technologies (that is, if its distribution $g(\varphi)$ is skewed towards the high values in the domain), the introduction of technology choice in the model (which opens up the possibility of adopting a superior production technology if a certain standard is met –that is, if the firm has a sufficiently high $\varphi -$ leads to an increase in revenue and profits, both for the individual firm holding the required φ and for the industry as a whole, as total and average revenue and profits increase. Welfare per worker also increases. On the contrary, if there are in the industry many firms whose productivity φ lies below the above mentioned thresholds (that is, if its distribution $g(\varphi)$ is skewed towards the low values in the domain), then the introduction of technology choice in the model leads only to a slight increase in welfare, revenue and profits, as very few firms will be in grade of adopting the superior technologies. Finally, if no firm in the industry is productive enough to adopt any of the superior technologies (that is, if the corresponding thresholds are too high to be relevant), then the results of the model are identical to those obtained prior to the introduction of technology choice: as no firm is in grade to choose any of the newly introduced technologies, the situation is virtually the same as if technology choice had not been introduced.

The heuristic explanation behind these results is that firm actual productivity has two components: on the one hand, idiosyncratic factors (which are captured by the parameter φ and cannot be modified –at least in the context of this model-, and on the other hand, the quality –that is, the efficiency- of the inputs used for production (namely, the quality of the intermediate capital goods and the qualification of the labor employed). If we added to this that in the real world it is reasonable to think that in the medium or long run the quality of the technology used exerts an influence on the firm's idiosyncratic productivity –a possibility that in the present model is excluded-, this would lead to the emergence of a virtuous circle (if the industry is characterized by a distribution $g(\varphi)$ skewed towards the high values in the domain) or a vicious circle (if the industry is characterized by a distribution $g(\varphi)$ skewed towards the low values in the domain).

The present model shares Melitz's result that when the economy opens up to trade, increased competition reallocates market shares toward the more efficient firms, thus forcing the least productive ones to exit, as they can no longer make nonnegative profits. The productivity threshold to enter the industry rises and therefore so does average productivity "at the factory gate". However, because exporters actual productivity when they arrive with their variety in the export destination is corrected downward to capture the effect of transport costs, and in the case of "High-Commitment Exporters" it is also corrected upward to capture the effect of their additional trade-related fixed investments, it cannot be assured that aggregate productivity $\tilde{\varphi}_t$ will actually increase, even though the higher the fixed export costs f^T_{lcx}, f^T_{hcx} and the effects of additional trade-related fixed investments β_{hc}, and the lower the transport cost τ, the greater the chances that $\tilde{\varphi}_t$ will be higher than the aggregate productivity in the closed economy setting, thus promoting an increase in aggregate welfare. On other grounds, even though the number of domestic firms decreases in the open economy, the total number of incumbent firms Z_t is likely to increase, leading as well to higher aggregate welfare due to increased variety.

Another important result is that the thresholds to enter each of the production technologies (that is, not only the threshold to enter L, but also those for entry to M and H) rise when the economy opens up to trade. This is because the shrinkage of their market share forces some firms who were using these technologies in autarky to downgrade to an inferior technology, as their sales in the open economy setting are no longer large enough to amortize the per period fixed cost corresponding to the technology they had been using in autarky. So they sell their equipment and buy another less costly in order to continue obtaining nonnegative (and the highest possible) profits[76]. This way, some former users of technology H become users of technology M, some former users of technology M become users of technology L, and some former users of technology L are forced out of the market, as they can no longer obtain nonnegative profits with any of the available production technologies. This results in an increase in each technology T average productivity, and consequently also in its average per firm revenue and profits. The absolute number of domestic firms using technology H undoubtedly decreases in every country, but as the total number of domestic firms decreases as well, it is not possible to anticipate –without making further assumptions on the shape of the distribution $g(\varphi)$ and on cost parameters- if the proportion of firms using technology H (which is the relevant thing for the determination of average variable production cost) actually decreases, remains unchanged or even increases, and the same applies to technologies M and L. So regarding the component of static production efficiency which relies on the quality of the inputs used, the result is indefinite in the general case. In the particular equilibrium in which we have focused (with $p_{inlcx}^{L} = 0$ and $p_{inlcx}^{M} = p_{inhcx}^{H} = 1$), it can be readily noted that the proportion of firms using technology L among all the firms competing in each country (domestic and foreign) decreases as the number of trading partners n rises because all the firms exporting to the home country are users of technologies M or H. Consequently, unless the proportion of firms using technology L among surviving domestic firms rises significantly when the economy opens up to trade, then the overall outcome will be a decreased participation of technology L users in the total number of firms (domestic and foreign) competing in each country, thus conducing to a lower average variable production cost and price.

As a result of all this, we cannot assure that static welfare per worker will always increase when the economy opens up to trade, which is an important difference with the Melitz (2003) model. However, what we do know is that if at least one of these three factors (variety, aggregate productivity or average variable production cost) are sufficiently better in the open economy setting than in autarky (that is: if at least one of the first two is sufficiently higher, or if the third is sufficiently lower), static welfare per worker will here too increase when trade is allowed. Meanwhile, dynamic welfare (based on the capacity of the country to absorb technical progress –which in the context of this model is done by means of using better quality capital goods in production) will increase if the proportion of domestic firms using the superior production technologies rises, especially if technology H becomes more widely adopted among domestic firms, and will decrease otherwise. Therefore, the outcome regarding dynamic welfare will depend exclusively on the value of parameters (which may be influenced by trade agreements and policy) and the shape of the distribution $g(\varphi)$. When it comes to individual firms' performance, the more efficient ones among those who remain in the same technology group as in autarky always do better both in terms of market share and profits, while at the same time firms who have downgraded technology are at a disadvantage compared to those who have not. An increase in profits is in all cases more difficult to achieve than an increase in market share.

Besides all the previously stated, an interesting additional result of the model, which stems from the way in which entry to the industry and to each alternative production technology are modeled (implying the existence of a "sort of insurance" to cover up from a greater loss in case the firm does not achieve a successful entry), a portion of the resources generated by the industry as a whole will always be absorbed by the most primitive production technology, with the consequence that this will never completely disappear –even if it shrinks- and, besides, it will almost always absorb more resources than it generates. In other words, whichever the equilibrium the industry may reach on the basis of its distribution $g(\varphi)$, it will always involve the transference of resources from the superior technologies toward the most primitive technology, unless of course no firm possesses a sufficiently high productivity φ to use a production technology other than the most primitive. If this last case would materialize, then all of the industry's resources would be generated and absorbed by the most primitive production technology, reproducing the result obtained in Melitz (2003) and blocking the possibility of increasing welfare as well as individual and average revenue and profits by means of utilization of better quality production inputs.

[76] Remember no depreciation is assumed.

Finally, it is worth noting that despite the model presented in this paper does not require that the superior technologies employ import capital goods –it is only required that the quality of the capital goods they employ be superior-, if we look at it in the light of the ideas cast in the introduction, then its results can be reinterpreted in the context of the problem of international technology diffusion. More precisely, it is possible to think that the country of origin of the intermediate capital goods employed in each alternative production technology is determinant of such goods' quality, being this higher the shorter the distance between the technology frontier belonging to the country where the capital good in question was produced and the world-technology-frontier. This highlights the crucial influence that a country's trade policy, including the choice of its trading partners, may exert over the productivity level it will be able to achieve, and consequently over its growth trajectory.

Because the results of the model are conditional on the shape of the exogenous productivity distribution $g(\varphi)$ and can vary depending on the value of supply and demand side parameters, an interesting extension would be to carry out computer simulations specifying different possible distributions –allowing as well for different skews- and value parameters. This could also allow establishing if and under which parameter restrictions an equilibrium in which firms sharing a certain export status do not necessarily share as well the same production technology could materialize.

7. References

Acemoglu, Daron (1998): "Why Do New Technologies Complement Skills? Directed Technical Change and Wage Inequality", *Quarterly Journal of Economics*, Vol. 113, Nº4, pp. 1055-1089.

Acemoglu, Daron (2003): "Patterns of Skill Premia", *Review of Economic Studies*, Vol. 70, N°2, pp. 199-230.

Bartel, Ann P. and Frank R. Lichtenberg Source (1987): "The Comparative Advantage of Educated Workers in Implementing New Technology", *The Review of Economics and Statistics*, Vol. 69, N°1, pp. 1-11.

Basu, Susanto and David N. Weil (1998): "Appropriate Technology and Growth", *Quarterly Journal of Economics*, Vol. 113, Nº4, pp. 1025-1054.

Bustos, Paula (2005): "The Impact of Trade on Technology And Skill Upgrading. Evidence from Argentina", http://www.crei.cat/people/bustos/WP/Trade,%20Technology%20and%20Skill.pdf

Caselli, Francesco and Wilbur J. Coleman (2000): "The World Technology Frontier", *NBER Working Paper 7904*, September 2000.

Coe, David T., Elhanan Helpman and Alexander W. Hoffmaister (1995): "North-South R&D spillovers", *NBER Working Paper 5048*, March 1995.

Dixit, A. and J. Stiglitz (1977): "Monopolistic Competition and Optimum Product Diversity", *American Economic Review*, Vol. 67, pp. 297-308.

Eaton, Jonathan and Samuel Kortum (1995a): "Trade in Ideas: Patenting and Productivity in the OECD", *NBER Working Paper 5049*, March 1995.

Eaton, Jonathan and Samuel Kortum (1995b): "Engines of Growth: Domestic and Foreign Sources of Innovation", *NBER Working Paper 5207*, August 1995.

Eaton, Jonathan and Samuel Kortum (1997): "Technology and Bilateral Trade", *NBER Working Paper 6253*, November 1997.

Keller, Wolfgang (2000): "Geographic Localization of International Technology Diffusion", *NBER Working Paper 7509*, January 2000.

Keller, Wolfgang (2001): "The Geography and Channels of Diffusion at the World's Technology Frontier", *NBER Working Paper 8150*, March 2001.

Keller, Wolfgang (2004): "International Technology Diffussion", *Journal of Economic Literature*, Vol XLII, pp. 752-782.

Krusell, Per; Lee E. Ohanian; Jose-Victor Rios-Rull and Giovanni L. Violante (2000): "Capital-Skill Complementarity and Inequality: A Macroeconomic Analysis", *Econometrica*, Vol. 68, N°5, pp. 1029-1053.

Melitz, Marc J. (2003): "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity", *Econometrica*, Vol. 71, N°6, pp. 1695-1725.

Restuccia, Diego (2004): "Barriers to Capital Accumulation and Aggregate Total Factor Productivity", *International Economic Review*, Vol. 45, N°1, pp. 225-238.

Zeira, Joseph (1998): "Workers, Machines and Economic Growth", *Quarterly Journal of Economics*, Vol. 113, Nº4, pp. 1091-1117.

8. Appendixes

Appendix A: Aggregation Conditions in the Closed Economy

The aggregate price, quantity, revenue (or expenditure) and profits can be derived using the expression of average industry productivity $\tilde{\varphi}$ in (29).

Derivation of the aggregate price P:

$$P = \left[\int_{\varphi_L^*}^{\varphi_M^*} p_d^L(\varphi)^{1-\sigma} L\mu(\varphi)d\varphi + \int_{\varphi_M^*}^{\varphi_H^*} p_d^M(\varphi)^{1-\sigma} M\mu(\varphi)d\varphi + \int_{\varphi_H^*}^{\infty} p_d^H(\varphi)^{1-\sigma} H\mu(\varphi)d\varphi\right]^{\frac{1}{1-\sigma}} =$$

$$= \left[\int_{\varphi_L^*}^{\varphi_M^*} \left(\frac{1}{\rho}\frac{c_L}{\varphi}\right)^{1-\sigma} L\mu(\varphi)d\varphi + \int_{\varphi_M^*}^{\varphi_H^*} \left(\frac{1}{\rho}\frac{c_M}{\varphi}\right)^{1-\sigma} M\mu(\varphi)d\varphi + \int_{\varphi_H^*}^{\infty} \left(\frac{1}{\rho}\frac{c_H}{\varphi}\right)^{1-\sigma} H\mu(\varphi)d\varphi\right]^{\frac{1}{1-\sigma}} =$$

$$= \left[\int_{\varphi_L^*}^{\varphi_M^*} \left(\frac{1}{\rho}c_L\right)^{1-\sigma} \frac{1}{\varphi^{1-\sigma}} L\mu(\varphi)d\varphi + \int_{\varphi_M^*}^{\varphi_H^*} \left(\frac{1}{\rho}c_M\right)^{1-\sigma} \frac{1}{\varphi^{1-\sigma}} M\mu(\varphi)d\varphi + \int_{\varphi_H^*}^{\infty} \left(\frac{1}{\rho}c_H\right)^{1-\sigma} \frac{1}{\varphi^{1-\sigma}} H\mu(\varphi)d\varphi\right]^{\frac{1}{1-\sigma}} =$$

$$= \left[L\int_{\varphi_L^*}^{\varphi_M^*} \left(\frac{1}{\rho}c_L\right)^{1-\sigma} \varphi^{\sigma-1}\mu(\varphi)d\varphi + M\int_{\varphi_M^*}^{\varphi_H^*} \left(\frac{1}{\rho}c_M\right)^{1-\sigma} \varphi^{\sigma-1}\mu(\varphi)d\varphi + H\int_{\varphi_H^*}^{\infty} \left(\frac{1}{\rho}c_H\right)^{1-\sigma} \varphi^{\sigma-1}\mu(\varphi)d\varphi\right]^{\frac{1}{1-\sigma}} =$$

$$= \left[L\left(\frac{1}{\rho}c_L\right)^{1-\sigma} \int_{\varphi_L^*}^{\varphi_M^*} \varphi^{\sigma-1}\mu(\varphi)d\varphi + M\left(\frac{1}{\rho}c_M\right)^{1-\sigma} \int_{\varphi_M^*}^{\varphi_H^*} \varphi^{\sigma-1}\mu(\varphi)d\varphi + H\left(\frac{1}{\rho}c_H\right)^{1-\sigma} \int_{\varphi_H^*}^{\infty} \varphi^{\sigma-1}\mu(\varphi)d\varphi\right]^{\frac{1}{1-\sigma}} =$$

$$= \left[L\left(\frac{1}{\rho}c_L\right)^{1-\sigma} \tilde{\varphi}_L{}^{\sigma-1} + M\left(\frac{1}{\rho}c_M\right)^{1-\sigma} \tilde{\varphi}_M{}^{\sigma-1} + H\left(\frac{1}{\rho}c_H\right)^{1-\sigma} \tilde{\varphi}_H{}^{\sigma-1}\right]^{\frac{1}{1-\sigma}} =$$

$$= \left[L\left(\frac{1}{\rho}c_L\right)^{1-\sigma} \left(\frac{1}{\tilde{\varphi}_L}\right)^{-(\sigma-1)} + M\left(\frac{1}{\rho}c_M\right)^{1-\sigma} \left(\frac{1}{\tilde{\varphi}_M}\right)^{-(\sigma-1)} + H\left(\frac{1}{\rho}c_H\right)^{1-\sigma} \left(\frac{1}{\tilde{\varphi}_H}\right)^{-(\sigma-1)}\right]^{\frac{1}{1-\sigma}} =$$

$$= \left[L\left(\frac{1}{\rho}c_L\right)^{1-\sigma} \frac{1}{\tilde{\varphi}_L{}^{1-\sigma}} + M\left(\frac{1}{\rho}c_M\right)^{1-\sigma} \frac{1}{\tilde{\varphi}_M{}^{1-\sigma}} + H\left(\frac{1}{\rho}c_H\right)^{1-\sigma} \frac{1}{\tilde{\varphi}_H{}^{1-\sigma}}\right]^{\frac{1}{1-\sigma}} =$$

$$= \left[L\left(\frac{1}{\rho}\frac{c_L}{\tilde{\varphi}_L}\right)^{1-\sigma} + M\left(\frac{1}{\rho}\frac{c_M}{\tilde{\varphi}_M}\right)^{1-\sigma} + H\left(\frac{1}{\rho}\frac{c_H}{\tilde{\varphi}_H}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} =$$

$$= [Lp_d^L(\tilde{\varphi}_L)^{1-\sigma} + Mp_d^M(\tilde{\varphi}_M)^{1-\sigma} + Hp_d^H(\tilde{\varphi}_H)^{1-\sigma}]^{\frac{1}{1-\sigma}}.$$

Derivation of the aggregate quantity Q:

$$Q=\left[\int_{\varphi_L^*}^{\varphi_M^*} q_d^L(\varphi)^\rho L\mu(\varphi)d\varphi+\int_{\varphi_M^*}^{\varphi_H^*} q_d^M(\varphi)^\rho M\mu(\varphi)d\varphi+\int_{\varphi_H^*}^{\infty} q_d^H(\varphi)^\rho H\mu(\varphi)d\varphi\right]^{\frac{1}{\rho}}=$$
$$=\left[\int_{\varphi_L^*}^{\varphi_M^*} q_d^L(\tilde{\varphi}_L)^\rho\left(\frac{\varphi}{\tilde{\varphi}_L}\right)^{\sigma\rho} L\mu(\varphi)d\varphi+\int_{\varphi_M^*}^{\varphi_H^*} q_d^M(\tilde{\varphi}_M)^\rho\left(\frac{\varphi}{\tilde{\varphi}_M}\right)^{\sigma\rho} M\mu(\varphi)d\varphi+\int_{\varphi_H^*}^{\infty} q_d^H(\tilde{\varphi}_H)^\rho\left(\frac{\varphi}{\tilde{\varphi}_H}\right)^{\sigma\rho} H\mu(\varphi)d\varphi\right]^{\frac{1}{\rho}}=$$
$$=\left[L\int_{\varphi_L^*}^{\varphi_M^*} q_d^L(\tilde{\varphi}_L)^\rho\left(\frac{\varphi}{\tilde{\varphi}_L}\right)^{\sigma-1}\mu(\varphi)d\varphi+M\int_{\varphi_M^*}^{\varphi_H^*} q_d^M(\tilde{\varphi}_M)^\rho\left(\frac{\varphi}{\tilde{\varphi}_M}\right)^{\sigma-1}\mu(\varphi)d\varphi+H\int_{\varphi_H^*}^{\infty} q_d^H(\tilde{\varphi}_H)^\rho\left(\frac{\varphi}{\tilde{\varphi}_H}\right)^{\sigma-1}\mu(\varphi)d\varphi\right]^{\frac{1}{\rho}}=$$
$$=\left[L\int_{\varphi_L^*}^{\varphi_M^*} q_d^L(\tilde{\varphi}_L)^\rho\frac{1}{\tilde{\varphi}_L{}^{\sigma-1}}\varphi^{\sigma-1}\mu(\varphi)d\varphi+M\int_{\varphi_M^*}^{\varphi_H^*} q_d^M(\tilde{\varphi}_M)^\rho\frac{1}{\tilde{\varphi}_M{}^{\sigma-1}}\varphi^{\sigma-1}\mu(\varphi)d\varphi+H\int_{\varphi_H^*}^{\infty} q_d^H(\tilde{\varphi}_H)^\rho\frac{1}{\tilde{\varphi}_H{}^{\sigma-1}}\varphi^{\sigma-1}\mu(\varphi)d\varphi\right]^{\frac{1}{\rho}}=$$
$$=\left[Lq_d^L(\tilde{\varphi}_L)^\rho\frac{1}{\tilde{\varphi}_L{}^{\sigma-1}}\int_{\varphi_L^*}^{\varphi_M^*}\varphi^{\sigma-1}\mu(\varphi)d\varphi+Mq_d^M(\tilde{\varphi}_M)^\rho\frac{1}{\tilde{\varphi}_M{}^{\sigma-1}}\int_{\varphi_M^*}^{\varphi_H^*}\varphi^{\sigma-1}\mu(\varphi)d\varphi+Hq_d^H(\tilde{\varphi}_H)^\rho\frac{1}{\tilde{\varphi}_H{}^{\sigma-1}}\int_{\varphi_H^*}^{\infty}\varphi^{\sigma-1}\mu(\varphi)d\varphi\right]^{\frac{1}{\rho}}=$$
$$=\left[Lq_d^L(\tilde{\varphi}_L)^\rho\frac{1}{\tilde{\varphi}_L{}^{\sigma-1}}\tilde{\varphi}_L{}^{\sigma-1}+Mq_d^M(\tilde{\varphi}_M)^\rho\frac{1}{\tilde{\varphi}_M{}^{\sigma-1}}\tilde{\varphi}_M{}^{\sigma-1}+Hq_d^H(\tilde{\varphi}_H)^\rho\frac{1}{\tilde{\varphi}_H{}^{\sigma-1}}\tilde{\varphi}_H{}^{\sigma-1}\right]^{\frac{1}{\rho}}=$$
$$=\left[Lq_d^L(\tilde{\varphi}_L)^\rho+Mq_d^M(\tilde{\varphi}_M)^\rho+Hq_d^H(\tilde{\varphi}_H)^\rho\right]^{\frac{1}{\rho}}.$$

Derivation of the aggregate revenue (or expenditure) R:

$$R=\int_{\varphi_L^*}^{\varphi_M^*} r_d^L(\varphi)L\mu(\varphi)d\varphi+\int_{\varphi_M^*}^{\varphi_H^*} r_d^M(\varphi)M\mu(\varphi)d\varphi+\int_{\varphi_H^*}^{\infty} r_d^H(\varphi)H\mu(\varphi)d\varphi=$$
$$=\int_{\varphi_L^*}^{\varphi_M^*} r_d^L(\tilde{\varphi}_L)\left(\frac{\varphi}{\tilde{\varphi}_L}\right)^{\sigma-1}L\mu(\varphi)d\varphi+\int_{\varphi_M^*}^{\varphi_H^*} r_d^M(\tilde{\varphi}_M)\left(\frac{\varphi}{\tilde{\varphi}_M}\right)^{\sigma-1}M\mu(\varphi)d\varphi+\int_{\varphi_H^*}^{\infty} r_d^H(\tilde{\varphi}_H)\left(\frac{\varphi}{\tilde{\varphi}_H}\right)^{\sigma-1}H\mu(\varphi)d\varphi=$$
$$=L\int_{\varphi_L^*}^{\varphi_M^*} r_d^L(\tilde{\varphi}_L)\left(\frac{\varphi}{\tilde{\varphi}_L}\right)^{\sigma-1}\mu(\varphi)d\varphi+M\int_{\varphi_M^*}^{\varphi_H^*} r_d^M(\tilde{\varphi}_M)\left(\frac{\varphi}{\tilde{\varphi}_M}\right)^{\sigma-1}\mu(\varphi)d\varphi+H\int_{\varphi_H^*}^{\infty} r_d^H(\tilde{\varphi}_H)\left(\frac{\varphi}{\tilde{\varphi}_H}\right)^{\sigma-1}\mu(\varphi)d\varphi=$$
$$=L\int_{\varphi_L^*}^{\varphi_M^*} r_d^L(\tilde{\varphi}_L)\frac{1}{\tilde{\varphi}_L{}^{\sigma-1}}\varphi^{\sigma-1}\mu(\varphi)d\varphi+M\int_{\varphi_M^*}^{\varphi_H^*} r_d^M(\tilde{\varphi}_M)\frac{1}{\tilde{\varphi}_M{}^{\sigma-1}}\varphi^{\sigma-1}\mu(\varphi)d\varphi+H\int_{\varphi_H^*}^{\infty} r_d^H(\tilde{\varphi}_H)\frac{1}{\tilde{\varphi}_H{}^{\sigma-1}}\varphi^{\sigma-1}\mu(\varphi)d\varphi=$$
$$=Lr_d^L(\tilde{\varphi}_L)\frac{1}{\tilde{\varphi}_L{}^{\sigma-1}}\int_{\varphi_L^*}^{\varphi_M^*}\varphi^{\sigma-1}\mu(\varphi)d\varphi+Mr_d^M(\tilde{\varphi}_M)\frac{1}{\tilde{\varphi}_M{}^{\sigma-1}}\int_{\varphi_M^*}^{\varphi_H^*}\varphi^{\sigma-1}\mu(\varphi)d\varphi+Hr_d^H(\tilde{\varphi}_H)\frac{1}{\tilde{\varphi}_H{}^{\sigma-1}}\int_{\varphi_H^*}^{\infty}\varphi^{\sigma-1}\mu(\varphi)d\varphi=$$
$$=Lr_d^L(\tilde{\varphi}_L)\frac{1}{\tilde{\varphi}_L{}^{\sigma-1}}\tilde{\varphi}_L{}^{\sigma-1}+Mr_d^M(\tilde{\varphi}_M)\frac{1}{\tilde{\varphi}_M{}^{\sigma-1}}\tilde{\varphi}_M{}^{\sigma-1}+Hr_d^H(\tilde{\varphi}_H)\frac{1}{\tilde{\varphi}_H{}^{\sigma-1}}\tilde{\varphi}_H{}^{\sigma-1}=$$
$$=Lr_d^L(\tilde{\varphi}_L)+Mr_d^M(\tilde{\varphi}_M)+Hr_d^H(\tilde{\varphi}_H).$$

Derivation of the aggregate profits Π:

$$\Pi=\int_{\varphi_L^*}^{\varphi_M^*}\pi_d^L(\varphi)L\mu(\varphi)d\varphi+\int_{\varphi_M^*}^{\varphi_H^*}\pi_d^M(\varphi)M\mu(\varphi)d\varphi+\int_{\varphi_H^*}^{\infty}\pi_d^H(\varphi)H\mu(\varphi)d\varphi=$$
$$=\int_{\varphi_L^*}^{\varphi_M^*}\left[\frac{1}{\sigma}r_d^L(\varphi)-f_L\right]L\mu(\varphi)d\varphi+\int_{\varphi_M^*}^{\varphi_H^*}\left[\frac{1}{\sigma}r_d^M(\varphi)-f_M\right]M\mu(\varphi)d\varphi+\int_{\varphi_H^*}^{\infty}\left[\frac{1}{\sigma}r_d^H(\varphi)-f_H\right]H\mu(\varphi)d\varphi=$$
$$=L\left[\frac{1}{\sigma}r_d^L(\tilde{\varphi}_L)-f_L\right]+M\left[\frac{1}{\sigma}r_d^M(\tilde{\varphi}_M)-f_M\right]+H\left[\frac{1}{\sigma}r_d^H(\tilde{\varphi}_H)-f_H\right]=$$
$$=L\pi_d^L(\tilde{\varphi}_L)+M\pi_d^M(\tilde{\varphi}_M)+H\pi_d^H(\tilde{\varphi}_H)$$

Appendix B: Existence and Uniqueness of the Cutoff Level φ_T^* (Closed Economy Equilibrium)

The equilibrium for each technology T is determined by the intersection of the FE^T and ECP^T curves. Therefore, for each technology, if it can be demonstrated that this intersection will actually take place, then the existence of equilibrium in that technology is proved. If, additionally, it is demonstrated that such intersection occurs only once, uniqueness of such equilibrium is also proved.

Technology L:

$FE^L=ECP^L\leftrightarrow\frac{\delta_L f_e^L}{[G(\varphi^{M*})-G(\varphi)]}=f_L k_d^L(\varphi)\leftrightarrow[G(\varphi^{M*})-G(\varphi)]f_L k_d^L(\varphi)=\delta_L f_e^L$ for some $\varphi\epsilon(0,\varphi^{M*})$.

The largest value of the left-hand side of the above expression is obtained when $\varphi\to 0$:

$$\lim_{\varphi\to 0}[G(\varphi^{M*})-G(\varphi)]f_L k_d^L(\varphi)=\infty$$

The smallest value of the left-hand side of the above expression is obtained when $\varphi\to\varphi^{M*}$:

$$\lim_{\varphi\to\varphi^{M*}}[G(\varphi^{M*})-G(\varphi)]f_L k_d^L(\varphi)=0$$

Because $[G(\varphi^{M*})-G(\varphi)]f_L k_d^L(\varphi)$ is continuous and monotonically strictly decreasing from infinity to zero in the interval $(0,\varphi^{M*})$, it can be assured that some φ exists so that such expression equals the constant $\delta_L f_e^L$. The existence and uniqueness of equilibrium in technology L in the closed economy is therefore demonstrated.

Technology M:

$FE^M = ECP^M \leftrightarrow \frac{\delta_M f_e^L}{[G(\varphi^{H*})-G(\varphi)]} + \delta_M(f_e^M - f_e^L) = [A_d^M h_d^M(\varphi) + f_M k_d^M(\varphi)] \leftrightarrow$

$\leftrightarrow [G(\varphi^{H*})-G(\varphi)]\{[A_d^M h_d^M(\varphi) + f_M k_d^M(\varphi)] - \delta_M(f_e^M - f_e^L)\} = \delta_M f_e^L$ for some $\varphi\epsilon(\varphi^{L*},\varphi^{H*})$.

The largest value of the left-hand side of the above expression is obtained when $\varphi \to \varphi^{L*}$:

$$\lim_{\varphi\to\varphi^{L*}}[G(\varphi^{H*})-G(\varphi)]\{[A_d^M h_d^M(\varphi) + f_M k_d^M(\varphi)] - \delta_M(f_e^M - f_e^L)\}$$
$$= [G(\varphi^{H*})-G(\varphi^{L*})]\{[A_d^M h_d^M(\varphi^{L*}) + f_M k_d^M(\varphi^{L*})] - \delta_M(f_e^M - f_e^L)\}$$

The smallest value of the left-hand side of the above expression is obtained when $\varphi \to \varphi^{H*}$:

$$\lim_{\varphi\to\varphi^{H*}}[G(\varphi^{H*})-G(\varphi)]\{[A_d^M h_d^M(\varphi) + f_M k_d^M(\varphi)] - \delta_M(f_e^M - f_e^L)\} = 0$$

We can assure $[G(\varphi^{H*})-G(\varphi)]\{[A_d^M h_d^M(\varphi) + f_M k_d^M(\varphi)] - \delta_M(f_e^M - f_e^L)\}$ is continuous and monotonically strictly decreasing from $[G(\varphi^{H*})-G(\varphi^{L*})]\{[A_d^M h_d^M(\varphi^{L*}) + f_M k_d^M(\varphi^{L*})] - \delta_M(f_e^M - f_e^L)\}$ to zero in the interval $(\varphi^{L*},\varphi^{H*})$ so long $A_d^M \geq \delta_M(f_e^M - f_e^L)$, that is, so long the profit obtained by the least productive firm using technology M is as least as big as the difference between the entry cost to technology M and the entry cost to technology L, multiplied by the probability of being hit by the bad shock and driven out of the market for any firm that is using technology M. In such case, as long as $\delta_M f_e^L \leq [G(\varphi^{H*})-G(\varphi^{L*})]\{[A_d^M h_d^M(\varphi^{L*}) + f_M k_d^M(\varphi^{L*})] - \delta_M(f_e^M - f_e^L)\}$ it can be assured that some φ exists so that $[G(\varphi^{H*})-G(\varphi)]\{[A_d^M h_d^M(\varphi) + f_M k_d^M(\varphi)] - \delta_M(f_e^M - f_e^L)\}$ equals $\delta_M f_e^L$. Under the above mentioned restrictions, the existence and uniqueness of equilibrium in technology M in the closed economy is therefore demonstrated.

Technology H:

$FE^H = ECP^H \leftrightarrow \frac{\delta_H f_e^L}{[1-G(\varphi)]} + \delta_H(f_e^H - f_e^L) = [A_d^H h_d^H(\varphi) + f_H k_d^H(\varphi)] \leftrightarrow$

$\leftrightarrow [1-G(\varphi)]\{[A_d^H h_d^H(\varphi) + f_H k_d^H(\varphi)] - \delta_H(f_e^H - f_e^L)\} = \delta_H f_e^L$ for some $\varphi\epsilon(\varphi^{M*},\infty)$.

The largest value of the left-hand side of the above expression is obtained when $\varphi \to \varphi^{M*}$:

$$\lim_{\varphi\to\varphi^{M*}}[1-G(\varphi)]\{[A_d^H h_d^H(\varphi) + f_H k_d^H(\varphi)] - \delta_H(f_e^H - f_e^L)\} = [1-G(\varphi^{M*})]\{[A_d^H h_d^H(\varphi^{M*}) + f_H k_d^H(\varphi^{M*})] - \delta_H(f_e^H - f_e^L)\}$$

The smallest value of the left-hand side of the above expression is obtained when $\varphi \to \infty$:

$$\lim_{\varphi\to\infty}[1-G(\varphi)]\{[A_d^H h_d^H(\varphi) + f_H k_d^H(\varphi)] - \delta_H(f_e^H - f_e^L)\} = 0$$

We can assure $[1-G(\varphi)]\{[A_d^H h_d^H(\varphi) + f_H k_d^H(\varphi)] - \delta_H(f_e^H - f_e^L)\}$ is continuous and monotonically strictly decreasing from $[1-G(\varphi^{M*})]\{[A_d^H h_d^H(\varphi^{M*}) + f_H k_d^H(\varphi^{M*})] - \delta_H(f_e^H - f_e^L)\}$ to zero in the interval (φ^{M*},∞) so long $A_d^H \geq \delta_H(f_e^H - f_e^L)$, that is, so long the profit obtained by the least productive firm using technology H is as least as big as the difference between the entry cost to technology H and the entry cost to technology L, multiplied by the probability of being hit by the bad shock and driven out of the market for any firm that is using technology H. In such case, as long as $\delta_H f_e^L \leq [1-G(\varphi^{M*})]\{[A_d^H h_d^H(\varphi^{M*}) + f_H k_d^H(\varphi^{M*})] - \delta_H(f_e^H - f_e^L)\}$ it can be assured that some φ exists so that $[1-G(\varphi)]\{[A_d^H h_d^H(\varphi) + f_H k_d^H(\varphi)] - \delta_H(f_e^H - f_e^L)\}$ equals $\delta_H f_e^L$. Under the above mentioned restrictions, the existence and uniqueness of equilibrium in technology H in the closed economy is therefore demonstrated.

Appendix C: Aggregate Labor Resources Used to Cover the Export Costs

The ratio of new "Low-Commitment Exporters" who use technology L to all "Low-Commitment Exporters" who use technology L is $\frac{p_{inlcx}^L p_{in}^L Z_e}{p_{inlcx}^L L} = \delta_L$ because the Aggregate Stability Condition for technology L implies $p_{in}^L Z_e = \delta_L L$. Analogously, the ratio of new "Low-Commitment Exporters" who use technology M to all "Low-Commitment Exporters" who use technology M is $\frac{p_{inlcx}^M p_{in}^M Z_e}{p_{inlcx}^M M} = \delta_M$ and the ratio of new "High-Commitment Exporters" who use technology M to all "High-Commitment Exporters" who use technology M is $\frac{p_{inhcx}^M p_{in}^M Z_e}{p_{inhcx}^M M} = \delta_M$ because the Aggregate Stability Condition for technology M implies $p_{in}^M Z_e = \delta_M M$. Finally, the ratio of new "High-Commitment Exporters" who use technology H to all "High-Commitment Exporters" who use technology H is $\frac{p_{inhcx}^H p_{in}^H Z_e}{p_{inhcx}^H H} = \delta_H$ because the Aggregate Stability Condition for technology H implies $p_{in}^H Z_e = \delta_H H$.

Appendix D: Comprehensive Measure of Aggregate Productivity in the Open Economy

$$\tilde{\varphi}_t^{\sigma-1} = \frac{1}{Z_t}\Big[Z\left(\frac{L}{Z}\int_{\varphi_L^*}^{\varphi_M^*}\varphi^{\sigma-1}\mu(\varphi)d\varphi + \frac{M}{Z}\int_{\varphi_M^*}^{\varphi_H^*}\varphi^{\sigma-1}\mu(\varphi)d\varphi + \frac{H}{Z}\int_{\varphi_H^*}^{\infty}\varphi^{\sigma-1}\mu(\varphi)d\varphi\right) + np_{inlcx}^{L+M+H}Z\left(\gamma\int_{\varphi_{lcx}^*}^{\varphi_M^*}\left(\frac{\varphi}{\tau}\right)^{\sigma-1}\mu(\varphi)d\varphi +\right.$$
$$\left.(1-\gamma)\int_{\varphi_M^*}^{\varphi_{hcx}^*}\left(\frac{\varphi}{\tau}\right)^{\sigma-1}\mu(\varphi)d\varphi\right) + np_{inhcx}^{L+M+H}Z\left(\delta\int_{\varphi_{hcx}^*}^{\varphi_H^*}\left(\frac{\varphi(1+\beta_{hc})}{\tau}\right)^{\sigma-1}\mu(\varphi)d\varphi + (1-\delta)\int_{\varphi_H^*}^{\infty}\left(\frac{\varphi(1+\beta_{hc})}{\tau}\right)^{\sigma-1}\mu(\varphi)d\varphi\right)\Big] =$$

$$\frac{1}{Z_t}\Big[L\int_{\varphi_L^*}^{\varphi_M^*}\varphi^{\sigma-1}\mu(\varphi)d\varphi + M\int_{\varphi_M^*}^{\varphi_H^*}\varphi^{\sigma-1}\mu(\varphi)d\varphi + H\int_{\varphi_H^*}^{\infty}\varphi^{\sigma-1}\mu(\varphi)d\varphi + np_{inlcx}^{L+M+H}Z\Big(\gamma\frac{1}{\tau^{\sigma-1}}\int_{\varphi_{lcx}^*}^{\varphi_M^*}\varphi^{\sigma-1}\mu(\varphi)d\varphi + (1-\gamma)\frac{1}{\tau^{\sigma-1}}\int_{\varphi_M^*}^{\varphi_{hcx}^*}\varphi^{\sigma-1}\mu(\varphi)d\varphi\Big) + np_{inhcx}^{L+M+H}Z\Big(\delta\Big(\frac{(1+\beta_{hc})}{\tau}\Big)^{\sigma-1}\int_{\varphi_{hcx}^*}^{\varphi_H^*}\varphi^{\sigma-1}\mu(\varphi)d\varphi + (1-\delta)\Big(\frac{(1+\beta_{hc})}{\tau}\Big)^{\sigma-1}\int_{\varphi_H^*}^{\infty}\varphi^{\sigma-1}\mu(\varphi)d\varphi\Big)\Big] =$$

$$\frac{1}{Z_t}\Big[L\tilde{\varphi}_L{}^{\sigma-1} + M\tilde{\varphi}_M{}^{\sigma-1} + H\tilde{\varphi}_H{}^{\sigma-1} + np_{inlcx}^{L+M+H}Z\Big(\gamma\frac{1}{\tau^{\sigma-1}}\tilde{\varphi}_{Llcx}{}^{\sigma-1} + (1-\gamma)\frac{1}{\tau^{\sigma-1}}\tilde{\varphi}_{Mxs}{}^{\sigma-1}\Big) + np_{inhcx}^{L+M+H}Z\Big(\delta\Big(\frac{(1+\beta_{hc})}{\tau}\Big)^{\sigma-1}\tilde{\varphi}_{Mhcx}{}^{\sigma-1} + (1-\delta)\Big(\frac{(1+\beta_{hc})}{\tau}\Big)^{\sigma-1}\tilde{\varphi}_{Hhcx}{}^{\sigma-1}\Big)\Big] =$$

$$\frac{1}{Z_t}\Big[L\tilde{\varphi}_L{}^{\sigma-1} + M\tilde{\varphi}_M{}^{\sigma-1} + H\tilde{\varphi}_H{}^{\sigma-1} + n\gamma p_{inlcx}^{L+M+H}Z\frac{1}{\tau^{\sigma-1}}\tilde{\varphi}_{Llcx}{}^{\sigma-1} + n(1-\gamma)p_{inlcx}^{L+M+H}Z\frac{1}{\tau^{\sigma-1}}\tilde{\varphi}_{Mlcx}{}^{\sigma-1} + n\delta p_{inhcx}^{L+M+H}Z\Big(\frac{(1+\beta_{hc})}{\tau}\Big)^{\sigma-1}\tilde{\varphi}_{Mhcx}{}^{\sigma-1} + n(1-\delta)p_{inhcx}^{L+M+H}Z\Big(\frac{(1+\beta_{hc})}{\tau}\Big)^{\sigma-1}\tilde{\varphi}_{Hhcx}{}^{\sigma-1}\Big] =$$

$$\frac{1}{Z_t}\Big[L\tilde{\varphi}_L{}^{\sigma-1} + M\tilde{\varphi}_M{}^{\sigma-1} + H\tilde{\varphi}_H{}^{\sigma-1} + np_{inlcx}^{L}L\frac{1}{\tau^{\sigma-1}}\tilde{\varphi}_{Llcx}{}^{\sigma-1} + np_{inlcx}^{M}M\frac{1}{\tau^{\sigma-1}}\tilde{\varphi}_{Mlcx}{}^{\sigma-1} + np_{inhcx}^{M}M\Big(\frac{(1+\beta_{hc})}{\tau}\Big)^{\sigma-1}\tilde{\varphi}_{Mhcx}{}^{\sigma-1} + np_{inhcx}^{H}H\Big(\frac{(1+\beta_{hc})}{\tau}\Big)^{\sigma-1}\tilde{\varphi}_{Hhcx}{}^{\sigma-1}\Big] =$$

$$\frac{1}{Z_t}\Big[L[\tilde{\varphi}_L{}^{\sigma-1} + np_{inlcx}^{L}\frac{1}{\tau^{\sigma-1}}\tilde{\varphi}_{Llcx}{}^{\sigma-1}] + M[\tilde{\varphi}_M{}^{\sigma-1} + np_{inlcx}^{M}\frac{1}{\tau^{\sigma-1}}\tilde{\varphi}_{Mlcx}{}^{\sigma-1} + np_{inhcx}^{M}\Big(\frac{(1+\beta_{hc})}{\tau}\Big)^{\sigma-1}\tilde{\varphi}_{Mhcx}{}^{\sigma-1}] + H[\tilde{\varphi}_H{}^{\sigma-1} + np_{inhcx}^{H}\Big(\frac{(1+\beta_{c})}{\tau}\Big)^{\sigma-1}\tilde{\varphi}_{Hhcx}{}^{\sigma-1}]\Big]$$

Appendix E: Existence and Uniqueness of the Cutoff Level φ^{T*} (Open Economy Equilibrium)

For the sake of analytical simplicity, the existence and uniqueness of equilibrium in each production technology in the open economy setting will be demonstrated for the particular case in which $\varphi_{lcx}^* = \varphi^{M*}$ and $\varphi_{hcx}^* = \varphi^{H*}$, and consequently $p_{inlcx}^L = p_{inhcx}^M = 0$ and $p_{inlcx}^M = p_{inhcx}^H = 1$, as it can be considered a limiting case in which the plausible ordering of productivity thresholds $\varphi^{L*} \le \varphi_{lcx}^* \le \varphi^{M*} \le \varphi_{hcx}^* \le \varphi^{H*}$ is maintained. Nevertheless, the generalization of this demonstration to prove the existence and uniqueness of equilibrium in each production technology in any other case in which all the firms using the same production technology share as well the same status regarding the export markets is straightforward.

Technology L:

$FE^L = ECP^L \leftrightarrow \frac{\delta_L f_e^L}{[G(\varphi^{M*})-G(\varphi)]} = f_L k_d^L(\varphi^{L*}) \leftrightarrow [G(\varphi^{M*}) - G(\varphi)]f_L k_d^L(\varphi) = \delta_L f_e^L$ for some $\varphi\epsilon(0,\varphi^{M*})$.

The largest value of the left-hand side of the above expression is obtained when $\varphi \to 0$:

$$\lim_{\varphi\to 0}[G(\varphi^{M*}) - G(\varphi)]f_L k_d^L(\varphi) = \infty$$

The smallest value of the left-hand side of the above expression is obtained when $\varphi \to \varphi^{M*}$:

$$\lim_{\varphi\to\varphi^{M*}}[G(\varphi^{M*}) - G(\varphi)]f_L k_d^L(\varphi) = 0$$

Because $[G(\varphi^{M*}) - G(\varphi)]f_L k_d^L(\varphi)$ is continuous and monotonically strictly decreasing from infinity to zero in the interval $(0,\varphi^{M*})$, it can be assured that some φ exists so that such expression equals $\delta_L f_e^L$. The existence and uniqueness of equilibrium in technology L in the open economy is therefore demonstrated.

Technology M:

$FE^M = ECP^M \leftrightarrow \frac{\delta_M f_e^L}{[G(\varphi^{H*})-G(\varphi)]} + \delta_M(f_e^M - f_e^L) = [A_d^M h_d^M(\varphi) + f_M k_d^M(\varphi)] + n[A_{lcx}^M h_{lcx}^M(\varphi) + f_{lcx}^M k_{lcx}^M(\varphi)] \leftrightarrow$

$\leftrightarrow [G(\varphi^{H*}) - G(\varphi)]\{[A_d^M h_d^M(\varphi) + f_M k_d^M(\varphi)] + n[A_{lcx}^M h_{lcx}^M(\varphi) + f_{lcx}^M k_{lcx}^M(\varphi)] - \delta_M(f_e^M - f_e^L)\} = \delta_M f_e^L$ for some $\varphi\epsilon(\varphi^{L*},\varphi^{H*})$.

The largest value of the left-hand side of the above expression is obtained when $\varphi \to \varphi^{L*}$:

$$\lim_{\varphi\to\varphi^{L*}}[G(\varphi^{H*}) - G(\varphi)]\{A_d^M h_d^M(\varphi) + f_M k_d^M(\varphi) + nA_{lcx}^M h_{lcx}^M(\varphi) + nf_{lcx}^M k_{lcx}^M(\varphi) - \delta_M(f_e^M - f_e^L)\} =$$
$$= [G(\varphi^{H*}) - G(\varphi^{L*})]\{A_d^M h_d^M(\varphi^{L*}) + f_M k_d^M(\varphi^{L*}) + nA_{lcx}^M h_{lcx}^M(\varphi^{L*}) + nf_{lcx}^M k_{lcx}^M(\varphi^{L*}) - \delta_M(f_e^M - f_e^L)\}$$

The smallest value of the left-hand side of the above expression is obtained when $\varphi \to \varphi^{H*}$:

$$\lim_{\varphi\to\varphi^{H*}}[G(\varphi^{H*}) - G(\varphi)]\{A_d^M h_d^M(\varphi) + f_M k_d^M(\varphi) + nA_{lcx}^M h_{lcx}^M(\varphi) + nf_{lcx}^M k_{lcx}^M(\varphi) - \delta_M(f_e^M - f_e^L)\} = 0$$

We can assure $[G(\varphi^{H*}) - G(\varphi)]\{A_d^M h_d^M(\varphi) + f_M k_d^M(\varphi) + nA_{lcx}^M h_{lcx}^M(\varphi) + nf_{lcx}^M k_{lcx}^M(\varphi) - \delta_M(f_e^M - f_e^L)\}$ is continuous and monotonically strictly decreasing from $[G(\varphi^{H*}) - G(\varphi^{L*})]\{A_d^M h_d^M(\varphi^{L*}) + f_M k_d^M(\varphi^{L*}) + nA_{lcx}^M h_{lcx}^M(\varphi^{L*}) + nf_{lcx}^M k_{lcx}^M(\varphi^{L*}) - \delta_M(f_e^M - f_e^L)\}$ to zero in the interval $(\varphi^{L*},\varphi^{H*})$ so long $A_d^M + nA_{lcx}^M \ge \delta_M(f_e^M - f_e^L)$, that is, so long the profit obtained by the least productive firm using technology M in the open economy is as least as big as the difference between the entry cost to technology M and the entry cost to technology L, multiplied by the probability of being hit by the bad shock and driven out of the market for any firm that is using technology M. In such case, as long as $\delta_M f_e^L \le [G(\varphi^{H*}) - G(\varphi^{L*})]\{A_d^M h_d^M(\varphi^{L*}) + f_M k_d^M(\varphi^{L*}) + nA_{lcx}^M h_{lcx}^M(\varphi^{L*}) + nf_{lcx}^M k_{lcx}^M(\varphi^{L*}) - \delta_M(f_e^M - f_e^L)\}$, it can be assured that some φ exists so that $[G(\varphi^{H*}) - G(\varphi)]\{A_d^M h_d^M(\varphi) + f_M k_d^M(\varphi) + nA_{lcx}^M h_{lcx}^M(\varphi) + nf_{lcx}^M k_{lcx}^M(\varphi) - \delta_M(f_e^M - f_e^L)\}$ equals $\delta_M f_e^L$. Under the above mentioned restrictions, the existence and uniqueness of equilibrium in technology M in the open economy is therefore demonstrated.

Technology H:

$FE^H = ECP^H \leftrightarrow \frac{\delta_H f_e^L}{[1-G(\varphi)]} + \delta_H(f_e^H - f_e^L) = [A_d^H h_d^H(\varphi) + f_H k_d^H(\varphi)] + n[A_{hcx}^H h_{hcx}^H(\varphi) + f_{hcx}^H k_{hcx}^H(\varphi)] \leftrightarrow$

$\leftrightarrow [1-G(\varphi)]\{A_d^H h_d^H(\varphi) + f_H k_d^H(\varphi) + nA_{hcx}^H h_{hcx}^H(\varphi) + nf_{hcx}^H k_{hcx}^H(\varphi) - \delta_H(f_e^H - f_e^L)\} = \delta_H f_e^L$ for some $\varphi \epsilon (\varphi^{M*}, \infty)$.
The largest value of the left-hand side of the above expression is obtained when $\varphi \to \varphi^{M*}$:

$$\lim_{\varphi\to\varphi^{M*}} [1-G(\varphi)]\{A_d^H h_d^H(\varphi) + f_H k_d^H(\varphi) + nA_{hcx}^H h_{hcx}^H(\varphi) + nf_{hcx}^H k_{hcx}^H(\varphi) - \delta_H(f_e^H - f_e^L)\} =$$
$$= [1-G(\varphi^{M*})]\{A_d^H h_d^H(\varphi^{M*}) + f_H k_d^H(\varphi^{M*}) + nA_{hcx}^H h_{hcx}^H(\varphi^{M*}) + nf_{hcx}^H k_{hcx}^H(\varphi^{M*}) - \delta_H(f_e^H - f_e^L)\}$$

The smallest value of the left-hand side of the above expression is obtained when $\varphi \to \infty$:

$$\lim_{\varphi\to\infty} [1-G(\varphi)]\{A_d^H h_d^H(\varphi) + f_H k_d^H(\varphi) + nA_{hcx}^H h_{hcx}^H(\varphi) + nf_{hcx}^H k_{hcx}^H(\varphi) - \delta_H(f_e^H - f_e^L)\} = 0$$

We can assure $[1-G(\varphi)]\{A_d^H h_d^H(\varphi) + f_H k_d^H(\varphi) + nA_{hcx}^H h_{hcx}^H(\varphi) + nf_{hcx}^H k_{hcx}^H(\varphi) - \delta_H(f_e^H - f_e^L)\}$ is continuous and monotonically strictly decreasing from $[1-G(\varphi^{M*})]\{A_d^H h_d^H(\varphi^{M*}) + f_H k_d^H(\varphi^{M*}) + nA_{hcx}^H h_{hcx}^H(\varphi^{M*}) + nf_{hcx}^H k_{hcx}^H(\varphi^{M*}) -$ $\delta HfeH{-}feL$ to zero in the interval $\varphi M{*}{,}\infty$ so long $AdH{+}nAhcxH{\geq}\delta HfeH{-}feL$, that is, so long the profit obtained by the least productive firm using technology H in the open economy is as least as big as the difference between the entry cost to technology H and the entry cost to technology L, multiplied by the probability of being hit by the bad shock and driven out of the market for any firm that is using technology H. In such case, as long as $\delta_H f_e^L \leq [1-G(\varphi^{M*})]\{A_d^H h_d^H(\varphi^{M*}) +$ $fHkdH\varphi M{*}{+}nAhcxHhhcxH\varphi M{*}{+}nfhcxHkhcxH\varphi M{*}{-}\delta HfeH{-}feL$, it can be assured that some φ exists so that $[1-G(\varphi)]\{A_d^H h_d^H(\varphi) + f_H k_d^H(\varphi) + nA_{hcx}^H h_{hcx}^H(\varphi) + nf_{hcx}^H k_{hcx}^H(\varphi) - \delta_H(f_e^H - f_e^L)\}$ equals $\delta_H f_e^L$. Under the above mentioned restrictions, the existence and uniqueness of equilibrium in technology H in the open economy is therefore demonstrated.

Appendix F: The Impact of Trade on Aggregate Welfare

Welfare (W) per worker, both in Autarky and in the Open Economy is measured by real per capita income/expenditure, which is obtained dividing aggregate real income (or revenue), $\frac{R}{P}$, by the number of workers constituting the labor force in the home country, $U+S$. By its definition $R = PQ$ and at the same time aggregate revenue adds up to total payments to the labor force $(R = U + S)$, which yields $W = \frac{1}{P} = \frac{1}{Z^{\frac{1}{1-\sigma}}\bar{p}}$. Thus:

$$\boldsymbol{W_{open} > W_{closed} \leftrightarrow Z_t^{\frac{1}{\sigma-1}}\frac{1}{\bar{p}_t} > Z_{closed}^{\frac{1}{\sigma-1}}\frac{1}{\bar{p}_{closed}}}$$

Appendix G: The Impact of Trade on the Reallocation of Market Shares and Revenues

Technology L: proof that $\boldsymbol{r_d^L(\varphi) < r_a^L(\varphi), \forall\varphi \geq \varphi^{L*}}$

Recall that $r_a^L(\varphi) = \left(\frac{\varphi}{\varphi_L^*}\right)^{\sigma-1} r_a^L(\varphi_L^*) = \left(\frac{\varphi}{\varphi_L^*}\right)^{\sigma-1}\sigma f_L$, $\forall\varphi \geq \varphi_L^*$.[77] Recall also that $r_d^L(\varphi) = \left(\frac{\varphi}{\varphi^{L*}}\right)^{\sigma-1} r_d^L(\varphi^{L*}) = \left(\frac{\varphi}{\varphi^{L*}}\right)^{\sigma-1}\sigma f_L$, $\forall\varphi \geq \varphi^{L*}$.[78] Because $\varphi_L^* < \varphi^{L*}$, this immediately yields $r_d^L(\varphi) < r_a^L(\varphi), \forall\varphi \geq \varphi^{L*}$.

Technology M: proof that $\boldsymbol{r_d^M(\varphi) < r_a^M(\varphi) < r_d^M(\varphi) + nr_{lcx}^M(\varphi), \ \forall\varphi \geq \varphi^{M*}}$

<u>Left-hand side of the inequality:</u> proof that $r_d^M(\varphi) < r_a^M(\varphi)$

Recall that $r_a^M(\varphi) = \left(\frac{\varphi}{\varphi_M^*}\right)^{\sigma-1} r_a^M(\varphi_M^*) = \left(\frac{\varphi}{\varphi_M^*}\right)^{\sigma-1}\sigma\left(A_{da}^M + f_M\right)$, $\forall\varphi \geq \varphi_M^*$.[79] Recall also that $r_d^M(\varphi) = \left(\frac{\varphi}{\varphi^{M*}}\right)^{\sigma-1} r_d^M(\varphi^{M*}) = \left(\frac{\varphi}{\varphi^{M*}}\right)^{\sigma-1}\sigma\left(A_d^M + f_M\right), \forall\varphi \geq \varphi^{M*}$.[80] On the one hand $\varphi_M^* < \varphi^{M*}$ and on the other hand it may be $A_{da}^M < A_d^M$. However, due to the way each factor enters the equation, assuming σ is sufficiently high this will yield $r_d^M(\varphi) < r_a^M(\varphi), \forall\varphi \geq \varphi^{M*}$.

<u>Right-hand side of the inequality:</u> proof that $r_a^M(\varphi) < r_d^M(\varphi) + nr_{lcx}^M(\varphi) = r_d^H(\varphi)\left[1 + n\left(\frac{\tau}{1+\beta_{lc}}\right)^{1-\sigma}\right] = r_d^M(\varphi)[1 +$ $n\tau 1{-}\sigma$

It is straightforward that $r_d^M(\varphi)[1 + n\tau^{1-\sigma}]$ decreases as τ increases. Because the autarky equilibrium is obtained as the limiting equilibrium as τ increases to infinity, then $r_a^M(\varphi) = \lim_{\tau\to\infty} r_d^M(\varphi)[1 + n\tau^{1-\sigma}]$. Thus $r_a^M(\varphi) < r_d^M(\varphi)[1 +$ $n\tau 1{-}\sigma$ for any finite τ.

---

[77] Using $\frac{r_a^L(\varphi)}{r_a^L(\varphi_L^*)} = \left(\frac{\varphi}{\varphi_L^*}\right)^{\sigma-1}$.

[78] Using $\frac{r_d^L(\varphi)}{r_d^L(\varphi^{L*})} = \left(\frac{\varphi}{\varphi^{L*}}\right)^{\sigma-1}$.

[79] Using $\frac{r_a^M(\varphi)}{r_a^M(\varphi_M^*)} = \left(\frac{\varphi}{\varphi_M^*}\right)^{\sigma-1}$.

[80] Using $\frac{r_d^M(\varphi)}{r_d^M(\varphi^{M*})} = \left(\frac{\varphi}{\varphi^{M*}}\right)^{\sigma-1}$.

Technology H: proof that $\boldsymbol{r_d^H(\varphi) < r_a^H(\varphi) < r_d^H(\varphi) + n r_{hcx}^H(\varphi)},\ \forall \boldsymbol{\varphi \geq \varphi^{H*}}$

Left-hand side of the inequality: proof that $r_d^H(\varphi) < r_a^H(\varphi)$

Recall that $r_a^H(\varphi) = \left(\frac{\varphi}{\varphi_H^*}\right)^{\sigma-1} r_a^H(\varphi_H^*) = \left(\frac{\varphi}{\varphi_H^*}\right)^{\sigma-1} \sigma\left(A_{da}^H + f_H\right), \forall\varphi \geq \varphi_H^*$.[81] Recall also that $r_d^H(\varphi) = \left(\frac{\varphi}{\varphi^{H*}}\right)^{\sigma-1} r_d^H(\varphi^{H*}) = \left(\frac{\varphi}{\varphi^{H*}}\right)^{\sigma-1} \sigma\left(A_d^H + f_H\right), \forall\varphi \geq \varphi^{H*}$.[82] On the one hand $\varphi_H^* < \varphi^{H*}$ and on the other hand it may be $A_{da}^H < A_d^H$. However, due to the way each factor enters the equation, assuming σ is sufficiently high this will yield $r_d^H(\varphi) < r_a^H(\varphi), \forall\varphi \geq \varphi^{H*}$.

Right-hand side of the inequality: proof that $r_a^H(\varphi) < r_d^H(\varphi) + n r_{hcx}^H(\varphi) = r_d^H(\varphi)\left[1 + n\left(\frac{\tau}{1+\beta_{hc}}\right)^{1-\sigma}\right]$

It is straightforward that $r_d^H(\varphi)\left[1 + n\left(\frac{\tau}{1+\beta_{hc}}\right)^{1-\sigma}\right]$ decreases as $\left(\frac{\tau}{1+\beta_{hc}}\right)$ increases, which will happen so long $\tau > 1 + \beta_{hc}$. On the contrary, $r_d^H(\varphi)\left[1 + n\left(\frac{\tau}{1+\beta_{hc}}\right)^{1-\sigma}\right]$ increases if $\left(\frac{\tau}{1+\beta_{hc}}\right)$ decreases, which will happen if $\tau < 1 + \beta_{hc}$. Because the autarky equilibrium is obtained as the limiting equilibrium as τ increases to infinity –while the highest possible value for β_{hc} is A, a finite positive number-, then $r_a^H(\varphi) = \lim_{\tau\to\infty} r_d^H(\varphi)\left[1 + n\left(\frac{\tau}{1+\beta_{hc}}\right)^{1-\sigma}\right]$. Thus $r_a^H(\varphi) < r_d^H(\varphi)\left[1 + n\left(\frac{\tau}{1+\beta_{hc}}\right)^{1-\sigma}\right]$ for any finite τ (whatever β_{hc}).

---

[81] Using $\frac{r_a^H(\varphi)}{r_a^H(\varphi_H^*)} = \left(\frac{\varphi}{\varphi_H^*}\right)^{\sigma-1}$.

[82] Using $\frac{r_d^H(\varphi)}{r_d^H(\varphi^{H*})} = \left(\frac{\varphi}{\varphi^{H*}}\right)^{\sigma-1}$.