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« Asymmetries with R&D-Driven Growth and Heterogeneous Firms »

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Asymmetries with R&D-Driven Growth and Heterogeneous Firms

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Abstract

This paper studies the impact of trade liberalization on the productivity growth of two asymmetric countries in a R&D driven growth model with heterogeneous firms. The Melitz's reallocation of production induces positive but asymmetric productivity gains. Growth is also affected in an asymmetric way because trade liberalization reduces innovation incentives with a different strength in the two countries. A more productive country suffers a higher slowdown in the productivity growth rate.

JEL Classification: F43, O47

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1 Introduction

Firm heterogeneity allows trade models to explain coexistence between exporters and non exporters, giving rise to a literature that studies the effect of trade liberalization on firms export decision and on aggregate productivity. [Melitz \(2003\)](#) finds that liberalization produces an intra-industry reallocation of production: when trade costs decrease, the less productive domestic firms are replaced by the more productive foreign firms. This reallocation effect leads to a direct and unambiguous positive effect on aggregate productivity. [Gustafsson and Segerstrom \(2010\)](#) integrate an innovation sector in a Melitz-type model in order to obtain a positive productivity growth rate in the long run.¹ In their model, trade liberalization still produces the direct reallocation effect of the [Melitz \(2003\)](#) model, and there is now an indirect channel that retards productivity growth. The growing competition in local markets increases the costs of developing a profitable variety and decreases firms innovation incentives in the R&D sector. Therefore economic growth slows down.

However, these papers do not consider comparative advantage or factor endowment differences but they offer a framework to understand the trade situation between two countries that are symmetric. It seems important to relax these symmetry assumptions to investigate the strength and the direction of these two different effects. I consider trade between asymmetric economies in terms of technology and factor endowments. Like [Falvey et al. \(2011\)](#), I allow for productivity and market size differences, but unlike them, I use a R&D-driven growth model that allows me to find asymmetric results on both the [Melitz \(2003\)](#) effect and the [Gustafsson and Segerstrom \(2010\)](#) effect.

First, I find that the direct Melitz reallocation effect has a positive effect on productivity in both country but the strength of this effect depends on productivity differences. The leading country benefits more than the laggard one because its threshold value for local market entry decreases more.

Second, the indirect "Gustafsson and Segerstrom effect" of trade liberalization on productivity growth is asymmetric and depends on productivity differences. In general, a more productive country suffers a higher slowdown of its productivity growth rate in the short run, and its share of produced variety decreases at the new equilibrium.

The rest of the paper is organized as follows. Section 2 presents the headlines of the model. Section 3 analyses the steady state equilibrium. Section 4 highlights the effects of trade liberalization and section 5 concludes.

¹[Baldwin and Robert-Nicoud \(2008\)](#) and [Unel \(2010\)](#) use similar models.

2 The R&D-driven growth model

This model is an extension of the model considered in [Gustafsson and Segerstrom \(2010\)](#). It is a R&D driven growth model where firms are heterogeneous as in the [Melitz \(2003\)](#) pioneer paper. There are two countries endowed with a single factor of production, labour which is inelastically supplied and denoted by L_{it} ($i = D, F$ denotes the domestic and the foreign country, respectively). As each individual is endowed by one unit of labour, L_{it} also refers to the population size of country i . Population of the two countries grows at the exogenous rate n . The model considers two sectors: the production sector works under the Dixit-Stiglitz monopolistic competition of differentiated products, whereas the innovation sector is perfectly competitive. Firms decision depends on an arbitrage between expected returns and costs. A new variety costs f_I unit of knowledge which price is defined as b_t . When a firm innovates, the new variety is developed and the firm learns the marginal cost associated to this particular variety denoted by a which is drawn from a Pareto probability density function $g(a)$.²

Then, firms have to decide whether they enter the local market, the foreign market, both or none. To enter the local (export) market, a firm needs to create f (f^*) unit of knowledge at price b_t . At time t , a firm must pay the sunk cost $b_t f$ for local market entry and $b_t f^*$ for export market entry. Usually they are viewed as the costs of adapting an innovation to the specific market standards, regulations and norms. To ensure coexistence of exporters and non exporters, I assume $f^* > f$.

Exporting firms also face transport costs ($\tau \geq 1$). Given a specific marginal cost a , the arbitrage in the product market implies that the discounted profit of a firm in a particular market (local or export) must exceed the sunk costs of entry in this particular market.

As in [Melitz \(2003\)](#), two productivity thresholds denoted by a_i and a_i^* appears, allowing for three types of firms: those who immediately exit the market with a too high marginal cost $a > a_i$, those who produce only in the domestic market with marginal cost included between a_i and a_i^* , and those with a marginal cost lower than a_i^* who can also make profit in the export market.

I follow [Gustafsson and Segerstrom \(2010\)](#) and define the flow of new varieties produced in country i as the labour resources attributed to R&D, divided by the expected cost of developing a profitable variety. This cost is defined as \bar{f}_i and is measured in unit of knowledge which price is b_t .

²As there is a single factor of production, labour, a can be seen as the inverse of the productivity.

2.1 R&D specification

At this point, the cost of one unit of knowledge (b_t) has to be specified. As [Jones \(1995\)](#) did first, I use the R&D specification proposed by [Grossman and Helpman \(1991\)](#) and add an intertemporal knowledge spillover parameter ϕ . This parameter allows for both strong scale effects ($\phi > 0$) and weak scale effects ($\phi < 0$). It generalizes the [Grossman and Helpman \(1991\)](#) specification which is $\phi = 1$. [Segerstrom \(1998\)](#) argues that strong scale effects ($\phi = 1$) are not relevant because "steadily increasing R&D effort has not lead to any upward trend in economic growth rates". Therefore, we have:

$$b_t \equiv \frac{1}{m_t^\phi}, \quad (1)$$

where m_t is the worldwide number of produced varieties. Unlike [Gustafsson and Segerstrom \(2010\)](#), I assume that there is perfect international spillovers, so that both countries have access to the same knowledge capital in the innovation sector. Therefore, the cost of a unit of knowledge is the same in both countries. If we let m_{Dt} and m_{Ft} refer to the number of varieties produced in each country, then we obviously have $m_t = m_{Dt} + m_{Ft}$. In what follow, $\gamma_{Dt} \equiv m_{Dt}/m_t$ and $\gamma_{Ft} \equiv m_{Ft}/m_t$ are the share of worldwide varieties produced by each country.

2.2 Asymmetries

The market size is directly connected with the population size L_{it} . Hence, domestic and foreign market size differ as long as $L_{Dt} \neq L_{Ft}$. Following [Falvey et al. \(2011\)](#), the productivity asymmetry appears in the country specific distribution function of firm's marginal cost. I assume Pareto cumulative distribution functions that are different and given by:

$$G_D(a) = \left(\frac{a}{\bar{a}_D}\right)^k, \quad G_F(a) = \left(\frac{a}{\bar{a}_F}\right)^k, \quad (2)$$

where k is a shape parameter. Productivity asymmetries take the form of two different values for the maximal marginal costs \bar{a}_D and \bar{a}_F that a firm can draw from its respective distribution. Assuming $\bar{a}_D < \bar{a}_F$ ensures that the marginal costs distribution of the domestic country always dominate the foreign one, and the domestic country has a strict comparative advantage. In practice, a firm of the foreign country can draw a higher marginal cost than a firm in the domestic country that draw the highest marginal cost available there. This choice of asymmetries also allows me to write the

productivity gap as function of \bar{a}_D and \bar{a}_F as in [Falvey et al. \(2011\)](#): $\mu \equiv \left(\frac{\bar{a}_F}{\bar{a}_D}\right)^k > 1$.

3 Steady-state equilibrium

3.1 Growth rate

In this model, R&D drives economic growth. Therefore, we have to determine the growth rate of varieties in both economies $g_D \equiv \dot{m}_{Dt}/m_{Dt}$ and $g_F \equiv \dot{m}_{Ft}/m_{Ft}$. From $m_t = m_{Dt} + m_{Ft}$, we have that m_{Dt} and m_{Ft} must grow at the same rate g at steady state, and we can solve for g . Differentiating the flow of new varieties, we can find:

$$g_D = g_F = g = \frac{n}{1 - \phi}, \quad (3)$$

where g is the worldwide growth rate of variety. As in [Jones \(1995\)](#) and [Segerstrom \(1998\)](#), we have a semi-endogenous growth model and the steady-state growth rate is constant and depends only on the population growth and the intertemporal knowledge spillover parameter ϕ . To ensure a positive growth rate, we assume that $\phi < 1$.³ Note that even with productivity asymmetries and different market size, the steady-state growth rates of both economies are constant and equal. Therefore, any shock like trade liberalization can only affect the short-run growth rate and ends up with level effect on the endogenous variables.

3.2 Threshold values

We can now determine the productivity threshold values of entry in the local and export markets using a system of six equations given by market entry conditions and innovation incentives in both countries:

$$a_D = \bar{a}_D \left[\frac{f_I}{f}(\beta - 1) \right]^{\frac{1}{k}} \left(\frac{1 - \mu\Omega}{1 - \Omega^2} \right)^{\frac{1}{k}}, \quad a_F = \bar{a}_F \left[\frac{f_I}{f}(\beta - 1) \right]^{\frac{1}{k}} \left(\frac{1 - \mu^{-1}\Omega}{1 - \Omega^2} \right)^{\frac{1}{k}}, \quad (4)$$

$$a_D^* = \bar{a}_D \left[\frac{f_I}{f^*}(\beta - 1) \right]^{\frac{1}{k}} \left(\frac{\mu\Omega - \Omega^2}{1 - \Omega^2} \right)^{\frac{1}{k}}, \quad a_F^* = \bar{a}_F \left[\frac{f_I}{f^*}(\beta - 1) \right]^{\frac{1}{k}} \left(\frac{\mu^{-1}\Omega - \Omega^2}{1 - \Omega^2} \right)^{\frac{1}{k}}, \quad (5)$$

³See the discussion in [Gustafsson and Segerstrom \(2010\)](#) for this assumption.

where $\beta \equiv k/(\sigma-1) > 1$ and σ is the elasticity of substitution between two varieties.⁴ $\Omega \equiv \tau^\beta (f^*/f)^{1-\beta}$ represent the degree of openness: if trade costs (sunk costs and/or transport costs) go to infinity, Ω goes to 0, and if trade is costless ($\tau = 1$ and $f^* = f$), Ω goes to 1. Therefore, an increase in Ω can be seen as trade liberalization.

The threshold values depend on the productivity differences but absolutely not on markets sizes. Unlike [Gustafsson and Segerstrom \(2010\)](#) results, these values are asymmetric for the two countries, for both local and export markets, and we need to impose $\mu = 1$ to obtain their results. In this paper, I focus on the asymmetric case ($\mu > 1$). In order to get relevant positive threshold values we need the restrictions $\Omega < \mu^{-1} < \mu >$. This restriction means that the productivity gap between the two countries must not be too large. With this assumption, we can study the relative threshold values:

$$\frac{a_D}{a_F} = \frac{a_F^*}{a_D^*} = \mu^{-\frac{1}{k}} \left(\frac{1 - \mu\Omega}{1 - \mu^{-1}\Omega} \right)^{\frac{1}{k}} < 1. \quad (6)$$

From (6), the threshold value for local market entry is lower in the domestic market. Unambiguously, we have here a productivity gap effect. To enter the local market, firms in the domestic (foreign) country must have a higher (lower) productivity level because their market is more (less) competitive. In the export market, the threshold value for market entry is higher in the domestic country meaning that firms need lower productivity to enter the export market. Finally, for a firm of the domestic country that produces a new variety, it is harder (in average) to enter the local market, but it is easier to export (compared to a foreign firm).

Knowing the threshold values for market entry, we can determine the costs of a profitable variety for an innovator:

$$\bar{f}_D = f \left(\frac{\beta}{\beta - 1} \right) \left[\frac{1 - \Omega^2}{1 - \mu\Omega} \right], \quad \bar{f}_F = f \left(\frac{\beta}{\beta - 1} \right) \left[\frac{1 - \Omega^2}{1 - \mu^{-1}\Omega} \right]. \quad (7)$$

As long as the domestic country has the productivity comparative advantage ($\mu > 1$), the expected cost of a profitable variety is lower in the foreign country.

3.3 Labour market

We now solve for the labour market equilibrium in both countries. As labour is not mobile internationally, all the labour in one country is employed in the production sector or in the innovation

⁴See Appendix for a detail of calculations.

sector. After calculations of the amount of production and innovation labour, the full employment equilibrium conditions in both countries imply:

$$L_{Dt} = \gamma_D \bar{f}_D m_t^{1-\phi} (g + (\sigma - 1)(\rho + \phi g)), \quad (8)$$

$$L_{Ft} = \gamma_F \bar{f}_F m_t^{1-\phi} (g + (\sigma - 1)(\rho + \phi g)), \quad (9)$$

where ρ is a discount rate. As \bar{f}_D is fixed by (7) and g is fixed by (3), from (8), we can state that any increase in γ_D must be balanced by a permanent decrease in m_t , in order to maintain equality in the labour market. The inverse is true in (9). Then, in the $(\gamma_D; m_t)$ space, the domestic steady state function is upward-sloping whereas the foreign steady state function is downward-sloping. The intersection of the two curves gives a unique steady state m_t corresponding to a specific share (γ_D, γ_F) of produced variety. Using (7), (8) and (9), we have:

$$\frac{\gamma_D}{\gamma_F} = \frac{L_{Dt}}{L_{Ft}} \left(\frac{\bar{f}_F}{\bar{f}_D} \right) = \frac{L_{Dt}}{L_{Ft}} \left(\frac{1 - \mu\Omega}{1 - \mu^{-1}\Omega} \right). \quad (10)$$

Note that both the relative market size and the productivity gap appear in this expression. Thus, they both play a role on the determination of γ_D and γ_F . If $\mu = 1$, and $L_{Dt} = L_{Ft}$, each country produces exactly the same number of varieties and we come back to the results of [Gustafsson and Segerstrom \(2010\)](#). Now we focus on different asymmetric cases.

Proposition 1 *If $\mu = 1$, i) $L_{Ft} > L_{Dt}$ implies $\gamma_F > \gamma_D$, and ii) $L_{Dt} > L_{Ft}$ implies $\gamma_D > \gamma_F$.*

As we can see from (4), if $\mu = 1$ the threshold values of local and export markets entry are equal in both countries, meaning that the cost of developing a profitable variety is also equalized ($\bar{f}_D = \bar{f}_F$). Then, from (10) a bigger country invests more labour forces in R&D, and develops more varieties. Then, market size differences allow the biggest country to invest more labour in R&D than the smaller country and to produce a bigger share of world varieties. This result corresponds to a pure market size effect.

Proposition 2 *If $L_{Dt} = L_{Ft}$ and $\mu > 1$, then $\gamma_F > \gamma_D$.*

When there is no market size difference and the domestic country has a productivity advantage, the foreign country produces a higher share of varieties at equilibrium. This result can be surprising and counter-intuitive but it can be explained by a lower innovation incentives for a potential entrant in the

domestic country. As $\mu > 1$, from (7), it is harder to develop a profitable variety ($\bar{f}_F/\bar{f}_D < 1$), so firms invest less in the R&D sector.

4 Trade liberalization

In this section, I assume that trade liberalization takes place, meaning that transport costs or sunk costs are reduced (τ or f^* are reduced) and Ω increases.

4.1 Impact on threshold values

As Ω appears in the expressions of the threshold values, its increase will have an impact on them. From (4), we see that both a_D and a_F are decreasing in Ω . Trade liberalization induces a reallocation of production (the Melitz effect) which unambiguously raises productivity in both countries. The new opportunities on the export markets due to trade liberalization induce a competitive pressure on the local market. Firms with the lowest productivity level are pushed out and the average productivity raises. However, the magnitude of this reallocation and the impact on productivity in the two countries are not symmetric. From (6), it clearly depends on μ . With $\mu > 1$, any increase in Ω leads to lower a_D/a_F and a_F^*/a_D^* ratios. First, the threshold value of local market entry decreases more in the domestic country than in the foreign one. Second, the threshold value of export market entry increases more in the domestic country than in the foreign one. This is consistent with the long run implication of the reallocation effect found by [Falvey et al. \(2011\)](#), in a static Melitz-type model.

Trade liberalization ($\Omega \uparrow$) induces a reallocation of production that both countries benefit ($a_D \downarrow$ and $a_F \downarrow$). However, this benefit is not symmetric. It does not depend on market size differences but on productivity differences between countries. From (6), when the domestic country has a productivity advantage ($\mu > 1$), its average productivity benefits more than the foreign country from the decreasing trade costs ($\frac{a_D}{a_F} \downarrow$).

4.2 Impact on growth

Trade liberalization does not have any effect on the long run growth rate of variety as Ω does not appear in (3). But in the short run, there is a temporary effect on growth that goes through the labour market. First, if $\mu = 1$, (7) implies that a higher Ω increases the costs of developing a profitable variety in both countries (\bar{f}_D and \bar{f}_F increase). Therefore, the equilibrium equations in labour market are

modified. From (10), the shares of produced varieties are not affected for $\mu = 1$. Therefore, equations (8) and (9) imply that for any permanent increase in \bar{f}_i , m_t must permanently decrease to maintain equality. A permanent decrease in m_t means that the long run level of produced variety permanently decreases so that the world growth rate of innovation temporarily drops under the long run value g . This drop is symmetric in both countries if there are no productivity differences ($\mu = 1$) and the shares of produced variety depend only on market sizes.

Proposition 3 *If $\mu = 1$, then $\frac{\partial \gamma_D / \gamma_F}{\partial \Omega} = 0$ and $\frac{\partial m_t}{\partial \Omega} = \frac{\partial m_{Dt}}{\partial \Omega} + \frac{\partial m_{Ft}}{\partial \Omega} < 0 \Rightarrow \frac{\partial m_{Dt}}{\partial \Omega} = \frac{\partial m_{Ft}}{\partial \Omega} < 0$.*

Proposition 3 states that if there is no productivity difference ($\mu = 1$), trade liberalization implies a permanent decrease in m_t but there is no modification of the shares of produced varieties as we can see from (10), meaning that both growth rates are retarded in the short run and the number of variety produced is lowered in each country identically. This result is similar to the second theorem of [Gustafsson and Segerstrom \(2010\)](#), but in their case, the shares of produced varieties are equal because the market sizes are the same. Here, the shares of produced varieties in both countries depend on the relative market size and only on them. If the domestic country is bigger, then more resources are employed in the innovation sector and more varieties are produced in the domestic country. In the asymmetric case however, the result is different:

Proposition 4 *If $\mu > 1$, then $\frac{\partial \gamma_D / \gamma_F}{\partial \Omega} < 0$ and $\frac{\partial \gamma_D}{\partial \Omega} < 0 < \frac{\partial \gamma_F}{\partial \Omega}$.*

From (10), any increase in Ω leads to a lower γ_D / γ_F ratio for constant market sizes. As $\gamma_D \equiv 1 - \gamma_F$, this means that the share of foreign produced varieties is higher while the share of domestic produced varieties is lower at the new equilibrium. The effect of trade liberalization on productivity growth is therefore clearly asymmetric. The competitive pressure on the local market induced by the reallocation effect reduces the expected profit of an innovation in both local and export markets. Moreover, the cost of a profitable variety increases because it becomes harder to enter the local market. The level of these variables are directly connected to the threshold values and therefore to the productivity gap μ .

As the local market entry threshold decreases more in the domestic country, proposition 4 can be interpreted as follows: innovation incentives are decreasing in both countries but the domestic one is more affected than the foreign one because the reallocation effect is stronger there. Therefore, in the short run, productivity growth decreases more in the domestic country.

In the long run, the growth rates reach their equilibrium values $g = g_D = g_F$ given by (3), and there are only level effects on the number of varieties m_{Dt} and m_{Ft} produced in each country and on the total number of produced varieties m_t . In the new equilibrium, we have a higher share γ_F of foreign produced varieties and a lower share γ_D of domestic produced varieties.

5 Conclusion

This paper shows that asymmetric results occur on the two channels through which trade liberalization affects productivity. First, the reallocation effect found by Melitz (2003) is asymmetric across the two countries and the productivity gains are bigger in the more productive country. Market size differences play no role in determining the threshold values of market entry and therefore have no influence on the reallocation effect. Second, I find that trade liberalization temporarily affects the productivity growth rate in an asymmetric way, leading to a change in the share of variety produced by each country at the new equilibrium. The more productive country suffers a decrease in its share of produced varieties and its productivity decreases relatively to the less productive country at the new equilibrium.

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Appendix: Threshold values

I use the same framework as in [Gustafsson and Segerstrom \(2010\)](#) in order to derive the threshold values given by (4) and (5). The asymmetry across countries yields different *arbitrage* equations for market entry in the domestic and the foreign country. These equations for both local and foreign markets are given by:

$$b_t f = \frac{\chi_D a_D^{1-\sigma}}{\psi_t}, \quad b_t f = \frac{\chi_F a_F^{1-\sigma}}{\psi_t}, \quad (11)$$

$$b_t f^* = \frac{\theta \chi_F a_D^{*1-\sigma}}{\psi_t}, \quad b_t f^* = \frac{\theta \chi_D a_F^{*1-\sigma}}{\psi_t}, \quad (12)$$

where $\chi_D \equiv \sigma^{-\sigma}(\sigma-1)^{\sigma-1} (E_{Dt}/P_{Dt}^{1-\sigma})$, $\chi_F \equiv \sigma^{-\sigma}(\sigma-1)^{\sigma-1} (E_{Ft}/P_{Ft}^{1-\sigma})$, E_{it} represents the aggregate expenditures in both countries, $\theta \equiv \tau^{1-\sigma}$, P_{it} is the aggregate price index in country i and ψ_t is a discount rate.

Also, the *arbitrage* equations for entry in the innovation process for firms of both countries are given by:

$$\begin{aligned} b_t \bar{f}_D &= \frac{1}{\psi_t} \left[\chi_D \int_0^{a_D} a^{1-\sigma} \frac{g(a)}{G(a_D)} da + \theta \chi_F \int_0^{a_D^*} a^{1-\sigma} \frac{g(a)}{G(a_D)} da \right], \\ b_t \bar{f}_F &= \frac{1}{\psi_t} \left[\chi_F \int_0^{a_F} a^{1-\sigma} \frac{g(a)}{G(a_F)} da + \theta \chi_D \int_0^{a_F^*} a^{1-\sigma} \frac{g(a)}{G(a_F)} da \right] \end{aligned} \quad (13)$$

where

$$\bar{f}_i \equiv f \frac{1}{G(a_i)} + f^* \frac{G(a_i^*)}{G(a_i)} \quad i = D, F \quad (14)$$

represent the *ex ante* expected cost of creating a profitable variety. From (11), we can write:

$$\chi_D = \psi_t b_t f a_D^{\sigma-1}; \quad \chi_F = \psi_t b_t f a_F^{\sigma-1} \quad (15)$$

Introducing (15) in (12) we can find:

$$\left(\frac{a_D^*}{a_F}\right) = \left(\frac{a_F^*}{a_D}\right) = \left(\frac{f^*}{\theta f}\right)^{\frac{1}{1-\sigma}}. \quad (16)$$

Then, we use (16) into both equations of (13) and the definition of Ω to find the local threshold values given by (4). Using (4) into (16) we obtain the export threshold values given by (5) Using (14), (4) and (5) we find the expression of the costs of developing a profitable variety in both country (7).

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