

R&D Investment, International Trade, and 'Home Market' and 'Competitiveness' Effects*

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Abstract

We analyze the effects of R&D investment on international trade. The importance of studying this comes from the fact that one of the most important characteristics of modern industrial organization is that firms try to influence market behavior through strategic variables as R&D. Moreover international competition between firms is, more and more, also centered in R&D competition (besides output and price competition). With this in mind, we develop an oligopolist reciprocal-markets model where firms engage in R&D investment to achieve future reductions in marginal costs. We find 'home market effects' at the level of R&D investment, i.e.: firms located in countries that host a higher share of skilled-labor perform higher levels of R&D investment. As consequence, firms in these countries are more competitive than firms in other countries, and as such they can penetrate more easily foreign markets. As result of this 'competitiveness effect', countries where these firms are located run trade surplus, while countries where firms perform lower levels of R&D investment incur in trade deficits.

Keywords: International Trade, R&D Investment, Home Market Effects, Competitiveness Effects.

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1 Introduction

In this paper we try to access in what ways R&D investment by individual firms can affect trade flows between countries. The existing literature on trade patterns under imperfect competition considers either monopolistic competition (Krugman, 1980) or oligopolist competition (Brander, 1981). The first case, assumes preference for variety and differentiated goods; while the second assumes strategic interactions between firms and (most of the times) homogeneous goods. Also, both presuppose that firms act strategically only in one strategic variable (prices in monopolistic competition models and outputs in oligopoly models); and firms do not influence future market behavior since they do not commit inter-temporally (more on this see Neary, 2002). Dynamically this means that firms behave always in the same way in every period since they do not take actions that can affect future performances (as is the case with R&D investment).

However, one of the most pervasive characteristics of modern industrial organization is that firms try to influence market behavior through strategic variables as R&D investment. Moreover international competition between firms is more and more centered also in R&D competition (besides output and price competition). If that is so it is important to analyze in what ways this type of strategic behavior can influence market outcomes, industry dynamics and international trade.

With this in mind, we developed an oligopolist reciprocal-markets model where firms engage in cost-reducing R&D investment. We consider that firms can act strategically in two strategic variables: R&D investment and output. We model the game as a two-stage game: firms invest in R&D in the first stage (pre-market stage) while in the second stage firms compete in outputs (market-stage). As in Spencer and Brander (1983) and Leahy and Neary (1996), the objective of R&D investment is future reductions in the levels of marginal costs.

The first result obtained is the presence of ‘home market effects’ in R&D investment, i.e.: firms located in the country with more skilled labor perform higher levels of R&D investment. As result, firms from this country are more competitive than firms from other countries, since they have lower marginal costs. This ‘competitiveness effect’, allow more efficient firms to penetrate more easily foreign markets.

Given this result, other from Krugman (1980) and Brander (1981) can be qualified. In fact, while in these models the behavior of outputs and prices do not depend on the distribution of demand and labor markets (they only depend on the distribution of firms), the contrary happens in the R&D model. This comes directly from the R&D investment channel, since if the spatial distribution of skilled-labor affects the levels of R&D investment it also affects the levels of outputs and prices.

As consequence, and since the traditional models (standard monopolistic competition and oligopolist models) predicted that exports are not affected when a country increases its share of skilled labor (an increase of skilled-labor in one country always mean a decrease in the other), in the RDM that is not exactly the case. In fact, exports by local firms can even increase when the

country share of skilled-labor increases, since firms in this country become more competitive than foreign firms (remember that firms in countries with more skilled-labor invest more in R&D and as such have lower marginal costs and prices). As result, the balance of trade of a more populated country does not need necessarily to deteriorate when foreign markets shrink (as it happens in the standard monopolistic competition and oligopolist models). In fact, our model predicts that countries with more skilled-labor will tend to run trade surplus, what is not necessarily the case in the models without R&D investment (i.e.: standard monopolistic and oligopolist trade models).

Besides this section this paper has more six sections. In the next section we introduce the base-line model. Our base model has two cases: the monopolistic competition model (from now on MCM) initially developed by Dixit and Stiglitz (1977) and applied to trade questions by people as Krugman (1980); and the Cournot-oligopoly model. In turn, in the Cournot oligopoly model we consider two sub-cases: the standard Cournot-oligopoly model as applied to trade questions by Brander (1981); and the R&D investment oligopoly model (see Spencer and Brander, 1983, for the duopoly case). In the standard Cournot model (from now SCM) firms only compete in quantities, while in the R&D investment model (from now RDM) firms compete in both outputs and R&D investment levels. Then, we present the production equilibrium of the three models as well as some comparative statics. After, we look at the overlapping market condition, i.e.: we establish conditions for trade to be profitable. Then, we analyze the patterns of trade implied by the MCM, the SCM and the RDM. We conclude by discussing the results.

2 The Model

We consider two general trade models: the MCM (see Krugman, 1980); and the oligopolist competition model (see Brander, 1981). The oligopoly model has two sub-cases: the standard oligopolist trade model (SCM) as in Brander (1981), and what we call the R&D investment oligopoly trade model (RDM) of what Spencer and Brander (1983) show the duopoly case. The RDM is the model of concern in this paper, the other two are used as counter-factual.

The encompassing model (i.e.: the common characteristics of all the models) considers two regions, two sectors and two factors of production. The regions/countries¹ are home (H) and foreign (F), where foreign variables are indicated by an asterisk. The two sectors considered are the increasing returns hi-tech sector (HTS) and the constant returns/traditional sector (TS). Note that in the MCM the HTS is also a monopolistic competition sector, while in the oligopoly model the HTS is a oligopolist sector. The goods are the increasing returns sector good (hi-tech good) and the constant returns sector good (traditional good). The traditional good as usual is the *numéraire*. Furthermore the TS -good can be freely trade between regions without having to incur in any type of costs (namely transport costs), while the HTS -good is subject

¹Through the paper we use indifferently regions and countries.

to trade/transport costs (t) when exchange between different regions². In the MCM, these costs take the iceberg form, while in the SCM and the RDM these costs take the form of ad-valorem trade costs. Below we will explain the form of these costs under each model analyzed below.

The two factors of production are unskilled-labor (A) and skilled-labor (L). Both factors are sector-specific: factor A can only be employed in the TS , while factor L in the HTS . Furthermore, the factor A is immobile between regions, and is distributed evenly between regions (i.e.: both home and foreign have $\frac{A}{2}$ units of unskilled-labor). On the contrary, the factor L is perfectly mobile between regions and u ($u \in (0, 1)$) denotes the share of this factor located at H (and $(1 - u)$ at F)³. Below, we will explain how these factors are used in production.

Make also $M = (A + L)$ the total number of workers/consumers (skilled plus unskilled-workers)⁴ in the world economy. Denominating r as the share of workers at H (and consequently $(1 - r)$ the share of consumers at F); then $rM = \frac{A}{2} + uL$ is the number of workers at H ; while $(1 - r)M = \frac{A}{2} + (1 - u)L$ is the number of workers at F . This means, that r is never equal to zero, since there are always a percentage of world workers that are immobile (i.e.: unskilled-labor). Furthermore:

$$\begin{aligned} r &= \frac{\frac{A}{2} + uL}{A + L} \\ (1 - r) &= \frac{\frac{A}{2} + (1 - u)L}{A + L} \end{aligned}$$

Then r only changes with u (since only the skilled-labor moves between locations) and rM is linear in uL . Due to this fact through the paper, and for simplification purposes, we sometimes work with rM instead of $\frac{A}{2} + uL$, but when deemed necessary we show results in terms of u , L and A (instead of r and M only).

Consider N to be the total number of firms in the HTS in the world economy and $sN = n$ the number of firms at H (therefore $(1 - s)N = n^*$ is the number of firms at F). As such s is the share of firms at H ; and $(1 - s)$ is the share of firms at F .

On the other side, in all models analyzed, technology in the TS sector requires 1 unit of A to produce one unit of output. Then, since the good produced in the TS is freely trade, it implies that in equilibrium unskilled labor wages are equal to one in both regions (i.e.: $w_A = w_A^* = 1$). Through the paper this sector is kept in the background. Just mention that the role of this sector is

²We use the terms trade costs and transport costs interchangeably through the paper.

³Note that this paper is not explicitly concern with location questions. Therefore the mobility of skilled workers is assumed not to study migration dynamics and how these affect the location of firms, but instead to analyze in what ways different spatial distribution of skilled workers affect trade flows.

⁴In our model workers (skilled and non-skilled) are both labor force and consumers.

to represent the rest of the economy and to correct trade imbalances that can occur in the *HTS*.

Turning to production in the *HTS*, we consider C as the marginal costs of production and Γ the fixed costs. In all models under analysis both costs are incurred only in terms of skilled-labor. This will be made clear bellow. We also made an additional simplification: we assume that the skilled labor wages are fixed in both regions and are equal to the unskilled labor wages⁵. This implies that $w_A = w_A^* = w_L = w_L^* = 1$, and that our model has a partial equilibrium nature. We assume this for two reasons. The first is for simplification purposes, since the R&D model becomes very cumbersome when wages are not fixed. The second reason, is that we want to isolate any income effects that can affect trade patterns, and concentrate only in the role of R&D (in the case of the RDM). In the other two models (MCM and SCM) we also keep this assumption in order to maintain a comparison basis between the three models.

We further define q as the sales of a representative home firm in the home market; x as the exports by a representative home firm to the foreign market, q^* as the sales of a representative foreign firm in the foreign market, x^* as the exports by a representative foreign firm to the home market, q_0 as the production and consumption of the numéraire good, and I the income.

We turn next to the models under analysis.

2.1 Monopolistic Competition Model

In the MCM the aggregate utility is a Cobb-Douglas function of the *TS* output (q_0) and a CES sub-utility function (Q) derived from consuming the *HTS* good⁶:

$$U = \left(\sum_l^N Q(l) \right)^{\mu \frac{\sigma}{\sigma-1}} q_0^{1-\mu} \quad (1)$$

Where $Q(l)$ is the amount of variety l demanded, and σ (with $\sigma > 1$) the elasticity of substitution between varieties, and μ is the share of nominal income (I) spent on manufactures.

Maximization subject to income (I) results that each consumer spends μI in each variety. Normalizing $\mu I = 1$ (as in Head et al., 2000), then the share spent on each variety is given by:

$$Q(l) = \frac{p_l^{1-\sigma}}{\sum_{m=1}^N p_m^{1-\sigma}}$$

⁵This assumption can be justified if we think of two countries in the same stage of development (for example Holland versus Belgium), since at this level wage differentials should be smaller. At the regional level this can also happen since most OECD countries follow the rule: “same job, same payment”. As corollary our model can hardly be applied in between countries with big wage differentials (e.g.: North-South countries) and/or countries with big regional wage differentials.

⁶In monopolistic competition models varieties equals the number of firms therefore l goes from 1 to N .

Where p is the mill price charged by a representative home firm (and respectively p^* for a representative foreign firm).

We define total profits by a representative home and foreign firm as:

$$\begin{aligned}\Pi_i &= (p_i - C_i) q_i (rM) + \left(\frac{p_i}{t} - C_i\right) x_i ((1-r)M) - \Gamma_i \\ \Pi_i^* &= (p_i^* - C_i) q_i (rM) + \left(\frac{p_i^*}{t} - C_i\right) x_i ((1-r)M) - \Gamma_i^*\end{aligned}\quad (2)$$

Here we are considering trade costs, t , on the iceberg form. Then for each unit consumed, the consumer must order $t > 1$ units (since a share $t - 1$ of the units ordered melts in transit).

Technology in the monopolistic *HTS* imply that both marginal costs and fixed costs are incurred in terms of skilled-labor. Then we have:

$$\begin{aligned}C_i &= c_i w_L \\ \Gamma_i &= f_i w_L\end{aligned}\quad (3)$$

Where c_i are the constant marginal costs, f_i the operational fixed costs, and w_L the wage rate in the increasing returns sector. Furthermore, since all firms are equal (symmetry assumption) then in equilibrium for all i and j (from both home and foreign firms), $c_i = c_j = c$, and also $f_i = f_j = f$. Then in the MCM we have $C_i = C_j = C$, and $\Gamma_i = \Gamma_j = \Gamma$.

2.2 Oligopoly Model

In the oligopoly model we consider quasi-linear preferences in the two goods with a quadratic sub-utility in the good produced by the oligopolist sector:

$$U = aQ - \frac{b}{2}Q^2 + q_0\quad (4)$$

And similarly for the foreign country. Where: $Q = \sum_{i=1}^n q_i + \sum_{i=1}^{n^*} x_i^*$ is the total home consumption of the hi-tech sector goods.

Each individual is endowed with a unit of labor (A or L), and $\bar{q}_0 > 0$ units of the *numéraire* good⁷. Then consumers have the following budget constraint:

$$PQ + q_0 = I + \bar{q}_0\quad (5)$$

From this maximization problem we can get the indirect demand. To do this, solve for q_0 in the budget constraint equation and substitute in the utility function. Then use the first order condition to obtain:

⁷This assumption is made in order to assure that the consumption of the traditional good is always positive (see Ottaviano et al., 2001).

$$P = a - bQ \quad (6)$$

Turning now to firms, we define total profits by a representative H and F firm, respectively as:

$$\begin{aligned} \Pi_i &= (P - C_i) q_i (rM) + (P^* - C_i - t) x_i (1 - r) M - \Gamma_i \\ \Pi_i^* &= (P^* - C_i) q_i^* (1 - r) M + (P - C_i - t) x_i^* (rM) - \Gamma_i \end{aligned} \quad (7)$$

Where t are the specific (per unit) transport costs. The structure of C and Γ will be explained below.

We consider two cases related with the nature of the game played by firms. The first case is the standard Cournot oligopoly model (see Brander, 1981). In this game firms play a simultaneous one shot game in quantities. The second case is the Cournot oligopoly with R&D investment (see Spencer and Brander, 1983 for the duopoly case; and Leahy and Neary, 1996 for the duopoly case with n -sectors)⁸. In this game firms play a two stage game, where in the first stage firms choose levels of R&D investment and in the second stage firms compete in quantities (*a la* Cournot).

Now we explain the structure of C (marginal costs) and Γ (fixed costs). Note that these costs differentiate the SCM from the RDM. In both cases analyzed (SCM and RDM), technology in the *HTS* implies that the marginal costs and fixed costs are incurred only in terms of skilled labor. Then in the SCM we have:

$$\begin{aligned} C_i &= c_i w_L \\ \Gamma_i &= f_i w_L \end{aligned} \quad (8)$$

Where c_i are the constant marginal costs of production, f the operational fixed costs, and w_L the wage rate in the increasing returns sector.

In the RDM we have that C and Γ are equal to:

$$C_i = (c_i - \theta k_i) w_L \quad (9)$$

$$\Gamma_i = \left(\gamma \frac{k_i^2}{2} + f \right) w_L \quad (10)$$

⁸Note that, skilled-workers in the SCM and also in the MCM do not have any special type of skill when compared to the skilled-workers in the RDM (i.e.: they not perform R&D investment). Then, is not accurate to think of them as skilled-labor, instead, and as in Krugman (1991), is more appropriate to designate them as industrial workers. In the same fashion, the good produced by the increasing returns sector in the SCM and in the MCM can hardly be thought as a hi-tech good. The same applies to consider the increasing returns sector in the SCM and in the MCM as a hi-tech sector. Therefore, it is more correct to think of the increasing returns sector in the SCM and in the MCM as a industrial sector that produces a industrial good using as only input industrial workers.

Where k is the level of R&D investment conducted by H firms, θ is a parameter that indicates the cost-reducing effect of R&D investment, and γ is another parameter that measures the cost of R&D investment. Then, R&D investment has two main characteristics: first, reduces marginal costs (that is why this type of R&D investment is also called cost-reducing R&D investment); second, it increases fixed costs. The net effect of R&D on the competitiveness of a firm depends therefore on the balance between marginal and fixed costs: the first increases competitiveness the second reduces profitability. Note also, that the SCM is a special case of the RDM when both θ and γ are zero.

Furthermore, since all firms are equal (symmetry assumption) then in equilibrium in both SCM and RDM, for all i and j (from home and foreign), $c_i = c_j = c$, and $f_i = f_j = f$. Then in the SCM we have $C_i = C_j = C$, and $\Gamma_i = \Gamma_j = \Gamma$. Note however that in the RDM C_i does not necessarily equals C_j and the same for Γ_i and Γ_j ⁹. This happens to be so because if firms perform different levels of R&D investment they can also endogenously differentiate themselves at the level of marginal and fixed costs (since both depend on the level of R&D investment).

3 Production and Equilibrium

In this section we derive expressions for outputs and prices for the SCM and MCM; and outputs, R&D and prices for the RDM. In principle this expressions must depend on both the spatial distribution of firms and workers, as such we derive it for any $s \in [0, 1]$, and $u \in [0, 1]$.

3.1 Monopolistic Competition Model

From profit maximization we get the standard result from MCMs that marginal revenue equals marginal costs:

$$\frac{\sigma - 1}{\sigma} p = c \quad (11)$$

And the same for foreign firm.

Then the individual demand functions for a representative variety produced in each country are given by:

⁹In practice, and since in these type of models firms are only symmetric at the national level (that is why these models are also called ‘national market games’), C_i can only be different of C_j^* (but $C_i = C_j$), and the same for Γ_i and Γ_j^* (but also $\Gamma_i = \Gamma_j$). Note however that in the SCM firms are only symmetric at the national level because of transport costs (at the level of marginal costs and fixed costs home and foreign firms are, unless otherwise assumed, symmetric). In the RDM national and foreign firms can be unsymmetrical, not only because of transport costs but also because of R&D investment. As it will be seen bellow, in this model asymmetries between firms (at the level of marginal costs) arise as a result of asymmetric labor markets.

$$\begin{aligned}
q &= \frac{p^{-\sigma}}{P^{1-\sigma}} \\
x &= \frac{p^{-\sigma}}{P^{*(1-\sigma)}} t^{1-\sigma} \\
q^* &= \frac{p^{-\sigma}}{P^{*(1-\sigma)}} \\
x^* &= \frac{p^{-\sigma}}{P^{1-\sigma}} t^{1-\sigma}
\end{aligned} \tag{12}$$

Where P and P^* are the price index at home and foreign respectively, and are defined as:

$$\begin{aligned}
P^{1-\sigma} &= N \left(s p^{1-\sigma} + (1-s) (p^* t)^{1-\sigma} \right) \\
P^{*(1-\sigma)} &= N \left(s (p t)^{1-\sigma} + (1-s) p^{*(1-\sigma)} \right)
\end{aligned} \tag{13}$$

Then substitute in the expressions for outputs for p and p^* , and P and P^* (noting that $p = p^* = \frac{\sigma}{\sigma-1} c$), to get:

$$\begin{aligned}
q &= \frac{1}{N p (s + (1-s) t^{1-\sigma})} \\
x &= \frac{t^{1-\sigma}}{N p (s t^{1-\sigma} + (1-s))} \\
q^* &= \frac{1}{N p (s t^{1-\sigma} + (1-s))} \\
x^* &= \frac{t^{1-\sigma}}{N p (s + (1-s) t^{1-\sigma})}
\end{aligned} \tag{14}$$

3.2 Standard Cournot Model

In this section we derive expression for outputs and prices for the SCM. The output equilibrium in the SCM is:

$$\begin{aligned}
q &= \frac{D + (1-s) N t}{b (N + 1)} \\
x &= \frac{D - ((1-s) N + 1) t}{b (N + 1)} \\
q^* &= \frac{D + s N t}{b (N + 1)} \\
x^* &= \frac{D - (s N + 1) t}{b (N + 1)}
\end{aligned} \tag{15}$$

Where $D = a - c$ is a measure of market size.

The prices at H and F associated with the level of outputs defined above, are:

$$\begin{aligned} P &= c + \frac{D + (1-s)Nt}{N+1} \\ P^* &= c + \frac{D + sNt}{N+1} \end{aligned} \quad (16)$$

3.3 R&D Investment Model

In this section we derive expression for outputs, R&D investment levels and prices for the RDM. We solve the RDM by backward induction, i.e.: we find first the output stage equilibrium and only then the R&D investment stage equilibrium. The output stage equilibrium is:

$$\begin{aligned} bq &= \frac{D + (1-s)Nt + \theta k((1-s)N+1) - (1-s)N\theta k^*}{N+1} \\ bx &= \frac{D - ((1-s)N+1)t + \theta k((1-s)N+1) - (1-s)N\theta k^*}{N+1} \\ bq^* &= \frac{D + sNt + \theta k^*(sN+1) - sN\theta k}{N+1} \\ bx^* &= \frac{D - (sN+1)t + \theta k^*(sN+1) - sN\theta k}{N+1} \end{aligned} \quad (17)$$

The first thing to note is that outputs increase with the level of local R&D investment (k)¹⁰ weight by the number of foreign firms plus one, and decreases with foreign R&D investment (k^*) weight by the number of foreign firms. This can be interpreted that the assumption of symmetry between national firms leads to ‘national market games’ type of outcomes, i.e.: home firms benefit from positive performance from other national firms (and conversely from negative performance from foreign firms). Note that this happens even without assuming R&D spillovers or other type of external economies.

To solve for the R&D investment stage equilibrium we suppose that there is no strategic R&D investment. In practice this means that firms make their output and investment decisions simultaneously. This hypothesis, made for simplification purposes, does not affect our primary goal that is to see the role of R&D investment in international trade. The only thing that we ignore is the possibility that firms over (or under) invest to influence the final market outcome. We are therefore analyzing the relation between R&D investment and trade patterns when firms invest at the optimal social market level¹¹. Then it comes that the R&D investment stage equilibrium is simply:

¹⁰Since $k_i = k_j = k$ for all $i, j \in n$.

¹¹It can be shown, that the question of strategic investment only matters in these issues when firms have different commitment power, i.e.: some firms can make strategic investment while others can not. When this is the case, asymmetry between firms arises affecting the

$$\begin{aligned}
\gamma k &= \theta M (qr + x(1-r)) \\
\gamma k^* &= \theta M (q^*(1-r) + x^*r)
\end{aligned} \tag{18}$$

It can be easily seen that R&D investment increases with total world population of workers (M) and the cost-reducing effect of R&D investment (θ); and decreases with the cost of R&D investment (γ). Furthermore, and most importantly, the level of R&D investment depends on the size of the local and foreign labor market (r and as such u): it increases with local share of skilled labor and decreases with the foreign share of skilled labor. Since in these type of models, firms depend more on local sales than exports, it is expected that an increase in the number of local skilled workers also increases the total level of R&D investment in that country (we will prove this assertion below).

The model can be solved simultaneously for q , q^* , x , x^* , k , and k^* . For simplification we set $b = 1$. Even so, the RDM gives quite cumbersome expressions for output variables. The only exception is the expression for the level of R&D investment. Given this fact, the strategy that we are going to follow is to present explicitly only the expression for R&D investment (but not the one for outputs), and show some comparative statics analysis for both outputs and R&D investment variables¹².

In the case of the level of R&D investment by a representative home and foreign firm we have that:

$$\begin{aligned}
k &= \frac{\theta M}{\phi} \left((\theta^2 M - \gamma) (D - t(1-r)) - 2\gamma Nt(1-s) \left(r - \frac{1}{2} \right) \right) \\
k^* &= \frac{\theta M}{\phi} \left(2\gamma s Nt \left(\left(r - \frac{1}{2} \right) \right) + (\theta^2 M - \gamma) (D - rt) \right)
\end{aligned} \tag{19}$$

With $\phi = \varphi(\theta^2 M - \gamma)$, where $\varphi = (\gamma(N+1) - \theta^2 M)$ ¹³. As shown in the appendix for having $k > 0$, we need two conditions to be satisfied. The first one, is that the determinant of the system implied by the R&D investment conditions is positive. This implies¹⁴:

comparative relation between firms in the market place (i.e.: some firms are more 'powerful' than others). When firms have the same commitment power (i.e.: whether all firms can make strategic investment, or all firms can not make strategic investment), only the level of R&D investment is affected (i.e.: when firms strategically invest they either over or under invest, and when they do not strategically invest they invest at the optimum level). However, the important point is that if all firms have the same commitment power then firms perform the same level of R&D investment (whatever over, under, or optimally investing), since they are symmetric. Then, also the comparative economic relation between existing firms is not altered, only the level of this relation is affected.

¹²The expressions for the other variables can be obtained upon request to the author.

¹³Note that, q , x , q^* and x^* also have ϕ as denominator.

¹⁴Note that, the condition $\gamma > \theta^2 M$ imply that the cost of R&D investment and the cost reducing effect of investment are closely linked. The parameter γ is only high if it is so in relation to θ . The reverse also holds. For example if $M = 100$, $\gamma = 2550$ is high if $\theta = 1$ (since

$$\gamma > \theta^2 M \quad (20)$$

We call this condition the ‘determinant condition’. This condition implies in turn that $\phi < 0$, and $\varphi > 0$.

From the side of a representative home firm we also need that market size is such that:

$$D > \frac{t}{\theta^2 M - \gamma} \left(\theta^2 M (1 - r) + \gamma \left(2N (1 - s) \left(r - \frac{1}{2} \right) - (1 - r) \right) \right) \quad (21)$$

We call this the ‘R&D condition’. In appendix we show that, as long as, $\gamma > \theta^2 M$, this condition is always satisfied for $r > \frac{1}{2}$ (and as such also for $u > \frac{1}{2}$), since the expression on the right side becomes negative, and D is positive. For $r < \frac{1}{2}$ (i.e.: for $u < \frac{1}{2}$), we need market size to be sufficiently big for this condition to be satisfied.

Note that this condition from the side of the foreign firm is just symmetric¹⁵:

$$D^* > \frac{t}{\theta^2 M - \gamma} \left(\theta^2 M r - \gamma \left(2sN \left(r - \frac{1}{2} \right) + r \right) \right) \quad (22)$$

Then, also as long as, $\gamma > \theta^2 M$, this condition is always satisfied for $u < \frac{1}{2}$; while for $u > \frac{1}{2}$ we need market size to be sufficiently big for this condition to be fulfilled. This means that the country with higher share of skilled labor performs always positive levels of R&D investment independently of market size. Then, the symmetry present in our model implies that if for example the R&D condition for home firms is not satisfied, the R&D condition for foreign firms is satisfied (and vice-versa). However as shown in appendix as long as countries do not differ very much at the level of labor markets, even for not very large market size levels, the two R&D conditions will most of the times be satisfied.

We can also solve for equilibrium prices. The general expression is:

$$\begin{aligned} P &= c + \frac{D + (1 - s) N t - \theta N (s k + (1 - s) k^*)}{N + 1} \\ P^* &= c + \frac{D + s N t - \theta N (s k + (1 - s) k^*)}{N + 1} \end{aligned} \quad (23)$$

Note first, that prices benefit from the levels of R&D investment of both H and F firms. R&D investment in this sense is world welfare improving, since it

the threshold level $\gamma = \theta^2 M$ is 100), but is low if $\theta = 5$ (because in this case the threshold level is 2500). Therefore what matters is not the absolute value of γ or θ , but their relative value.

¹⁵We denote market size by an asterisk to stress that this is the R&D condition from the side of the foreign firm. Note that we do not intend to mean that the foreign market has a different market size. We continue to assume symmetry between countries at this level.

diminishes prices in both countries (but of course it diminishes more the prices in the country where firms that invest are established since consumers do not have to pay the associated extra transport costs).

The explicit expressions for home and foreign prices are:

$$\begin{aligned} P &= c + \frac{\gamma(N+1)(D+Nt(1-s)) - \theta^2 M(D(N+1) - 2Nt(1-r)(s - \frac{1}{2}))}{\varphi(N+1)} \\ P^* &= c + \frac{\gamma(N+1)(D+sNt) - \theta^2 M(D(N+1) + 2rNt(s - \frac{1}{2}))}{\varphi(N+1)} \end{aligned} \quad (24)$$

4 Comparative Statics

In this section we show some comparative statics on the short-run behavior of these three models. We will see that the first two models (MCM and the SCM) have fairly similar behaviors, but the same does not happen with the RDM.

4.1 Monopolistic Competition Model

The comparative statics on the MCM will be used to derive two known results from this model, namely the ‘competition’ and the ‘price index’ effects.

4.1.1 Behavior of Outputs: Competition Effect

The first thing to note, in the MCM is that outputs do not depend on the distribution of demand and labor markets¹⁶:

$$\frac{dq}{du} = \frac{dx}{du} = 0 \quad (25)$$

Whatever the size of the home or foreign market, firms do not appear to react to new market opportunities, i.e.: firms do not increase (decrease) outputs when demand at home or foreign increase (decrease).

On the other side since $\sigma > 1$ local sales decrease with the share of local firms:

$$\frac{dq}{ds} = -\frac{1}{p} \frac{t^{2\sigma} - t^{\sigma+1}}{N(st^\sigma + t(1-s))^2} < 0 \quad (26)$$

This is the so called ‘competition effect’: local sales of a representative firm diminishes with the level of local competition.

¹⁶Note that since outputs do not depend on the distribution of demand, then in order to derive the demand effects (that says that demand per firm is higher in the country with more skilled-labor) we would need to use the profit expressions of a representative home and foreign firm, namely the profit differential between operating at home and at foreign. See Head et al. (2000) on this.

On the contrary, and also since $\sigma > 1$, exports of a representative home firm increase with the share of local firms:

$$\frac{dx}{ds} = \frac{1}{p} \frac{t^{\sigma+1} - t^2}{N (ts + t^\sigma (1-s))^2} > 0 \quad (27)$$

This results also from the ‘competition effect’, when there is less competition in the foreign market local firms find it easier to export.

4.1.2 Behavior of Prices: Price Index Effect

The first thing to be observed is that the price index in a location do not depend on the spatial distribution of demand or labor markets:

$$\frac{dP}{du} = 0$$

Therefore labor and demand patterns do not affect price policies of firms.

On the other side, the relation between the price index and the local share of firms is:

$$\frac{dP}{ds} = -(-1)^{\frac{1}{1-\sigma}} p (s (t^{1-\sigma} - 1) - \rho)^{\frac{\sigma}{1-\sigma}} N^{\frac{1}{1-\sigma}} \frac{1 - t^{1-\sigma}}{1 - \sigma}$$

Since $\sigma > 1$, then it can be checked that this derivative is negative, i.e.: price index is lower in the country that hosts a large share of firms. This is the so called ‘price index effect’, and results from the fact that home produce varieties do not have to incur in transport costs while imports have. As such the country that host more firms (and varieties by consequence of equality between firms and varieties) has a lower price index.

4.2 Standard Cournot Model

The comparative statics on the SCM will be used to show that the MCM and the SCM have similar comparative statics results, and in consequence it also features ‘competition’ and the ‘price index’ effects.

4.2.1 Behavior of Outputs: Competition Effect

As it happened with the MCM, both q and x , in the SCM do not depend directly on the distribution of demand or labor markets¹⁷:

¹⁷Also, as referred above for the MCM, since outputs do not depend on the distribution of demand, in order to derive the demand effects we would need to use the profit expressions of a representative home and foreign firm, namely the profit differential between the two. See Head et al. (2000) on this.

$$\frac{dq}{du} = \frac{dx}{du} = 0 \quad (28)$$

We think that this is so, because when consumers increase in a location this will not result in more sales per firm but the possibility of more firms enter the market in a proportion that maintain constant the level of sales per firm. However this is the economic mechanism in place, this can be thought as a not totally satisfactory explanation for real world events.

On the other side, we can see that local sales per firm decrease with the share of local firms:

$$\frac{dq}{ds} = -\frac{Nt}{(N+1)b} < 0 \quad (29)$$

An increase in the number of local firms make local competition more fiercer leading to a decrease in the level of local sales per firm. Note that this ‘competition effect’ is also present in the MCM.

On the contrary, and also as in the MCM, exports per firm increase with the number of local firms:

$$\frac{dx}{ds} = \frac{Nt}{(N+1)b} > 0 \quad (30)$$

This is so, because when the number of local firms increases (and given the symmetry of the model) the number of foreign firms decreases and as such it is more easy for home firms to penetrate the foreign market.

4.2.2 Behavior of Prices: Price Index Effect

Again the first thing to note is that prices do not depend on the distribution of demand or labor markets:

$$\frac{dP}{du} = 0$$

Once again, as in the MCM, prices do not depend on labor markets or spatial distribution of demand.

On the contrary, we have that prices fall with the number of local firms:

$$\frac{dP}{ds} = -\frac{Nt}{N+1} < 0$$

This results from the competition effect: more competition in a market drives prices down. Note then, that similarly to MCMs, the SCM also predicts ‘price index effects’: the countries with more industry have lower prices.

4.3 R&D Investment Model

The comparative statics on the RDM will show in first place that the results derived before for the SCM and the MCM need to be qualified under the RDM; and second a new set of results will be derived namely ‘home market’ effects on R&D, ‘competitiveness’ effects, and ‘price discrimination’ effects. None of these results are present either on the MCM or SCM.

4.3.1 Behavior of R&D Investment: Home Market Effects in R&D

Comparative statics on the behavior of R&D investment is very important, since in our model, R&D can make firms asymmetric. Has consequence some firms can become more competitive in the market place and affect trade patterns.

The derivative of k in relation to s tell us what happens to the level of R&D investment when competition in a country increases or decreases:

$$\frac{dk}{ds} = \frac{2\theta MN\gamma t}{\phi} \left(r - \frac{1}{2} \right) \quad (31)$$

It happens that this relation depends on the share of workers in each market. A bigger local share of skilled-workers ($u > \frac{1}{2}$) decreases the level of R&D investment when competition increases. The contrary happens for $u < \frac{1}{2}$. When there is a symmetric distribution of skilled-workers ($u = \frac{1}{2}$) the level of R&D investment is unaltered, even when the share of firms is increasing in the region.

Therefore, what determines the behavior of R&D investment in relation to the competitive environment is the share of skilled workers/demand in a region. This is so for three motives. The first one, is that when the local labor market is bigger, local firms have a natural cost advantage over foreign firms since they do not have to incur in trade costs to serve local consumers. As such local firms do not need to invest so much in R&D to capture market share. The second reason, is that when competition in the local market increases the probability that an increase in R&D investment will lead to conquer market share can be very small since fierce competition have already probably lead prices down to break even levels (i.e.: close to marginal costs). The third reason, is that when firms have local markets of the same size ($u = \frac{1}{2}$), firms invest the same even if faced with more competition, the adjustment will come through the number of local firms and not through the level of R&D investment.

To show the existence of ‘home market effects’ in R&D, we look at the derivative of R&D investment in relation to local share of skilled-workers:

$$\frac{dk}{du} = -\frac{\theta Lt}{\phi} (\gamma (2(1-s)N + 1) - \theta^2 M) \quad (32)$$

It can be easily seen, that the level of R&D investment always increase

with the share of local skilled-workers¹⁸. Firms located in the region that hosts a higher share of skilled-workers (and demand) will perform higher levels of R&D investment. Therefore we have ‘home market effects’ at the level of R&D investment. This in turn implies that firms located in the country with more skilled labor are more competitive than their foreign counterparts (since they have lower marginal costs, i.e.: a ‘better’ production technology). Therefore, R&D investment, through the labor market channel, allow firms to become endogenously asymmetric: firms that perform higher levels of R&D investment will have lower marginal costs, and this allows them to make higher profits. The asymmetry results from different labor market conditions, i.e.: labor markets can differentiate firms at the level of costs because it allows them to perform different levels of R&D investment according to the spatial distribution of skilled labor.

4.3.2 Behavior of Outputs: Competition Effect Revisited

We start by analyzing how local sales change with local competition. The derivative of q in relation to s is:

$$\frac{dq}{ds} = -\frac{Nt}{\phi(N+1)} (2\theta^2 M (1-r) (\gamma(N+2) - \theta^2 M) - \gamma^2 (N+1)) \quad (33)$$

The sign of this derivative is not straight forward and we had opted to use simulation techniques to see its behavior.

We start by setting $N = 100$, $A = 50$, $L = 50$ (i.e.: $M = 100$), $t = 2$, $\theta = 5$, $\gamma = 3000$, and $D = 5000$. This is our central case. As we can see in the figure bellow the derivative is negative only for u superior to a threshold value (the expression is negative for $u > 0.30$, and the reverse for $u < 0.30$). This comes in contrast with the SCM and RDM where local sales always decrease with local share of firms. Here local sales only decrease with local sales when a country hosts a share of skilled-labor superior to a threshold value. This shows that the local sales of firms located in small countries (as mirrored by the low share of skilled-labor located there) can increase when the level of competition in the local market increases since they can take away sales to foreign exports.

We also check how these results change with different values. The first thing to note, is that changing the level of trade costs (t), or the number of firms (N), does not change the results. Only changes in γ , θ , M , or in the relation between A and L affects the results. Note then, that increasing γ is the same as decreasing θ , or M , and decreasing γ is the same as increasing θ , or M , since these are connected through the stability condition $\gamma > \theta^2 M$.

Increasing γ for 5000 (keeping constant the rest of the parameters) we get that the derivative is negative for any value of u (see figure bellow). The same scenario arises if we increase $A = 90$ and $L = 10$ (keeping therefore constant M).

¹⁸In fact, the derivative of k in relation to u is always positive, since what is inside paren-

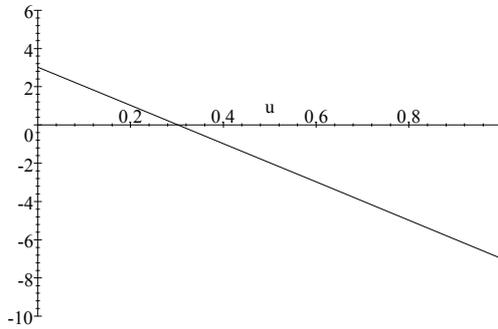


Figure 1: Derivative of q in relation to s (central case)

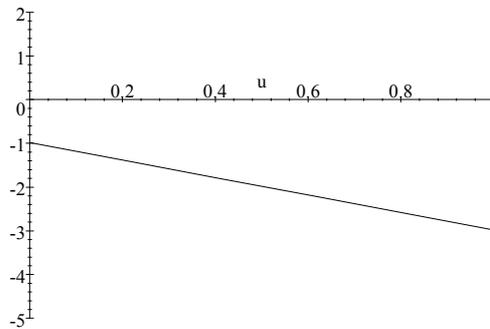


Figure 2: Derivative q in relation to s ($\gamma = 5000$, $A = 90$ and $L = 10$)

Decreasing γ for 2550 or increasing L in relation to A (but keeping M constant, for example setting $A = 10$, and $L = 90$) we get that the threshold value increases from the central case to values close to one-half (see figure below).

The rationale for this is that, when γ is low, firms located in the country that hosts less workers can take sales away from firms from the country with more skilled labor (i.e.: more competitive firms) because R&D investment is not too costly, and so they can ameliorate their competitive position vis-a-vis their foreign competitors through less expensive R&D activities. Therefore, lower costs of R&D helps less competitive firms (since firms located in the country with less skilled labor perform lower levels of R&D investment). As corollary, the competition effect present in the SCM and in the MCM needs some further

thesis is always positive. To see this, note that the first term is always positive and being that so, it means that the first term is also always bigger than the second since $\gamma > \theta^2 M$.

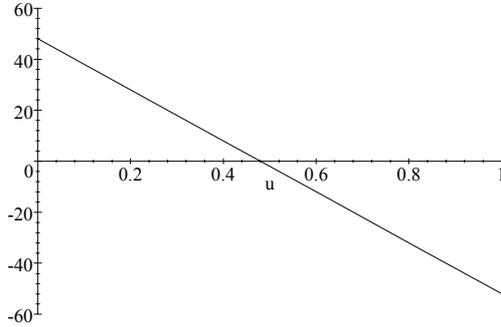


Figure 3: Derivative q in relation to s ($\gamma = 2550$, $A = 10$ and $L = 90$)

qualifications under the RDM. In fact some firms can benefit from increases in local competition as long as these firms are less competitive (i.e.: as long they are located in the country with less skilled-labor).

Also if A is relatively larger than L , competition (for local inputs and markets) is too fierce, and therefore local sales always decrease with local share of firms. If on the contrary L is relatively large to A , then competition is not so strong and the level of competition only affects negatively local sales when a country hosts a share of skilled labor above a threshold value.

The derivative of exports in relation to local share of firms is:

$$\frac{dx}{ds} = \frac{Nt}{\phi(N+1)} (2r\theta^2M(\gamma(N+2) - \theta^2M) - \gamma^2(N+1)) \quad (34)$$

We opted again to use simulation methods to check the sign of the derivative. The central case is once again: $N = 100$, $A = 50$, $L = 50$ (i.e.: $M = 100$), $t = 2$, $\theta = 5$, $\gamma = 3000$, and $D = 5000$. As it can be seen in the figure bellow the derivative is only positive for u inferior to a threshold value. For u superior to a threshold value the derivative is negative (the expression is negative for $u > 0.70$, and the reverse for $u < 0.70$). This comes in contrast with the SCM and MCM. This happens to be so because for higher values of u the exporting market becomes too small for allowing exports to increase for home firms. The RDM therefore captures the effects of the size of the exporting market.

We also check how these results change with different values. Once again, changing the level of trade costs (t), or the number of firms (N), does not affect the results.

The derivative is only sensible to changes in γ , θ , or M , or in the relation between A and L . Increasing γ for 5500 (keeping constant the rest of the parameters) we get that the derivative is positive for any value of u . The same happens if increase $A = 90$ and decrease $L = 10$ (keeping constant M).

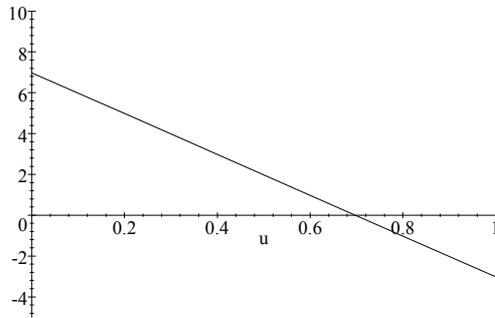


Figure 4: Derivative of x in relation to s (central case)

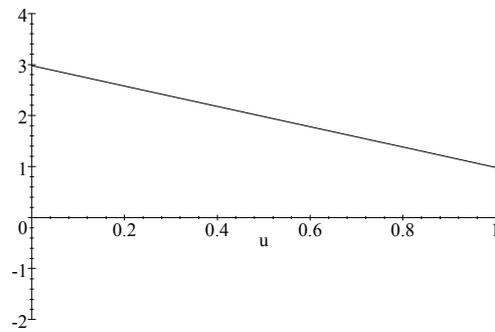


Figure 5: Derivative of x in relation to s ($\gamma = 5000$, $A = 90$ and $L = 10$)

Decreasing γ for 2550, or making L relatively larger than A (for example $A = 10$, and $L = 90$) we get that the threshold value of u decreases in relation to the central case to values close to one half (see figure bellow).

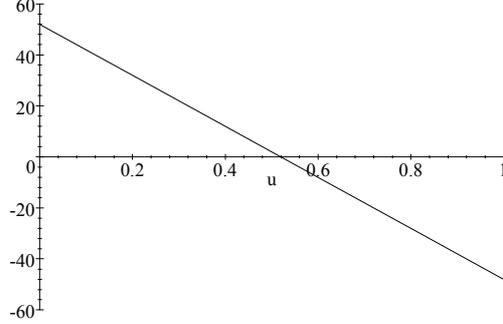


Figure 6: Derivative of x in relation to s ($\gamma = 2550$, $A = 10$ and $L = 90$)

The rationale for this is that when γ is low, more competitive firms (i.e.: firms located in the country with more skilled-labor) find it harder to impose their competitive edge over less competitive firms. Once again lower costs of R&D investment can help less competitive firms¹⁹. And as such less competitive firms can compete more efficiently with exports of more competitive firms.

Furthermore if A is relatively larger than L , exports always increase with local share of firms, since the location patterns of skilled-labor do not affect very much export behavior. If on the contrary L is relatively large to A , location patterns of skilled-labor can affect export behavior, and the derivative is negative for u bigger than a threshold value. This happens because when skilled-labor is very abundant less competitive firms have more easy access to this factor to compete in more equal terms with more competitive firms.

4.3.3 Behavior of Outputs: Competitiveness Effect

The derivative of local sales and exports in relation to u is the same in both cases:

$$\frac{dq}{du} = \frac{dx}{du} = -t\theta^2 L \frac{(\gamma(2N(N+2)(1-s)+1) - \theta^2 M(2N(1-s)+1))}{\phi(N+1)} \quad (35)$$

¹⁹This result agrees with those who defend that one of the main roles of industrial policy is to create conditions for firms to have low costs of R&D investment in order to compete with more competitive foreign firms. Note that we are not only referring to R&D subsidies policies but any other policy that promotes R&D investment (as training, R&D infrastructures, universities, and so on).

First note, that this derivative is unambiguously positive²⁰. As expected (but even so not the case under the SCM or MCM), local demand contributes positively for local sales (demand effect). The same is not straight forward in the case of exports. The rationale for exports to increase with u is that when u increases, k also increases, and so local firms become more competitive than foreign firms. As consequence of this ‘competitiveness effect’, firms located in the country with more skilled labor can gain market share in the foreign market. Note that this comes in contrast with both the SCM and MCM in which u did not affect exports and local sales.

This shows the presence of ‘competitiveness effects’ in the RDM. When u increases in a location this makes firms in this location to invest more in R&D (‘home market effects’ in R&D). In turn, this makes local firms more competitive than foreign ones, since they will have lower marginal costs (‘competitiveness effects’) due to R&D investment. Therefore asymmetric labor markets turn firms asymmetric through the R&D channel leading to ‘home market effects’ in R&D and ‘competitiveness effects’.

4.3.4 Behavior of Prices: Spatial Price Discrimination Effect

The derivative of prices in relation to home share of skilled-labor is:

$$\frac{dP}{du} = - \left(s - \frac{1}{2} \right) \frac{2\theta^2 NtL}{\varphi(N+1)}$$

Prices decrease with local share of skilled-workers for $s > \frac{1}{2}$, increases for $s < \frac{1}{2}$, and are unchanged for a symmetric pattern location of firms (i.e.: $s = \frac{1}{2}$). When demand is increasing in the small industrial country prices can go up for two reasons. First, because some of this extra demand has to be satisfied by foreign firms whose products incur in trade costs. Second, because an increase in demand in this country can mean more monopoly power (and as such higher prices) for existing firms. The contrary happens in the country that hosts more firms since an increase in local share of consumers has as side effect an increase in R&D and as such reduction in costs and (in the end) in prices. Demand and labor market spatial patterns, and contrary to what happens in the SCM and MCM, therefore influence directly the behavior of prices and this fact comes in side with the evidence on spatial price discrimination literature.

The behavior of prices in relation to home share of firms is:

$$\frac{dP}{ds} = - \frac{Nt}{\varphi(N+1)} (\gamma(N+1) - 2\theta^2 M(1-r))$$

Prices at home decrease when competition at home also increases (competition effect). See proof in appendix. The rationale is the same as before for

²⁰To see this note that the multiplicative term is always positive, and the same happens with what is inside parenthesis since $\gamma > \theta^2 M$.

the SCM and MCM, when more firms are located in one country, consumers from that location do not have to pay for so many products the extra cost of transport costs. As such, in the RDM we also have in place a mechanism similar to the ‘price index’ effect present in the MCM and SCM: prices are lower in the countries with more industry, and as such welfare is also higher in these locations.

5 Overlapping Market Condition

The overlapping market condition (OMC) gives the threshold level of market size (or trade costs) that makes trade profitable for firms (see Brander, 1981). Below this threshold level we are in autarchy: exports are too costly for firms; above this threshold trade is possible: exports are profitable.

As showed by Brander (1981), the *OMC* from the side of the foreign firm is obtained by setting $x^* = 0$, at $s = 1$ and solving for trade costs or market size²¹. Therefore, the OMC states the minimum market size necessary (or maximum trade costs level) for a potential foreign firm be able to export profitably to the home country when home hosts all the firms. This condition can also be defined from the point of view of the home firm. The correspondent OMC from the side of the home firm is obtained by setting $x = 0$ at $s = 0$ and then also solve for market size or trade costs. The interpretation is the same as before for the OMC from the side of the foreign firm. We will see below that under the SCM and MCM this condition is the same for both home and foreign firms. However, under the RDM that is not the case anymore. This happens because firms can endogenously become asymmetric as result of R&D investment, and being that so, is also natural that home and foreign firms have different levels of market access to international markets (i.e.: they have different OMC).

5.1 Monopolistic Competition Model

In the MCM, the OMC is the same for both a representative home and foreign firm. In fact whatever setting $x^* = 0$ at $s = 1$, or $x = 0$ at $s = 0$, and then solve for trade costs, the result comes that for all levels of trade costs trade is always possible, since $t > 1$ ²². Therefore under the MCM trade is never forbidden.

5.2 Standard Cournot Model

In both the SCM and the RDM we opt by defining the *OMC* in relation to market size²³. Then by setting $x^* = 0$, at $s = 1$ and solving for D we get:

²¹Note that in all models considered is possible to solve the OMC for the trade costs variable. On the contrary it is only possible to solve the OMC for the market size variable in the oligopoly model (since the monopolistic competition model does not have the variable market size).

²²Only when $t = 0$, it is not profitable for a potential home or foreign firm to export, but since iceberg trade costs assume $t > 1$, then trade is always possible under the MCM.

²³We opt for define the OMC in relation to market size for two reasons. The first one, is that is completely indifferent to define it in relation to trade costs or market size. The second

$$D > t(N + 1) \tag{36}$$

As such in the SCM the *OMC* gives the relation between market size (D) and trade costs (t), and the total number of firms in the world economy (N), that makes trade profitable for an individual firm. Trade is restricted the higher the trade costs and the larger the number of firms in the world economy. The role of trade costs is self explanatory: higher trade cost makes exports more costly. More firms means more competition, and therefore less output per firm, and this in turn less profitability of exports.

One further point must be made about the *OMC*. We need to stress that as we have explained in the introduction to this section, the way we defined the *OMC* above, sees trade from the point of view of the foreign firm: if home host all the industry, the *OMC* gives the trigger level of market size that makes exports profitable for a potential foreign firm (a similar analysis can be made from the point of view of the home firm). Below this threshold level foreign firms are not able to export to the home market and therefore the home country in practice is protected from foreign competition (i.e.: autarchy)²⁴. However, and since the model is symmetric the same condition applies for home firms to export to the foreign market²⁵. Therefore, for $D < t(N + 1)$ we are in fact technically in autarchy.

Since we are concerned we international trade questions we want therefore to prevent cases where trade is forbidden. As such we assume through the paper that the *OMC* for the SCM is always satisfied, i.e.: $D > t(N + 1)$.

Finally, we show some comparative statics in the behavior of the *OMC*. The important thing to note is that, the *OMC* is not affected by changes in the local share of consumers (u):

$$\frac{dOMC}{du} = 0$$

Firms decision to export is not affected by the size of the consumer or labor markets in the destination country (i.e.: trade is not affected by the exporting market demand conditions). This comes as a not very realistic result, since higher potential demand in a country should make it easier for a foreign firm to export to that country (i.e.: demand should facilitate trade).

reason, is that we think that the natural way for a exporting firm to look at the foreign market is to know if the market size in that country is sufficiently big to compensate for trade costs (or all other type of costs as it comes in the R&D model), and not if trade costs are sufficiently low to export.

²⁴Note however, that the *OMC* is not an entry condition, if firms are not able to export they can always sell in their own market. Also, even if export is profitable, it does not necessarily mean that firms can enter the market. For example foreign and local competition can prevent entry. Entry and exit analysis need to consider other type of issues as competition, demand, and in general profitability.

²⁵To see this make $x = 0$ at $s = 0$, and solve for D . The result state above follows.

5.3 R&D Investment Model

The *OMC* for the RDM (from the perspective of the foreign firm) comes (setting as before $x^* = 0$, at $s = 1$ and solving for D)²⁶:

$$D^* = t(N + 1) + N\theta k - \theta k^*(N + 1) \quad (37)$$

In the RDM the *OMC* gives the relation between market size, trade costs, and R&D investment by H and F firms that makes trade possible. It can also be seen that the *OMC* increases with trade cost, and the level of R&D investment by H firms, while it decreases with the level of R&D investment by foreign firms. This comes at no surprise, since the more the home firms invest in R&D more difficult foreign firms will find to export to the home market. Conversely, also the more the foreign firms invest more easily they will find to export to the home market.

However now the *OMC* from the perspective of the home firm is not equal to the *OMC* from the perspective of the foreign firm (as it happen in the SCM). In fact the *OMC* from the perspective of the home firm is:

$$D = (t(N + 1) + N\theta k^* - \theta k(N + 1))$$

This increases as before with trade costs and the total number of firms in the world economy, but now the role of R&D investment by home and foreign firms is inverted. The *OMC* from the perspective of the home firm, increases with foreign R&D investment and decreases with home R&D investment.

We can derive the explicit expressions for both *OMC* (substituting for k and k^*). The *OMC* from the perspective of a potential foreign and home firm, respectively, are:

$$D^* = t \frac{\theta^2 M (\theta^2 M (2N+1)(1-r) - \gamma (2(N^2+1) + 5N - r(2N(N+2)+1))) + \gamma^2 (N+1)^2}{\gamma (N+1) (\gamma - \theta^2 M)} \quad (38)$$

$$D = t \frac{\gamma^2 (N(N+2)+1) - \gamma \theta^2 M (r(2N(N+2)+1) + (N+1)) + r \theta^4 M^2 (2N+1)}{\gamma (N+1) (\gamma - \theta^2 M)} \quad (39)$$

Once again we stress that since this paper is concerned with international trade questions, we want to rule out cases where trade is not possible for all firms. However under the RDM, as we will see bellow, it can happen that trade is not possible for foreign firms but possible for home firms (and *vice-versa*). This happens because home and foreign firms have different *OMC*. Being that so we only rule out cases where both home and foreign firms can not export, but this not necessarily means that we need to assume that the two *OMC* of the RDM have to be satisfied. For example it can happen that only the *OMC*

²⁶We denote market size by an asterisk to stress that this is the *OMC* from the side of the foreign firm. Note that we do not intend to mean that the foreign market has a different market size. We continue to assume symmetry between countries at this level.

from the side of home firms is satisfied (while the OMC for foreign firms is not). Then home firms can export to the foreign country, but foreign firms can not. If this is the case we will accept this scenario as valid for our analysis. Therefore we only rule out cases where both OMCs (OMC from the side of home firms and OMC from the side of foreign firms) are not satisfied.

5.3.1 Access to International Markets

If home and foreign firms have different OMC, they also can have different levels of market access. This does not happen in the SCM or MCM where all firms, under all possible scenarios have the same level of market access since they are symmetric in all aspects. On the contrary in the RDM, firms from one country can have better access to exports markets, since firms can become asymmetric due to asymmetric labor markets and R&D investment. We investigate under what conditions some firms can penetrate more easily foreign markets than their foreign competitors. To do this, first note that the difference between the OMC of a representative home firm and the OMC of a representative foreign firm is:

$$D_{OMC} - D_{OMC}^* = -2t\theta^2 M \left(r - \frac{1}{2} \right) \frac{\gamma(2N(N+2)+1) - \theta^2 M(2N+1)}{\gamma(N+1)(\gamma - \theta^2 M)}$$

It can be easily check that this difference is negative for $u > \frac{1}{2}$, positive for $u < \frac{1}{2}$, and zero for $u = \frac{1}{2}$ ²⁷. Then, when $u > \frac{1}{2}$, home firms can penetrate more easily the foreign market (than their foreign counterparts the home market), since the OMC for home firms is smaller than the OMC for foreign firms. The reverse happens for $u < \frac{1}{2}$. This is so because when a country hosts more skilled-labor, firms located in this country perform more R&D and therefore are more efficient and competitive. When this happens firms from different countries have different levels of market access.

At $u = \frac{1}{2}$ the equality for the two OMC observed in the SCM is restored. In fact at $u = \frac{1}{2}$ both OMC are equal and simplify to:

$$D = D^* = \frac{1}{2} \left(2\gamma(N+1)^2 - \theta^2 M(2N+1) \right) \frac{t}{(N+1)\gamma}$$

Therefore, as long as skilled-workers are evenly distributed firms have the same level of access to international markets. This happens because for $u = \frac{1}{2}$ home and foreign firms invest the same, and therefore they not become asymmetric. If they are not asymmetric they can not also have different levels of market access.

The problem comes for $u \neq \frac{1}{2}$, since countries are not only made asymmetric because of different labor spatial patterns, but also firms are asymmetric because they perform different levels of R&D investment, i.e.: firms located in

²⁷To see this note that since $\gamma > \theta^2 M$, then both the nominator and the denominator are positive.

the country that hosts a large share of skilled workers invests more what makes them more competitive. Being that so, more competitive firms also find more easily to penetrate foreign markets than their counterparts.

Given this, we are interested in four issues related with the OMC of the RDM. The first thing, is to sign the OMC (i.e.: under what conditions is positive or negative). If it is negative, then we know that it is always satisfied since $D > 0$. If on the contrary it is positive, for trade to be possible firms depend on market size to be able to export. The second issue, relates with how the OMC is related with demand and labor market patterns. More demand in a country makes it easier for firms to export to that market, or the contrary happens because of labor market effects? This last case can result, because firms located in countries more endowed in skilled labor are more competitive. The third issue, concerns with how the OMC is related with the OMC of the SCM, i.e.: under what model trade is more restricted (or promoted). Finally, we want to know if the OMC is a sufficiently condition for the R&D condition (i.e.: condition that assures that R&D investment levels are positive) be satisfied.

5.3.2 Sign of the OMC: R&D as an Barrier to Trade

It is not a simple task to sign the OMC expression ²⁸. We have chosen to use simulations to see how this change with different parameter and variable values. We start by setting $\theta = 5$, $M = 100$, $\gamma = 3000$ (remember that we need that $\gamma > \theta^2 M$), $t = 2$, and $N = 100$ (see figure bellow²⁹). For these values we get that the OMC is negative for $u < 0.30$, and positive for $u > 0.30$. This means that for $u < 0.30$, trade is always possible for a potential foreign firm, since $D > 0$.

The figure also illustrates the role of market size in international market access. For high values of market size, as it is expected (and as is the case in the SCM), trade is always possible since the OMC is satisfied. For lower levels of market size (and contrary to the SCM), trade is not possible only for higher values of u (i.e.: when home hosts relatively more skilled-labor), for lower values of u foreign firms can penetrate the home market since the OMC is negative and D is always positive. Under the SCM for lower levels of market size trade is never profitable.

We also check the robustness of the results. The first thing to note from this analysis is that changing the level of trade costs (t), or the number of firms (N) does not change the threshold value of u . In fact, for example, for $N = 10$, or $t = 1$, we have a similar picture³⁰:

The same for $N = 1000$, $t = 50$, we have³¹:

²⁸We check the sign of the OMC from the perspective of a representative foreign firm, but note that the same results apply by symmetry to the OMC from the perspective of a representative home firm.

²⁹The red line shows the OMC from the side of a representative foreign firm. The blue line shows the OMC from the side of a representative home firm.

³⁰This figure is plot for $t = 1$, but a similar picture is obtained for $N = 10$.

³¹This figure is plot for $t = 200$, but a similar picture is obtained for $N = 1000$.

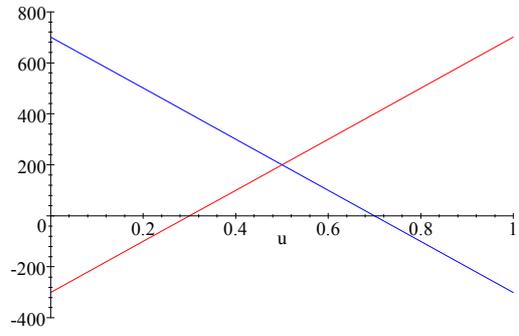


Figure 7: OMC: central case

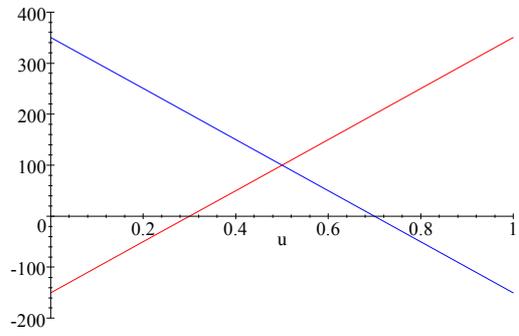


Figure 8: OMC: $t = 1, N = 10$

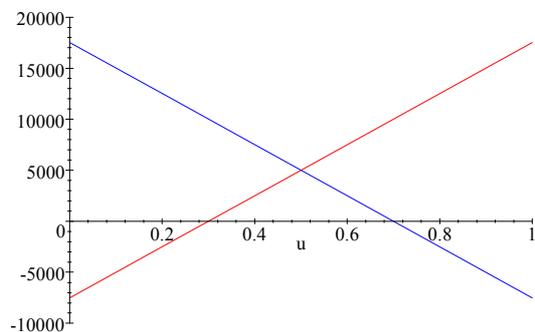


Figure 9: OMC: $N = 1000, t = 50$

The only difference in relation to the central case is that the maximum value of market size needed for trade to be always possible is bigger when t or N are larger, and small when t or N are smaller. Therefore when trade costs are smaller and competition softer, trade is made easier.

On the contrary changes in γ , θ , M , or in the relation between A and L affects the threshold value of u . Note then that increasing γ is the same as decreasing θ , or M , and decreasing γ is the same as increasing θ , or M , since these are connected through the stability condition $\gamma > \theta^2 M$. Increasing γ for 5000 (keeping constant the rest of the parameters) we get that the OMC is positive for any value of u . Then trade to be possible (or not) will depend on whatever market size is sufficiently high (or not) to make trade possible (see figure).

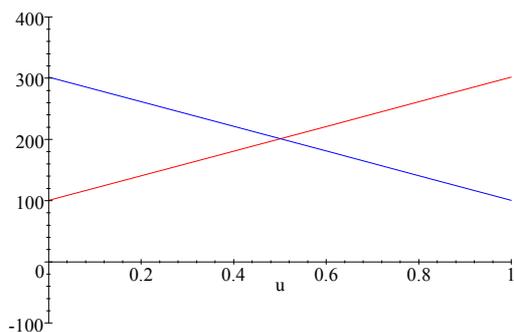


Figure 10: OMC: $\gamma = 5000$

Decreasing γ for 2550 we get that the OMC is negative for $u < 0.48$, and positive for $u > 0.48$ (see figure)³².

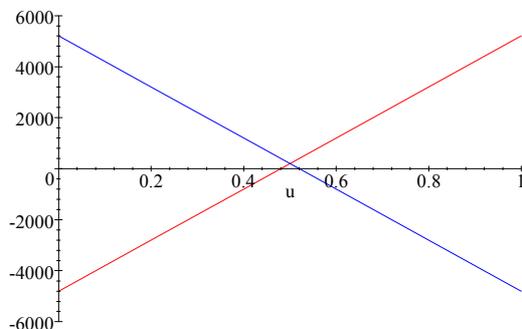


Figure 11: OMC: $\gamma = 2550$

Then, we have that for very high γ in relation to $\theta^2 M$, the OMC is always positive. Therefore, when this is the case we always need market size to be sufficiently big for trade to be possible. For lower levels of γ (in relation to $\theta^2 M$), the OMC is positive for u superior to a threshold value of u , and negative for the reverse. This threshold level of u has its maximum at γ close to $\theta^2 M$ (where the threshold is one-half), and the minimum $u = 0$ for very high γ .

As corollary, firms in the country with more skilled-workers are more protected from foreign competition. This happens to be so because firms in this country invest more in R&D, as such R&D investment protects firms from foreign competitors and its role is similar to trade costs and trade barriers since it prevents foreign firms to enter the local market through exports. Note however that the maximum value of market size need for trade to be profitable is lower when γ is bigger. This means that higher costs of R&D gives less competitive advantage to firms from countries that host a higher share of skilled-labor.

Changing the relation between A and L (but keeping constant $M = A + L$), also affects the results. If A is relatively larger in relation to L (for example if $A = 90$, and $L = 10$) then the derivative is positive for any value of u (see figure).

If L is relatively larger in relation to A (for example if $A = 10$, and $L = 90$), the OMC is positive for $u > 0.40$, and the negative for $u < 0.40$.

However, the maximum value of market size need for trade to be possible is smaller when unskilled-labor is relatively more than skilled-labor. This happens to be so because when unskilled-labor is relatively more than the skilled-labor firms find it difficult to gain competitive advantage over foreign firms even when the country where they are located host more skilled-labor.

³²At $\gamma = 2501$ the OMC is positive for $u > 0.5$ and negative for $u < 0.5$. Therefore the OMC for $u > 0.5$ is always positive.

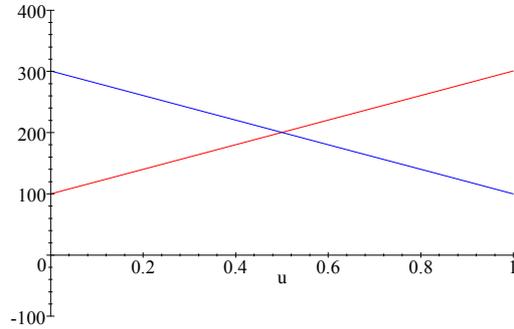


Figure 12: OMC: $A = 90$, $L = 10$

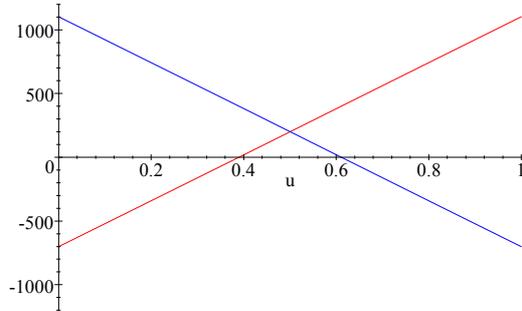


Figure 13: OMC: $A = 10$, $L = 90$

Then the OMC (from the side of a representative foreign firm) increases with L , N , t , and θ ; and decreases with A and γ ³³. When the world endowment of skilled-labor is big, this will allow more firms to coexist (whatever the spatial distribution of this factor) and therefore make markets more competitive and exports less profitable. When N is big the same effect occurs, more competition and as such trade more difficult for firms. Also when R&D is very effective (i.e.: high θ), competition will be fiercer and exports more penalized. On the contrary when γ is high, competition will be softer because less firms can stay in the market when the costs of R&D (i.e.: the fixed costs) are larger. When A is relatively larger than L , trade is made easier because there is less skilled-labor to make firms asymmetric and as such competition harder. Therefore trade is

³³We have shown this by simulation methods, but the same result can be obtained by making use of derivatives.

both related with competition and R&D investment patterns.

5.3.3 OMC and u : Spatial Labor Markets as a Barrier to Trade

Other important thing, is that now, and contrary to the SCM, the OMC depends on the share of consumers in a location. In fact the derivative of the OMC in relation to u is:

$$\frac{dOMC}{du} = -t\theta^2 L \frac{\gamma(2N(N+2)+1) - \theta^2 M(2N+1)}{\gamma(N+1)(\gamma - \theta^2 M)}$$

The derivative of the OMC in relation to the local share of consumers is negative (i.e.: increasing u makes trade more difficult for foreign firms)³⁴. This is so because when home host a large share of skilled-workers, home firms also invest more in R&D than their foreign counterparts, and as such home firms are more competitive than foreign firms. Therefore, foreign firms find it hard to penetrate the home market both because of trade costs and because home firms have a competitive edge over them. The contrary happens with home firms, higher levels of u make it more easy for them to penetrate the foreign market.

In fact, since the two OMC of the RDM are symmetric (see also figures above), while the OMC from the side of foreign firms increase with u , the OMC from the side of home firms decrease with u . Then it can happen that for high values of u trade is not possible for foreign firms but it is possible for home firms (and the reverse for low values of u). These cases are not possible under the SCM (or MCM) but are important since these can lead to different trade patterns not present in the SCM or MCM, as we will see bellow.

5.3.4 OMC RDM versus OMC SCM: R&D, Trade and Efficiency³⁵

As shown in appendix the OMC for the RDM (from the side of the foreign firm, and by symmetry for the OMC form the side of the home firm) is superior to the OMC of the SCM for $u > \frac{1}{2}$, and the reverse for $u < \frac{1}{2}$. Therefore, when the home country hosts a larger share of skilled-workers, trade for foreign firms is restricted relatively to the SCM case. On the contrary, when home hosts less skilled-workers, then foreign firms will find it easier to export to the home market under the RDM case than under the SCM case. Then, we conclude that R&D investment is an impediment for trade for firms that are not so competitive, but promotes trade for firms that are more efficient, i.e.: there is a close link between R&D, trade and efficiency.

³⁴To see this note that the multiplicative term is always positive, and the same for what is inside parenthesis (since $\gamma > \theta^2 M$).

³⁵Note that both the SCM and the RDM, are more restricted to trade than the MCM. In fact, in the MCM for all levels of trade costs, trade is possible, on the contrary, both the SCM and the RDM, depend on a relation between some variables and parameters for trade to be possible.

5.3.5 OMC RDM versus R&D condition: Trade as Promoter of R&D

We subtract the OMC (from the side of a foreign firm) to the R&D condition from the side of a representative home firm (equation 21), since we want to see the relation between the access of foreign firms to the home market and the level of R&D performed by home firms.

This difference depend on both s and u , but the analysis shows that u determines this relation. To prove this we use again simulation methods, but complement this with graphical analysis. We start by setting $\theta = 5$, $M = 100$, $\gamma = 3000$, $t = 2$, and $N = 100$. Plotting the final result we get:

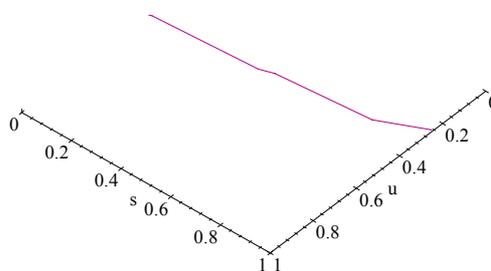


Figure 14: OMC versus R&D condition: central case

This is positive for the left of the isoline, and negative to the right. Then for u bigger than a threshold level the OMC is always superior to the R&D condition, and the reverse for u smaller than the threshold level. This threshold value changes however with s .

We also check the robustness of the results. The first thing to note from this analysis is that changing the level of trade costs (t), or the number of firms (N) does not affect the results. Only changes in γ , θ , M , or in the relation between A and L affects the results. Note then that increasing γ is the same as decreasing θ , or M , and decreasing γ is the same as increasing θ , or M , since these are connected through the stability condition $\gamma > \theta^2 M$. Increasing γ for 7500 (keeping constant the rest of the parameters) we get that this relation is positive for any value of u . Then for high values of γ , if the OMC is satisfied this is a sufficient condition for all firms to perform positive levels of R&D. Decreasing γ for 2550 we get that the threshold value increases as shown in the figure bellow. When this is the case firms from the country that host a high share of skilled-labor perform positive levels of R&D as long as the OMC is satisfied. Firms from the country with less skilled-labor depend on market size for performing positive levels of R&D.

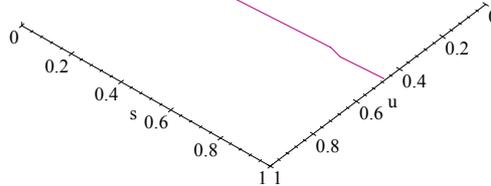


Figure 15: OMC versus R&D condition: $\gamma = 2550$

Changing the relation between A and L (but keeping constant $M = A + L$), also affects the results. If A is relatively larger in relation to L (for example if $A = 90$, and $L = 10$) then the derivative is positive for most of the values of u , except for u and s very close to zero. If L is relatively larger in relation to A (for example if $A = 10$, and $L = 90$), the threshold value increases from the central case.

Therefore, for most cases if the OMC is satisfied so it is the R&D condition, i.e.: trade promotes R&D investment. For other cases, firms to have positive levels of R&D investment will depend on the market size. Note that this problem only arises for firms in the country with less skilled-workers. The country that hosts a larger share of firms will always have positive levels of R&D investment. This also indicates that firms in the market with less skilled-workers have more difficulties to compete in the world market (and therefore exit of firms can be promoted). Also, when the HTS is small in the world economy (due for example to a low share of skilled-labor in the world labor markets), then firms in the HTS will find more easy to perform positive levels of R&D investment as long as trade is possible.

6 Patterns of Trade

In this section we try to look at the patterns of trade implied by the MCM, SCM and the RDM. To do this we follow Head et al. (2000) defining the Balance of Trade for the home country as:

$$B = MN((1 - r) sx - r(1 - s)x^*) \quad (40)$$

Where $(1 - r)MsNx$ represents total home exports, and $rM(1 - s)Nx^*$ total home imports. Then, if $B = 0$ trade is balanced; if $B > 0$ home runs a trade surplus; if $B < 0$ home runs a trade deficit.

In all models analyzed is a difficult task to define when a country runs a trade deficit or trade surplus. In alternative we first fix at each time s and u equal to one-half, and then we rely on simulation exercises to analyze the balance of trade in the general case (i.e.: when we do not restrict s and u to any value). We fix s and u to be equal to one-half to give us a first feeling of how trade balance changes with the economic environment. In this sense, the symmetric firm location equilibrium (i.e.: $s = \frac{1}{2}$) must be thought as an equilibrium where firms are symmetrically located and cannot exit or enter or move to another location (at least in the short run). Skilled-workers on the contrary are allowed to move (i.e.: to change location). This however, should be thought as the balance of trade around the symmetric firm location equilibrium. In fact if u changes greatly it should also affect the spatial distribution of firms. Even if not, at least changes the production conditions of firms in a country. In fact at $u = 0$, $s = \frac{1}{2}$ can hardly be an equilibrium since home firms have no skilled workers to produce.

On the other side the symmetric skilled-worker location equilibrium (i.e.: $u = \frac{1}{2}$) represents an equilibrium where skilled-workers can not move (at least in the short run). On the contrary, firms are allowed to change location. However, the symmetric location of workers can also pose some limitations to the productive structures of countries since firms can only move to another location when they have locally workers to produce. In this sense we must also think of this, as the balance of trade around the symmetric skilled-worker location equilibrium.

6.1 Monopolistic Competition Model

The trade balance under the MCM is:

$$B = \frac{Mt^{1-\sigma}}{p} \left(2 \frac{r(s-\frac{1}{2})-s(r-\frac{1}{2})(t^{1-\sigma}(1-s)+s)}{(1-s(1-t^{1-\sigma}))(t^{1-\sigma}+s(1-t^{1-\sigma}))} \right) \quad (41)$$

In the general case is difficult to define when a country runs a trade deficit or surplus since it depends on both u and s ³⁶. The strategy we follow, is first to fix at each time s and u equal to one-half, and then use simulation and graphic methods to analyze the general case.

6.1.1 Case: symmetric firm location equilibrium

By fixing $s = \frac{1}{2}$, the net exports expression becomes:

³⁶Head et al. (2000) derive the explicit conditions for the sign of this derivative in relation to s . Since they have done this we of course will not repeat the exercise (then one of the reasons to fix r and s to equal one-half at each time). The other reason, and the main one, to fix the balance of trade around the two symmetric equilibrium is however to allows us to compare directly with our central model the R&D model, since in the RDM the general case is too cumbersome. Note also that, Head et al. (2000) do not sign this derivative in relation to u .

$$(B)_{s=\frac{1}{2}} = - \left(r - \frac{1}{2} \right) \frac{2Mt^{1-\sigma}}{p(t^{1-\sigma}+1)} \quad (42)$$

Then it is easy to note that home runs a trade deficit when hosts a large share of skilled-workers (i.e.: $B < 0$ for $u > \frac{1}{2}$). On the contrary if home hosts a small share of skilled workers runs a trade surplus (i.e.: $B > 0$ for $u < \frac{1}{2}$). Trade is balanced when workers are symmetrically located (i.e.: $B = 0$, for $u = \frac{1}{2}$). This looks like a odd result, the country with bigger labor market incurs in trade deficits. This happens because workers are at same time labor force and consumers and as such the country with a small labor market does not have to import so much to satisfy local consumers. On the contrary in the country with a larger labor market this extra demand has to be satisfy from imports.

6.1.2 Case: worker symmetric location equilibrium

The balance of trade for the MCM when $u = \frac{1}{2}$ is:

$$(B)_{u=\frac{1}{2}} = \left(s - \frac{1}{2} \right) \frac{Mt^{1-\sigma}}{p(1-s(1-t^{1-\sigma}))(s+t^{1-\sigma}(1-s))} \quad (43)$$

Since, $0 < t^{1-\sigma} < 1$, then it can be easily seen that for $s > \frac{1}{2}$, $B > 0$; for $s < \frac{1}{2}$, $B < 0$, and for $s = \frac{1}{2}$, $B = 0$. This means that the country with more industry runs a trade surplus when workers are symmetrically located.

6.1.3 General case: MCM

In the general case we use simulation and graphic methods to sign the Balance of Trade under the MCM. In the central case we fix: $N = 100$, $A = 50$, $L = 50$ (i.e.: $M = 100$), $t = 2$, $c = 10$, $\sigma = 1.5$. We have the following trade pattern:

The isoline gives the values of u and s when trade is balanced. For the right of isoline home runs a trade surplus ($B > 0$), for the left of isoline home runs a trade deficit ($B < 0$). The first thing to note is that when home hosts more skilled-workers, more difficult is for the home country to have a positive trade balance. In fact when home hosts more skilled workers the threshold value of s that makes $B > 0$ is bigger (close to $s = 0.7$). For lower values of u , $B > 0$ for lower values of s (close to $s = 0.3$).

We also check the robustness of this results. The first thing to note is that results are not sensible to different values of c , M , or N . Decreasing t or σ , also does not change the results. Only changes in the relative value of A and L , and increases in t and σ affects the results. Decreasing A in relation to L (but maintaining $M = A + L$ constant), we get the following trade balance pattern:

As before home runs a trade surplus for the right of isoline ($B > 0$), and a trade deficit for the left of isoline ($B < 0$). However now the threshold value of s that makes $B > 0$ (when home hosts more skilled-labor), is now bigger than before. In the same way, when u is close to zero the threshold value of s that

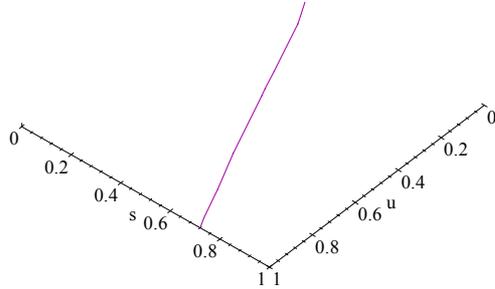


Figure 16: Balance of Trade MCM: central case

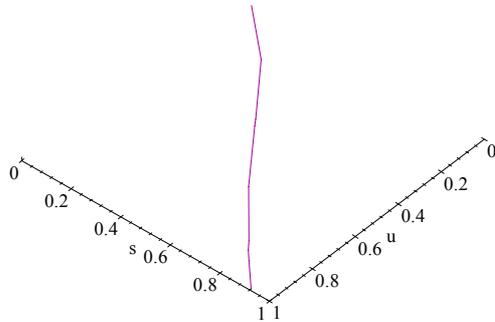


Figure 17: Balance of Trade MCM: $A = 10$, $L = 90$

makes $B > 0$, is now smaller. Therefore when A is relatively small than L , the country that hosts more skilled-labor find it harder to have a positive balance of trade. First, because in this situation the foreign market is very small for exports (since consists mainly of few unskilled-workers); and second because, when L is relatively large, even when a country hosts a small percentage of world skilled-labor it can still maintain industry active exporting for the bigger country. The fact that the this country has a large market also helps this exporting behavior from the part of the country with less skilled-labor.

The contrary happens when A is relatively larger than L :

When this is the case the threshold value of s that makes $B > 0$ is smaller (close to one-half), and always the same for all values of u . This is so because when the amount of skilled-labor in the world economy is relatively smaller than unskilled-labor, the country that hosts more firms has always a positive

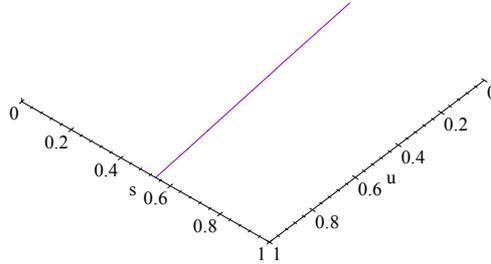


Figure 18: Balance of Trade MCM: $A = 90, L = 10$

trade balance because the spatial distribution of L does not affect greatly trade patterns.

A similar behavior happens for high values of t and σ :

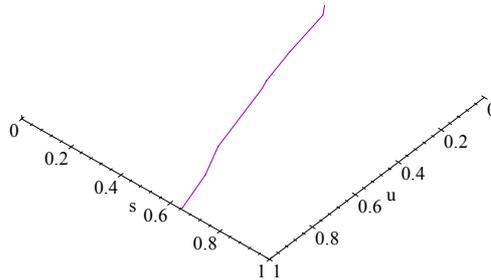


Figure 19: Balance of Trade MCM: $t = 20, \sigma = 15$

High trade costs makes trade more difficult, and this benefits the country with more industry, since this restricts the number of firms in the world economy. On the other side high σ , i.e.: high elasticity of substitution between varieties, restricts the number of varieties available in the world economy (and therefore also the number of firms), and this is beneficial for the country with more firms since this will face less competition from foreign firms, what will promote trade surplus for the country with more firms..

6.2 Standard Cournot Model

The Balance of Trade in the SCM is:

$$B = \frac{MN}{(N+1)b} \left((D-t)(s-r) + 2tsN(1-s) \left(r - \frac{1}{2} \right) \right) \quad (44)$$

In the general case is difficult to state when a country runs a trade deficit or surplus³⁷. The strategy we follow, is first to fix at each time s and u equal to one-half, and then use simulation and graphic methods to analyze the general case.

6.2.1 Case: symmetric firm location equilibrium

Starting first by fixing $s = \frac{1}{2}$, then the expression for balance of trade becomes:

$$(B)_{s=\frac{1}{2}} = -\frac{MN}{(N+1)b} \left(r - \frac{1}{2} \right) \left(\left(D - \frac{t}{2}(N+2) \right) \right) \quad (45)$$

Then (and as long the *OMC* for the SCM is satisfied) with $s = \frac{1}{2}$, trade is balanced for $u = \frac{1}{2}$; home runs a trade deficit for $u > \frac{1}{2}$; and a trade surplus for $u < \frac{1}{2}$. The region with a bigger labor market imports more than it exports. The rationale for this is as before for the MCM, if firms are equally distributed then if a country has more workers it has also to import more than what produces. But this can not be always the case, since the country that has a bigger labor market can also produce more, and being that so, it can also export more than it imports. However the SCM (and also the MCM) does not capture this effect.

6.2.2 Case: worker symmetric location equilibrium

Fixing now $u = \frac{1}{2}$, then the expression for balance of trade comes:

$$(B)_{u=\frac{1}{2}} = \frac{MN}{(N+1)b} \left(s - \frac{1}{2} \right) (D-t) \quad (46)$$

It can be easily shown that, and as long the *OMC* for the SCM is satisfied, then trade is balanced for $s = \frac{1}{2}$; home runs a trade surplus for $s > \frac{1}{2}$; and a trade deficit for $s < \frac{1}{2}$. This comes at no surprise since it is expected that the country with more firms (and therefore more production) exports more than it imports.

³⁷Head et al. (2000) also derive the explicit conditions for the sign of this derivative in relation to s . Note also that Head et al. (2000) do not sign this derivative in relation to u . The same reasons point out above for the MCM for fixing u and s at each time to equal one-half, also apply for the SCM.

6.2.3 General case: SCM

In the general case we use simulation and graphic methods to sign the Balance of Trade under the SCM. The central case considers: $N = 100$, $A = 50$, $L = 50$ (i.e.: $M = 100$), $t = 2$, $D = 5000$, $b = 1$ (to normalize it to the same intercept as in the RDM). This gives the following picture:

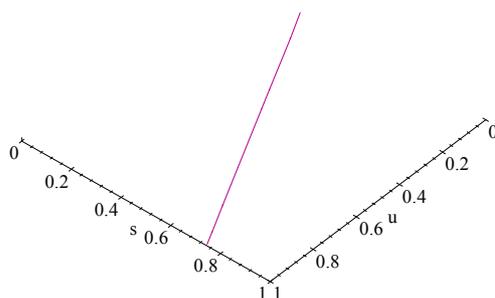


Figure 20: Balance of Trade SCM: central case

As in the case of the MCM, home runs a trade surplus for the right of the isoline, and a trade deficit to the left of the isoline. Also as in the MCM, for high values of u , the threshold value of s that makes $B > 0$ is bigger. For low values of u , this threshold value is smaller. Then the region that hosts a higher share of skilled-labor tends to run trade deficits, except when this region also hosts a very high share of firms.

Checking the sensibility of results gives similar results to the MCM. In fact, changing M , decreasing t , or N , and increasing D has no effects in the results. Only changes in the relative value of A and L , and increases in t or N , and decreases in D affects the results. Then the only difference in relation to the MCM is that results are sensible to increases in the number of firms in the world economy (N), and this was not the case under the MCM. Increasing L relatively to A (but maintaining $M = A + L$ constant), gives a similar picture to the one obtained under the MCM:

This shows once again that when the world endowment of skilled-labor is very large (relatively to the world endowment of unskilled-labor), then this tends to support a bigger hi-tech sector and in consequence when a country hosts a larger share of this factor home consumers will tend to consume from foreign firms, while home firms will only export to a small foreign market. The contrary happens when unskilled-labor is relatively large to the skilled-labor:

When this is the case the country that hosts more firms will tend to run trade surplus, even when it hosts more skilled labor. This is so, as in the MCM, because unskilled-labor makes a big market for exporting, while the contrary

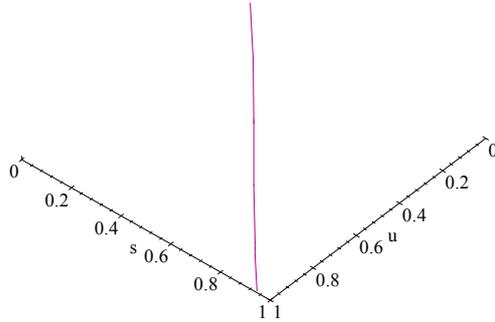


Figure 21: Balance of Trade SCM: $A = 10, L = 90$

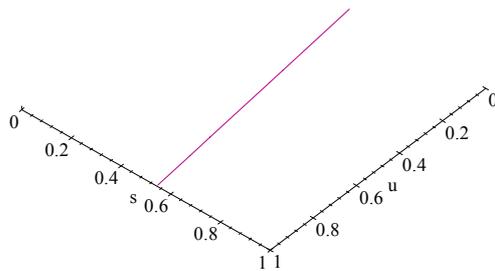


Figure 22: Balance of Trade SCM: $A = 90, L = 10$

happens with skilled-labor.

A similar picture arises if we increase t , and N , or decrease D ³⁸:

This makes competition fiercer, and therefore exports less profitable, what is beneficial for the trade balance of the country that hosts more firms. A note in relation to the MCM. Under the MCM the level of competition did not affected the results (remember that results were not sensible to increases or decreases in N). The contrary happens under the SCM. For higher values of N , the results are affected. Therefore, the level of competition under the SCM can affect the trade balance of a country.

³⁸Note that for these values of t , N , and D , the OMC is always satisfy. We only consider values where the OMC is satisfied, because we want to rule out cases where trade is not possible, since these are not interesting cases for the issue under analysis: international trade.

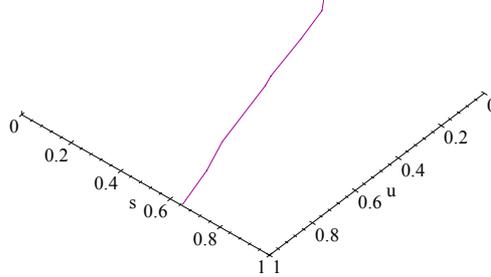


Figure 23: Balance of Trade SCM: $D = 205$, $N = 1498$, $t = 29$

6.3 R&D Investment Model

We do not show the expression for balance of trade in the general case (i.e.: the one that does not restrict u or s to take specific values) since this is too cumbersome to be presented. Anyway, as before, the strategy we follow to study B , is first to fix at each time s and u equal to one-half, and then use simulation and graphic methods to analyze the general case.

6.3.1 Case: symmetric firm location equilibrium

The Balance of Trade with $s = \frac{1}{2}$ comes:

$$(B)_{s=\frac{1}{2}} = -\frac{NM\gamma}{\phi} \left(r - \frac{1}{2} \right) \left(\theta^2 M (D - t) - \gamma \left(D - \frac{t}{2} (N + 2) \right) \right) \quad (47)$$

We show in appendix that for $u = \frac{1}{2}$ trade is balanced; for $u > \frac{1}{2}$ home runs a trade surplus; and for $u < \frac{1}{2}$ home runs a trade deficit. Note that this result is the opposite from the SCM and MCM. This happens to be so because for $u > \frac{1}{2}$ home firms invest more in R&D than foreign firms and therefore are more competitive. As such, due to this competitiveness effect, home firms can penetrate more easily the foreign market and also make it more difficult to foreign firms to enter the home market.

This shows that labor markets can influence trade patterns since these affect industry dynamics. Namely since asymmetric labor markets turn firms asymmetric at the level of R&D investment (and in consequence marginal costs and level of efficiency and competitiveness) the country that hosts more skilled-labor hosts also the more efficient firms what will work in favor of the balance of trade of this country. This also shows that labor force can not be thought only as consumers but also as a factor of production that can affect production and trade patterns between countries.

6.3.2 Case: worker symmetric location equilibrium

The Balance of Trade when $u = \frac{1}{2}$ is:

$$(B)_{u=\frac{1}{2}} = \frac{NM}{2\varphi(N+1)} \left(s - \frac{1}{2} \right) (\theta^2 Mt + 2\gamma(N+1)(D-t)) \quad (48)$$

Since $\varphi > 0$, and that the second expression in the second parenthesis is always positive (as long as the *OMC* for the is satisfied) then it comes that trade is balanced for $s = \frac{1}{2}$, home runs a trade surplus for $s > \frac{1}{2}$, and home runs a trade deficit for $s < \frac{1}{2}$. This is the same result as in the *SCM* and *MCM*. We therefore see, that in the *RDM*, asymmetric labor markets are essential for deriving the results presented in this section and through the paper, since when $u = \frac{1}{2}$ firm never endogenously differentiate themselves at the level of technology, i.e.: they are always symmetric as it happens in the *SCM* and *MCM*. With asymmetric labor markets the *RDM* collapses to the *MCM* and *SCM*.

6.3.3 General case: RDM

In the general case we use simulation and graphic methods to sign the balance of trade. The central case considers: $N = 100$, $A = 50$, $L = 50$ (i.e.: $M = 100$), $t = 2$, $D = 5000$, $\theta = 5$, and $\gamma = 3000$ (since we need at least that $\gamma > \theta^2 M$, i.e.: $\gamma > 2500$). The picture obtained in the central case, is similar to the one obtained under the *SCM* and *MCM*:

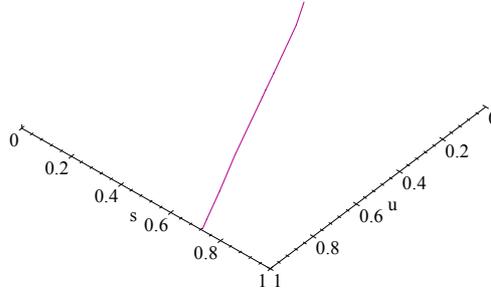


Figure 24: Balance of Trade RDM: central case

As before home runs a trade surplus for the right of the isoline, and a trade deficit to the left of the isoline.

Checking the sensibility of results gives similar results to the *MCM* and *SCM* in what concerns changes in the relative value of A and L , and small increases

in t or N , and small decreases in D . The results differ from the SCM and MCM for big changes in these values. As before decreasing t , and N ; increasing D , and now also increasing γ has no effects in the results. Results are only sensible to changes in the relative value of A and L ; increases in t and N ; and decreases in D and γ (and as such also increases in θ and M since these are connected through the R&D condition: $\gamma > \theta^2 M$). Therefore now, and contrary to the SCM and MCM, M affects the results since world population affects R&D investment behavior of firms.

Increasing L relatively to A (but maintaining $M = A + L$ constant), gives a similar picture to the one obtained under the MCM and SCM:

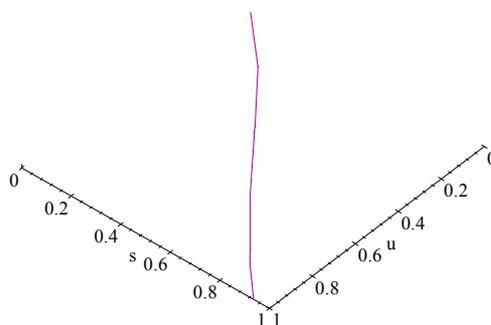


Figure 25: Balance of Trade RDM: $A = 10$, $L = 90$

As in the SCM and MCM, when the world endowment of skilled labor is relatively more than the unskilled-labor the country that hosts more skilled-labor only runs a trade surplus for very high values of s . This is so, because as before in the MCM and SCM, the majority of consumers (in this case skilled-labor) are located in one country, and firms from this country have only a small foreign market to export.

Decreasing A in relation to L (but maintaining constant $M = A + L$), we get again a similar picture to the one obtained under the SCM and MCM:

When unskilled-labor is relatively large to the skilled-labor, then the country that host more firms tend to run trade surplus for any value of u . This is so, as before for the SCM and MCM, because unskilled-labor make a big market for exports.

Decreasing D , and γ , or increasing N , t , and θ for intermediate values we get the following picture³⁹:

Home runs a trade surplus for lower values of s (close to one-half), and for any value of u . This is so because decreasing D , γ , and increasing N , t , θ increases the level of competition what makes exports more costly. But since

³⁹Note that for these values, both OMC (from the side of the foreign and home firm) are satisfied.

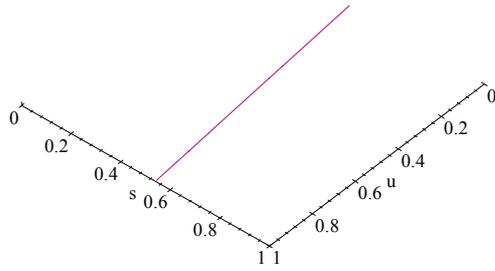


Figure 26: Balance of Trade RDM: $A = 90$, $L = 10$

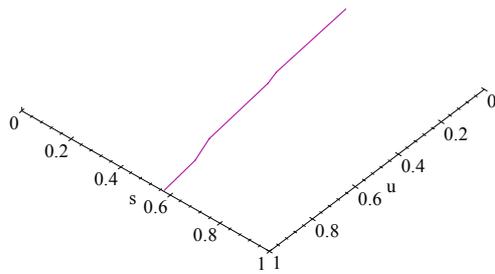


Figure 27: Balance of Trade RDM: $D = 750$, $\gamma = 2552$, $\theta = 5.42$, $N = 714$, $t = 14$

the level of competition is higher in the country with a higher share of firms this firms will tend to export to the foreign country since here competition is softer. If we take in account the R&D parameters (γ and θ), we know that when the cost of R&D is smaller and the cost-reducing effect of R&D higher competition is also stronger, what accentuates the effects mentioned above.

Decreasing D , and γ , or increasing N , t , and θ below and above a threshold value we get the following picture:

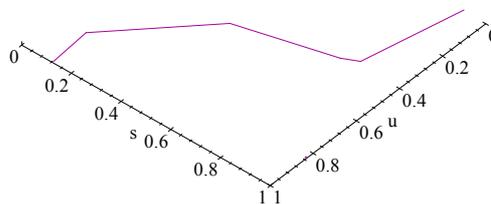


Figure 28: Balance of Trade RDM: $D = 20$, $\gamma = 2505$, $\theta = 5.47$, $N = 5000$, $t = 50$

To interpret this picture we have to have two things in attention. The first one, is that the for values consider in the picture above, the OMC from the side of a representative foreign firm is not satisfied for higher values of u (but note that for high values of u the OMC from the side of a representative home firm is satisfied). The contrary happens for the OMC from the side of a representative home firm: for lower values of u the OMC from the side of a representative home firm is not satisfied (but for low values of u the OMC from the side of a representative foreign firm is satisfied). For intermediate values of u both OMC can be satisfied (see picture below⁴⁰). Then for lower values of u home will tend to run trade deficits (for most values of s), since home firms are not able to penetrate the foreign market; while for higher values of u home will tend to run trade surplus (for most values of s), since home firms have access to the foreign markets, but foreign firms have restrict access to the home market.

The second thing to note is that this is related with R&D investment. For higher values of u , home firms invest more in R&D than foreign firms ('home market effects' in R&D). This makes home firms more competitive ('competitiveness effects'). Since home firms are more competitive, comparatively they can penetrate the foreign markets more easily than foreign firms the home market. This is specially true when competition is made fiercer by market and

⁴⁰The red line shows the OMC from the side of a representative foreign firm. The blue line shows the OMC from the side of a representative home firm.

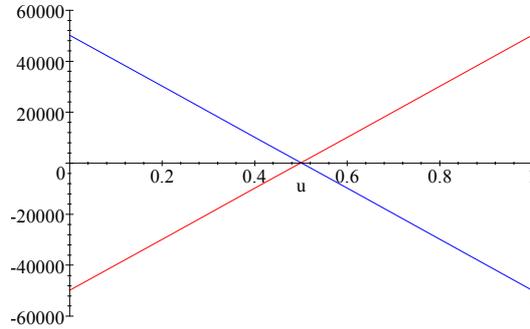


Figure 29: OMC RDM: $D = 20$, $\gamma = 2505$, $\theta = 5.47$, $N = 5000$, $t = 50$

industry conditions as is the case for very low levels of market size, cost of R&D, and very high values of trade costs, cost-reducing effect of R&D, and the number of firms in the world economy.

7 Discussion

In this paper we had analyzed the influence of R&D investment on international trade. Contrary to most literature on trade (that are either based on standard monopolistic competition or oligopolist trade models) we had used instead a game theoretical Cournot model where firms are allowed to perform R&D investment to obtain future reductions in marginal costs.

The differences in our formalization strategy are important in two ways. First, it allows us to look at other types of firms strategies rather than only choosing prices (in the MCM) or quantities (in the SCM), namely R&D investment. Second, because with this model we derive results not present in the referred literature.

The first result to be noted is that there are ‘home market effects’ in the level of R&D investment what results in ‘competitiveness effects’. In fact, firms located in the country that hosts a larger share of skilled workers perform higher levels of R&D investment and as a consequence of this, firms in this country are more competitive than their foreign counterparts (since through R&D investment they achieve lower marginal costs, i.e.: they develop a more cost-effective manufacturing technology). Local labor markets can therefore make firms that initially own the same technology (or at least with access to the same technology) asymmetric. This means that the competitiveness of firms does not depend only in the access to technology but also in their labor markets. One crucial policy for countries is therefore human resources education, formation and development.

In fact it was also shown that for firms located in the country with more skilled labor, trade is more easily made possible (i.e.: profitable). The contrary happens in the country with less skilled labor where the lower competitiveness of firms restricts trade. This means that R&D investment can be a barrier to trade for less competitiveness firms, and a promoter of trade for more competitive firms (under the same market conditions some firms may be able to export while others not), i.e.: R&D investment gives different market access conditions to international markets for firms. Also, since the asymmetry of firms result from asymmetric labor markets, this can be a good channel to influence trade patterns through R&D investment. Furthermore, it was also shown that trade promotes R&D investment, since as long trade is profitable more likely firms perform positive levels of R&D investment in order to face competition. As such in our paper there is a direct link between labor markets, R&D, efficiency and trade. Labor markets encourage R&D; R&D promotes efficiency; and efficiency trade. In fact asymmetric labor markets make firms asymmetric at the level of R&D investment and marginal costs, then firms that performs more R&D are more efficient and being that so they have better access to international markets since they are more competitive in foreign markets.

In terms of trade patterns some results can be point out. The first thing to note, is that countries with higher demand can have a tendency to run trade deficits (except when they have a exceptionally high share of world firms in the sector of concern).

Also when skilled-labor is relatively large unskilled-labor (i.e.: when the high-tech sector is very important in the world economy) this picture tends to be confirmed. This happens because firms located in the country that host a large share of skilled-labor have a small foreign market (consisting mainly of unskilled-labor) to export, but foreign firms have a large destination country (of skilled-labor) to penetrate.

The contrary happens when skilled-labor is relatively less than the unskilled-labor. In this case the country with more firms tend to run trade surplus independently of the share of skilled-labor that hosts. This is so because the destination country have a large market of unskilled-labor to be served by exports.

In the MCM this last case also happens for high trade costs and large elasticity of substitution. In the SCM this happens for low levels of markets size, and high trade costs and high number of firms active in the high-tech sector. However in the RDM this is only the case for intermediate low levels of market size and cost of R&D, and intermediate high cost-reducing effect of R&D investment, high trade costs, and high number of firms active in the high-tech sector. The reason for this to happen (both under the SCM, MCM and RDM) is that high levels of competition (as mirrored by high cost-reducing effect of R&D, high trade costs, high number of firms in the high-tech sector, and large elasticity of substitution; and low market size and low costs of R&D) benefits the country with more industry since foreign firms find it difficult to export to this very competitive market, while the contrary happens for firms in the country with a large industrial sector that find the foreign country a very attractive market for

exports since the level of competition here is lower.

However the RDM differs from the SCM and RDM for very low levels of market size and cost of R&D, and very high cost-reducing effect of R&D, trade costs, and number of firms in the high-tech sector. When this is the case the country with a larger share of skilled-labor always run trade surplus. This is so, because when a country hosts more skilled labor this makes their local firms more competitive than foreign one. As result of this ‘competitiveness effect’, firms located in the country with more skilled labor also penetrate more easily in the foreign market, while the contrary happens for foreign firms. In short, the ‘competitiveness effect’ resulting from R&D investment and asymmetric labor markets promotes exports from the more competitive firms located in the country with more skilled labor, and restricts exports from less competitive firms.

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9 Appendix

In this section we give mathematical proofs for some of the relations presented in the text.

Sign of ϕ Remember again the expression for R&D investment (equation 19):

$$k = \frac{\theta M}{\phi} \left((\theta^2 M - \gamma) (D - t(1-r)) - 2\gamma N t(1-s) \left(r - \frac{1}{2} \right) \right)$$

With $\phi = \varphi(\theta^2 M - \gamma)$, and where $\varphi = (\gamma(N+1) - \theta^2 M)$. It can be easily seen that ϕ is quadratic in γ . The two associated solutions are $\gamma = \theta^2 M$ and $\gamma(N+1) = \theta^2 M$. Therefore for having a solution for k , we can not have $\gamma = \theta^2 M$, or $\gamma(N+1) = \theta^2 M$. Note also that ϕ is concave in γ ($\frac{d^2\phi}{d\gamma^2} = -2(N+1)$). As such for $\gamma < \frac{\theta^2 M}{N+1}$, and $\gamma > \theta^2 M$, $\phi < 0$; on the contrary for $\frac{\theta^2 M}{N+1} < \gamma < \theta^2 M$, $\phi > 0$. The question is what is the case that applies in our model.

We can investigate this by looking at the determinant implied by the R&D investment system. We want this determinant to be positive. The determinant can be found by using the general conditions for k and k^* (equation 18) and substitute for q , q^* , x and x^* (equation 17). In matrix form we will have:

$$\begin{bmatrix} \gamma - \frac{\theta^2 M}{N+1}((1-s)N+1) & \frac{\theta^2 M}{N+1}(1-s)N \\ \frac{\theta^2 M}{N+1}sN & \gamma - \frac{\theta^2 M}{N+1}(sN+1) \end{bmatrix} \begin{bmatrix} k \\ k^* \end{bmatrix} = \begin{bmatrix} \frac{\theta M}{N+1}(D+t(r(1-s)N - (1-r)((1-s)N+1))) \\ \frac{\theta M}{N+1}(D-t(r(sN+1) - (1-r)sN)) \end{bmatrix}$$

The determinant of this system is just $(\gamma(N+1) - \theta^2 M)(\gamma - \theta^2 M)$ or $-\phi$. Then it comes out that the determinant is positive for $\gamma < \frac{\theta^2 M}{N+1}$ and for $\gamma > \theta^2 M$. Therefore we can rule out the solution $\frac{\theta^2 M}{N+1} < \gamma < \theta^2 M$.

Note however, that for $\gamma < \frac{\theta^2 M}{N+1}$ the model can predict negative levels of R&D investment. To see this note that the multiplicative term in equation 19 is always negative. On the contrary, the first term on parenthesis is always positive as long as the *OMC* for the SCM is satisfied. Then it comes, that we have negative levels of R&D investment for $r \leq \frac{1}{2}$, since the second term in parenthesis is positive for $r < \frac{1}{2}$, and zero for $r = \frac{1}{2}$ (making the all expression in parenthesis positive). Therefore, we also want to rule out the case where $\gamma < \frac{\theta^2 M}{N+1}$ since we are not interested in negative levels of R&D investment (at most firms do not invest).

On the contrary, if $\gamma > \theta^2 M$ the model can predict positive levels of R&D investment. In fact, we have again that the multiplicative term is negative, but now the first term on parenthesis is also negative. Therefore, for $r \geq \frac{1}{2}$ the model predicts that all firms have positive levels of R&D investment, since the second term in parenthesis is zero for $r = \frac{1}{2}$ and negative for $r > \frac{1}{2}$. For $r < \frac{1}{2}$, we have that the second term in parenthesis is positive. As such, for having positive levels of R&D investment, we will need that the first term in parenthesis is bigger than the second one, or that the relation between market size and the level of trade costs and R&D investment variables is such that:

$$D > \frac{t}{\theta^2 M - \gamma} \left(\theta^2 M(1-r) + \gamma \left(2N(1-s) \left(r - \frac{1}{2} \right) - (1-r) \right) \right)$$

We can easily see that if $\gamma > \theta^2 M$ this condition is always negative for $r > \frac{1}{2}$. To see this, note that the multiplicative term is negative and that the condition is linear in γ . Then note also, that at $\gamma = \theta^2 M$, the condition simplifies to $2\theta^2 MN(1-s)(r - \frac{1}{2})$. Therefore, for $r > \frac{1}{2}$ this condition is always negative and therefore also always satisfied since $D > 0$. On the contrary, for $r < \frac{1}{2}$ the condition is positive and as such for the OMC to be satisfied we need that the value of D to be superior to the value implied by the condition.

Then, for having $k > 0$, we need that $\gamma > \theta^2 M$ (what implies $\varphi > 0$), and that market size is sufficiently big to satisfy the R&D condition.

Sign of the R&D Condition Using simulation techniques we try to sign the R&D condition of a representative home firm. Our central case is: $N = 100$, $A = 50$, $L = 50$ (i.e.: $M = 100$), $t = 2$, $D = 5000$, $\theta = 5$, and $\gamma = 3000$ (since we need at least that $\gamma > \theta^2 M$, i.e.: $\gamma > 2500$). The result is plotted in the figure below⁴¹.

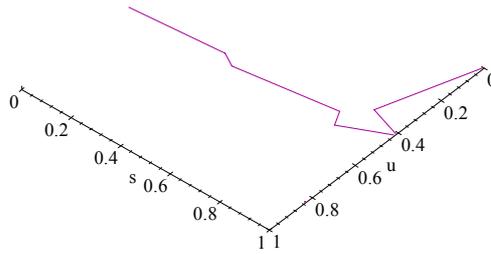


Figure 30: Sign of home R&D Condition

The R&D condition is positive for the left of the isoline and negative for the right of the isoline. Then as long as labor markets are not very asymmetric at the level of spatial distribution of skilled-labor, firms will always perform positive levels of R&D investment independent of market size (since D is always positive).

For lower values of u (i.e.: for very asymmetric labor markets) the R&D condition is always satisfied for high values of D and γ , and for low levels of t and N . Even when this is not the case (for example for intermediate values of market size) the R&D condition can be satisfied for s superior to a threshold value.

⁴¹The resulting picture is not sensible to different parameter or variable values. We re-simulated the R&D condition for $t = 1, t = 50, t = 200$ $N = 10, N = 1000, N = 5000$, $A = 10$ and $L = 90, A = 90$ and $L = 10, \gamma = 2505, \gamma = 2550, \gamma = 5000$.

Note that for low levels of u (for example $u = 0$) it is natural that the R&D condition is not satisfied, since potential firms in this country have no factors of production either to produce or to perform R&D investment. However, even in this extreme case, if for example we set $D = 5000$, and taking the central simulation values above mentioned, only for very high t (for example $t = 50$), high N (for example $N = 1000$), or low γ (for example $\gamma = 2505$), the R&D condition is not satisfied below a threshold level of s .

The important point, as referred in the text, however is that if the R&D conditions for home firms is not satisfied, the contrary happens for the R&D condition for foreign firms, therefore the model assures that there is always firms performing R&D investment.

Sign of derivatives of P The derivative of prices in relation to home share of firms is:

$$\frac{dP}{ds} = -\frac{Nt}{\varphi(N+1)} (\gamma(N+1) - 2\theta^2 M(1-r))$$

Prices at home decrease when competition at home also increases. In fact the multiplicative term $(-\frac{Nt}{\varphi(N+1)})$ is always negative, while what is inside parenthesis is always positive as long as $N \geq 1$ (what is always the case since this is a oligopoly model). To see this, note that what is inside parenthesis has the solution $\gamma = \frac{2\theta^2 M}{N+1} (1-r)$. Since $\gamma > \theta^2 M$ then what is inside parenthesis is always positive for $N \geq 1$ (subtract to $\theta^2 M$, $\frac{2\theta^2 M}{N+1} (1-r)$ to get $\frac{\theta^2 M}{N+1} (2(r - \frac{1}{2}) + N)$, and the result stated above follows).

OMC RDM versus OMC SCM The difference between the OMC (from the side of the foreign firm) of the RDM and the OMC of the SCM is:

$$OMC^{R\&D} - OMC^{Cournot} = t\theta^2 M \frac{\gamma(-N(N+3)+2rN(N+2)-(1-r))+\theta^2 M(1-r)(2N+1)}{\gamma(N+1)(\gamma-\theta^2 M)}$$

It can be easily seen that the expression in the denominator is always positive. The nominator is more difficult to sign, but note that at $\gamma = \theta^2 M$ the expression simplifies to $2(N+1)\theta^2 MN(r - \frac{1}{2})$, and this is positive for $u > \frac{1}{2}$, and the reverse for $u < \frac{1}{2}$. Therefore, and since the expression is linear in γ , this is always the case for $\gamma > \theta^2 M$. Then, the OMC of the RDM is bigger than the OMC of the SCM for $u > \frac{1}{2}$, i.e.: trade is more restricted under the RDM. However for $u < \frac{1}{2}$, the OMC of the RDM is smaller than the OMC of the SCM, i.e.: trade is promoted under the R&D case.

Balance of Trade: symmetric firm location equilibrium The Balance of Trade with $s = \frac{1}{2}$ is:

$$(B)_{s=\frac{1}{2}} = -\frac{NM\gamma}{\phi} \left(r - \frac{1}{2} \right) \left(\theta^2 M(D-t) - \gamma \left(D - \frac{t}{2}(N+2) \right) \right)$$

It comes that, the multiplicative term is positive (since $\phi < 0$) and that the expression in the second parenthesis is also positive. To see this, note that, the expression in the second parenthesis is linear in γ , and that at $\gamma = \theta^2 M$ the expression simplifies to $\frac{1}{2}M\theta^2 tN$, and this is always positive. As such, for $\gamma > \theta^2 M$ the expression in the second parenthesis is also positive. Therefore, for $u = \frac{1}{2}$ trade is balanced, for $u > \frac{1}{2}$ home runs a trade surplus, and for $u < \frac{1}{2}$ home runs a trade deficit.