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Beyond Trade Costs: Firms' Endogenous access to International Markets

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Beyond Trade Costs: Firms' Endogenous Access to International Markets

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Abstract

In this paper we argue that the level of access to international markets by firms is related not only to exogenous factors such as trade costs, but also to endogenous factors such as strategic competition on R&D. In particular, we show that: (1) higher efficiency of R&D (like low trade costs) makes trade easier for firms (given that R&D increases the profitability of exports); (2) firms with a first-mover advantage in R&D have higher competitiveness levels, and as a result they also have better access to export markets; and (3) the volume of trade is always higher when firms can invest in R&D than when they cannot invest in R&D.

Keywords: R&D Investment, Commitment Power, Endogenous Asymmetric Firms, Market Access.

JEL Classification: F12, L13, L25.

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1 Introduction

Trade costs are at the cornerstone of most international economic analysis[1]. This is the case for both theoretical and empirical models. In fact, trade costs are fundamental to the 'new' trade theory (Krugman, 1980 and Brander, 1981), to the 'new' economic geography (Krugman, 1991 and Venables, 1996) and to the theory on multinational firms (Horstman and Markusen, 1992 and Brainard, 1997).

Not surprising then that trade costs also play an important role in the empirical literature on international economics. First, there is a long tradition of papers that estimates the magnitude of transportation costs in international trade (Moneta, 1959; Waters, 1970; Finger and Yeats, 1976; Harrigan, 1993; Rauch, 1999 and Hummels 1999, 2001). Second, the most important empirical model in international economics is the gravity model where trade costs are quintessential (see the excellent review on trade costs and gravity models by Anderson and Wincoop, 2004).

In addition, some stylized facts on international trade are explained by making use of trade costs. For example, the exponential increase in the world trade in the last century (Baier and Bergstrand, 2001), the "border puzzle" and the observed "home bias" in consumption (Trefler, 1995 and Anderson and Wincoop, 2003)[2].

In this paper we do not deny the importance of trade costs in international trade. However, we look at other factors besides trade costs that can affect the level of international market access by firms. In particular, following the industrial organization literature on innovation started by Spence (1984), we focus on the role of strategic interactions between firms that work through investment in R&D.

With this purpose in mind we use a simple Cournot duopoly model with three R&D scenarios. In the first case firms do not invest in R&D (benchmark). In the second case firms can invest in process R&D as in Leahy and Neary (1997). In the third case, we extend the second case to allow for firms to differ in the capacity to commit to their R&D decisions. Following Bagwell (1995), a firm is said to have R&D commitment power when the R&D

[1] We interpret trade costs in a broad way such that includes all impediments to trade from transport costs, to tariffs, to non-tariff barriers and so on.

[2] Accordingly, the "border puzzle" and the "home bias" in consumption relate with the empirical fact that equally distant regions, trade more with each other if they are located in the same country than if they are located in different counties.

choices have commitment value for the output stage, i.e.: when R&D is chosen in a previous stage to outputs. Conversely, a firm does not have R&D commitment power when the R&D choices have no commitment value to the output stage, i.e.: when R&D and outputs are chosen simultaneously[3].

Although having firms with different levels of R&D commitment power gives the R&D leader a first-mover advantage in the spirit of von Stackelberg (1934), the consequences of having R&D leader advantages are much more pervasive than of just having output leader advantages as in Stackelberg (1934). This is so because given the strategic nature of R&D, commitment power differences can also endogenize competitiveness asymmetries between firms (i.e.: firms can end up with different marginal costs). In a standard Stackelberg model this is never possible, since firms are always symmetric in terms of competitiveness independently of being a leader or a follower.

The endogenous competitiveness property of our model is particularly important because it allows us to show that firms can also affect international trade patterns by acting strategically against rivals. In fact, firms with higher R&D commitment power over-invest in innovation not only to become more competitive than rivals but also to reduce rivals' involvement in export markets. As a result, firms with higher commitment power are also more active in international markets (i.e.: they export more) than competitors with no commitment power.

The result that some firms export more than others relies heavily on recognizing the fact that firms are by nature heterogeneous. This is especially crucial in international markets where competition is extremely fierce and amongst a small number of very powerful oligopolist firms (Tybout, 2003). In fact there is also strong empirical evidence that only the more competitive firms are active in international markets (see for example Roberts and Tybout, 1997 and Bernard et al., 2003). This empirical fact started a whole new theoretical literature on heterogeneous firms. Melitz (2003) and Bernard et al. (2003), for instance, noticed that only with heterogeneous firms is it possible to have firms with different levels of international market access. However, in Melitz (2003) and Bernard et al. (2003) firm heterogeneity is still exogenous, i.e.: firm competitiveness depends only on exogenous factors such as trade costs and fixed costs at the firm level[4]. As a result, in Melitz

[3]In other words, the difference between the second and the third case above is that in the former firms have symmetric levels of commitment power, while in the latter some firms have more commitment power than others.

[4]Melitz (2003) and Bernard et al. (2003) generate firm heterogeneity by allocating

(2003) and Bernard et al. (2003), asymmetries between firms cannot be explained and it is also impossible for firms to affect rivals' behavior in terms of market access (i.e.: market access is exogenous to firms).

In this paper, however, by allowing firms to differ in R&D commitment power, we are able to endogenize competitiveness asymmetries between firms. In our opinion, this result has some interesting consequences. First, we present one reason for firm heterogeneity: R&D competition. Second, we explain why firms can have different levels of market access: asymmetries in competitiveness. Third, we explain why the more competitive firms are more active internationally: strategic competition.

In this sense we argue that although trade costs are central to international trade, their role has probably been overstressed in the literature leaving no room to look at other factors. In effect, we will also show that, similarly to trade costs, the rate of efficiency of R&D can also affect firms' access to international markets: higher efficiency (like low trade costs) promotes trade, while lower efficiency (like high trade costs) discourages trade. In addition, the presence of R&D will always increase trade volumes relatively to the no R&D case. In this way technological progress, similar to the one that we have witnessed in the last century, can also have effects on trade patterns analogous to those usually attributed to trade costs alone.

2 Model

The world economy consists of two symmetric countries, home and foreign, and two firms, the home and the foreign firm. Foreign variables are indicated by an asterisk. The home and the foreign firm produce a homogenous good to sell in their respective home market and to export. Since the model is symmetric, in most of the following we concentrate our attention in the home country. Equations for the foreign country (and for the foreign firm) apply by symmetry.

The home and the foreign firm face the following indirect demand in the home country:

$$P = a - b\left(q + x^{*}\right) \tag{1}$$

where q is the domestic sales of the home firm and x^{*} is the exports of the

productivity levels to firms randomly accordingly to some *ex-ante* statistical distribution.

foreign firm to the home country (similar interpretation holds for q^* and x). Likewise, a and b stand respectively for the intercept of demand and for an inverse measure of market size.

In turn profits by the home firm can be written as:

$$\Pi = (P - C)\, q + (P^* - C - t)\, x - \Gamma \tag{2}$$

where $t > 0$ is a general measure of all barriers to trade with $t = t^*$, i.e.: trade costs affect the home and the foreign firm symmetrically. This is a standard assumption in the literature, and in the context of our model it means that the home and the foreign firm initially have the same level of access to international markets. In turn C and Γ are the home firm's marginal and fixed costs respectively.

Like in Leahy and Neary (1997), we introduce R&D investment through C and Γ. In particular we assume that the home and the foreign firm can invest in process R&D that reduces marginal costs (C) but increases fixed costs (Γ). For the home firm this amounts to:

$$\begin{aligned} C &= (c - \theta k) \\ \Gamma &= \gamma \tfrac{k^2}{2} + f \end{aligned} \tag{3}$$

where k is R&D investment by the home firm, θ is the cost-reducing effect of R&D, γ is the cost of R&D, f is the exogenous fixed costs of production and c is the initial marginal cost. The foreign firm has a similar cost structure with $c = c^*$, $f = f^*$, $\theta = \theta^*$ and $\gamma = \gamma^*$. We assume that firms have symmetric technology parameters so that competitiveness asymmetries between the home and the foreign firm can only arise endogenously.

At this point it is important to define a parameter η that is equal to:

$$\eta = \tfrac{\theta^2}{\gamma b} \tag{4}$$

Like in Leahy and Neary (1997) η represents the "relative" return on R&D. Accordingly, a high η stands for a large return on innovative activities, since the cost-reducing effect of R&D (θ) weighted by market size ($1/b$) is large relatively to the cost of R&D (γ). The reverse holds for low η. In this sense η can be interpreted as a metaphor for technological progress.

2.1 Three R&D Games

We are interested in knowing how R&D and differences in R&D commitment power affect international trade. Following Bagwell (1995), a firm has R&D commitment power when the R&D decisions have commitment value for the output stage, i.e.: R&D levels are chosen in a previous stage to outputs. The contrary happens when a firm has no commitment power: the firm sets outputs and R&D levels simultaneously. Thus, when a firm has commitment power, it can use R&D with two objectives: to improve its own productive efficiency and also to affect the rival strategic decisions. When a firm does not have R&D commitment power, only the former holds.

We then compare three games that differ in the nature of R&D competition and R&D commitment power. In the first game, firms cannot invest in R&D (i.e.: $\theta = k = k^* = 0$) and therefore we call it the benchmark no R&D game. In the second and third games firms can invest in R&D but these two games differ in the commitment power ability that firms have. Accordingly, in the second game firms have symmetric R&D commitment power, while in the third game the home and the foreign firm have asymmetric R&D commitment power. In particular, in the third game we assume that only the home firm has R&D commitment power.

Variables referring to each of these three games will be identified by the following subscripts: B for the benchmark no R&D game, S for the symmetric commitment power game and A for the asymmetric commitment power game (see figure 1).

2.2 Timing of the Three Games

Figure 1 shows the timing of the three games introduced above. In the benchmark no R&D game there is only one stage where the home and the foreign firm make their output decisions simultaneously (q_B, x_B, q_B^* and x_B^*).

In the symmetric commitment power game, the home and the foreign firm make their R&D decisions (k_S and k_S^*) in stage 1 and in stage 2 they make their output decisions (q_S, x_S, q_S^* and x_S^*).

In the asymmetric commitment power game, the home firm chooses R&D (k_A) in stage 1, and in stage 2 the home firm chooses output levels (q_A and x_A) while the foreign firm chooses both outputs (q_A^* and x_A^*) and R&D levels (k_A^*)[5].

[5] As defended by Hamilton and Slutsky (1990), in order to justify the first-mover ad-

Stage \ Game	Benchmark no-R&D (B)	Symmetric Commitment Power (S)	Asymmetric Commitment Power (A)
Stage 1		k_S, k_S^*	k_A
Stage 2	q_B, x_B, q_B^*, x_B^*	q_S, x_S, q_S^*, x_S^*	q_A, x_A, q_A^*, x_A^*, k_A^*

Figure 1: Timing of the Games

In this sense the asymmetric commitment power game is a type of Stackelberg (1934) leader game, since the home firm has a first-mover advantage in R&D. R&D commitment power therefore gives leader advantages to a firm that competes with a firm that lacks such capability. As a result, and as will be seen below, firms with different commitment capabilities can become endogenously asymmetric because their R&D choices internalize the differences that they have at this level.

We are now ready to define the production equilibrium in the three games considered in this paper.

3 Production and Entry

As usual the model is solved by backward induction. Accordingly, to compute outputs we use the first order conditions (FOCs) for outputs to obtain:

$$\begin{aligned} q &= \frac{D+t+2\theta k-\theta k^*}{3b} \\ x &= \frac{D-2t+2\theta k-\theta k^*}{3b} \\ q^* &= \frac{D+t+2\theta k^*-\theta k}{3b} \\ x^* &= \frac{D-2t+2\theta k^*-\theta k}{3b} \end{aligned} \tag{5}$$

where $D = (a - c)$ is a measure of a firm's "initial cost competitiveness" (i.e.: without R&D investment).

vantage in the context of our model it can be helpful to think of the home firm as an incumbent that moves in R&D before the entrant foreign firm. However since the focus of this paper is not the entry decision of the foreign firm we abstract from this issue here. We are then implicitly assuming that the fixed costs are sufficiently small so that they do not promote exit. On incumbent-entrant models see Spence (1977).

Note that by making $k = k^* = 0$ in equation 5, we obtain the final output expressions for the benchmark no R&D game. For the other two games, however, we have to proceed to find the R&D expressions.

To compute R&D levels we use the FOCs for R&D. The FOCs for R&D however depend on whether a firm has R&D commitment power or not. To see this, note that the FOC for R&D for the home firm can be decomposed into the following three terms:

$$\frac{d\Pi}{dk} = \frac{\partial\Pi}{\partial k} + \frac{\partial\Pi}{\partial q^*}\frac{dq^*}{dk} + \frac{\partial\Pi}{\partial x^*}\frac{dx^*}{dk} \quad (6)$$

The first term on the right hand side of equation 6 is usually called the non-strategic motive for R&D, while the second and third terms are the strategic motives for R&D[6]. Accordingly, R&D is strategic when the second and third terms are non-zero. This is the case if a firm chooses R&D in a previous stage to outputs, i.e.: when a firm has R&D commitment power (as for the home and the foreign firm in the symmetric commitment power game and for the home firm in the asymmetric commitment power game). Conversely, R&D is not strategic when the second and third terms are zero. This is the case if a firm chooses R&D at the same time as outputs, i.e.: when a firm has no R&D commitment power (like the foreign firm in the asymmetric commitment power game).

Since the home firm always has commitment power, R&D levels by the home firm are of the same nature under both the symmetric and the asymmetric commitment power games:

$$k_i = \frac{4\theta}{3\gamma}\left(q_i + x_i\right) \text{ with } i = S \text{ or } A$$

The foreign firm on the contrary only has R&D commitment power in the symmetric commitment power game. In this case R&D levels by the foreign firm equal:

$$k_S^* = \frac{4\theta}{3\gamma}\left(q_S^* + x_S^*\right) \quad (7)$$

In turn in the asymmetric commitment power game, R&D investment by the foreign firm is:

[6] Note that the whole FOC for R&D for the home firms is: $\frac{d\Pi}{dk} = \frac{\partial\Pi}{\partial k} + \frac{\partial\Pi}{\partial q}\frac{dq}{dk} + \frac{\partial\Pi}{\partial x}\frac{dx}{dk} + \frac{\partial\Pi}{\partial q^*}\frac{dq^*}{dk} + \frac{\partial\Pi}{\partial x^*}\frac{dx^*}{dk}$. However, from the FOCs for outputs $\frac{\partial\Pi}{\partial q} = \frac{\partial\Pi}{\partial x} = 0$. As such these terms cancel-out.

$$k_A^* = \frac{\theta}{\gamma}\left(q_A^* + x_A^*\right) \tag{8}$$

Then in the symmetric commitment power game, since the home and the foreign firm have symmetric R&D commitment power, they also have symmetric incentives to invest in R&D. On the contrary, in the asymmetric commitment power game, since the home and the foreign firm have asymmetric commitment power levels, they now have asymmetric incentives to invest in R&D.

The explicit output and R&D expressions for the two R&D games can now be found by solving simultaneously for q, x, k, q^*, x^* and k^*. Specifically for the symmetric commitment power game we have:

$$\begin{aligned}
q_S &= q_S^* = \tfrac{3D+t(3-4\eta)}{b(9-8\eta)} \\
x_S &= x_S^* = \tfrac{3D-2t(3-2\eta)}{b(9-8\eta)} \\
k_S &= k_S^* = \tfrac{4\theta(2D-t)}{b\gamma(9-8\eta)}
\end{aligned} \tag{9}$$

In turn, for the asymmetric commitment power game we obtain:

$$\begin{aligned}
q_A &= \frac{3D(1-2\eta)+t\left((3-11\eta)+8\eta^2\right)}{b(9-4\eta(7-4\eta))} \\
x_A &= \frac{3D(1-2\eta)-t\left((6-17\eta)+8\eta^2\right)}{b(9-4\eta(7-4\eta))} \\
q_A^* &= \frac{D(3-8\eta)+t\left((3-10\eta)+8\eta^2\right)}{b(9-4\eta(7-4\eta))} \\
x_A^* &= \frac{D(3-8\eta)-t\left(2(3-9\eta)+8\eta^2\right)}{b(9-4\eta(7-4\eta))} \\
k_A &= \tfrac{4\theta(2D-t)(1-2\eta)}{b\gamma(9-4\eta(7-4\eta))} \\
k_A^* &= \tfrac{\theta(2D-t)(3-8\eta)}{b\gamma(9-4\eta(7-4\eta))}
\end{aligned} \tag{10}$$

Therefore, when firms are symmetric in commitment power they end up being symmetric in every respect. However, when firms are asymmetric in commitment power they become endogenously asymmetric, i.e.: the home and the foreign firm end up producing and investing differently. In the next sections we will analyze the consequences of this endogenous asymmetry on international trade.

Proposition 1 *In an international duopoly, differences in R&D commitment power conduce to endogenous asymmetries between firms.*

4 Autarchy versus Trade

In this section we study the threshold level of trade costs between autarchy and trade. We then define $\hat{t}$ and $\hat{t}^*$ as the autarchy threshold level of trade costs for the home and the foreign firm, respectively[7].

In the benchmark no R&D case, $\hat{t}$ and $\hat{t}^*$ can be found by solving x_B and x_B^* for t at $k = k^* = 0$ in equation 5 to obtain:

$$\hat{t}_B = \hat{t}_B^* < \tfrac{1}{2}D \tag{11}$$

For the symmetric commitment power game, again we solve x_S and x_S^* for t from equation 9 to get:

$$\hat{t}_S = \hat{t}_S^* < \tfrac{3D}{2(3-2\eta)} \tag{12}$$

For the asymmetric commitment power game, we proceed in the same way as before, by solving x_A and x_A^* for t from equation 10 to get:

$$\begin{aligned} \hat{t}_A &< \tfrac{3(1-2\eta)}{6-\eta(17-8\eta)}D \\ \hat{t}_A^* &< \tfrac{1}{2}\tfrac{(3-8\eta)}{3-\eta(9-4\eta)}D \end{aligned} \tag{13}$$

We then have that in the benchmark no R&D game and in the symmetric commitment power game, the home and the foreign firm have symmetric levels of access to international markets. This is so because in these two games firms are always symmetric in competitiveness. The same, however, does not occur in the asymmetric commitment power game. In this game, as we have seen, due to differences in commitment power, the home and the foreign firm can become endogenously asymmetric in competitiveness. This implies that the home and the foreign firm also have different levels of access to international markets.

Proposition 2 *In an international duopoly, differences in R&D commitment power conduce to different levels of access to international markets.*

[7] The asterisk in $\hat{t}^*$ does not mean that the foreign firm faces different trade costs from the home firm. We continue to assume symmetry at the level of trade costs (i.e.: $t = t^*$). However, we need to differentiate $\hat{t}^*$ from $\hat{t}$, since the autarchy threshold level of trade costs can be different for the home and the foreign firm.

The next step is to analyze the relation between the different autarchy threshold levels of trade costs, $\hat{t}_B$, $\hat{t}_S$, $\hat{t}_A$ and $\hat{t}_A^*$. We are interested in knowing under which game trade is easier for firms. As shown in appendix we have that:

$$\begin{aligned} \hat{t}_A &> \hat{t}_S > \hat{t}_B > \hat{t}_A^* \text{ for } \eta > \tfrac{1}{4} \\ \hat{t}_A &> \hat{t}_S > \hat{t}_A^* > \hat{t}_B \text{ for } \eta < \tfrac{1}{4} \end{aligned} \tag{14}$$

Then, two cases arise that depend on the return on R&D parameter (η). For high return on R&D ($\eta > \frac{1}{4}$), trade is more easy for an R&D leader (the home firm in the asymmetric commitment power game), and more difficult for an R&D follower (the foreign firm in the asymmetric commitment power game). In second and third places in the market access ranking come respectively a firm that faces a rival with symmetric R&D commitment power (the home and the foreign firm in the symmetric commitment power game) and a firm that does not invest in R&D (the home and the foreign firm in the benchmark no R&D game).

If the return on R&D is instead relatively low ($\eta < \frac{1}{4}$), the first and second positions in the market access ranking are not altered. However, the firm with low commitment power (the foreign firm in the asymmetric commitment power game) can start to have better market access than a firm that does not invest in R&D (the home and the foreign firm in the benchmark no R&D game).

Proposition 3 *In an international duopoly, the firm that leads in commitment power (i.e.: the more competitive firm) has better access to international markets than the firm that lags behind in commitment power.*

What this tells us is that market access depends not only on exogenous factors, such as trade costs, but also on endogenous factors, such as strategic competition in R&D. Accordingly, through R&D investment a firm can affect its own level of international market access but also that of competitors, because innovation affects the competitiveness balance in the market.

In what follows we will only consider the parameter space that assures that trade is possible under the three games. As can be seen from equations 11 to 14 this is the case if:

$$
\begin{aligned}
0 &< t < \tfrac{1}{2}D \\
0 &< \eta < \tfrac{3}{8}
\end{aligned} \tag{15}
$$

5 R&D and Trade

In this section we intend to show that, similar to trade costs, R&D investment also has an important role to play in international trade patterns. First, R&D can have the same type of effects as trade costs on market access: higher efficiency of R&D, like low trade costs, increases trade (and *vice-versa*). Second, R&D competition introduces some new dimensions previously disregarded in the trade literature: such as market access being endogenous to firms' strategic decisions.

To study the effects of R&D on international trade we compute the derivatives of $\hat{t}$, $\hat{t}^*$, x and x^*, in relation to η. For the symmetric commitment power game we have (see appendix):

$$
\frac{d\hat{t}_S}{d\eta} > 0 \text{ and } \frac{dx_S}{d\eta} > 0 \tag{16}
$$

In turn, for the asymmetric commitment power game the relation is the following (see appendix):

$$
\begin{gathered}
\frac{d\left(\hat{t}_A\right)}{d\eta} > 0 \text{ and } \frac{d(x_A)}{d\eta} > 0 \\
\frac{d\left(\hat{t}_A^*\right)}{d\eta} > 0 \text{ and } \frac{d\left(x_A^*\right)}{d\eta} > 0 \text{ for } 0 < \eta < \frac{3-\sqrt{3}}{8} \\
\frac{d\left(\hat{t}_A^*\right)}{d\eta} < 0 \text{ and } \frac{d\left(x_A^*\right)}{d\eta} < 0 \text{ for } \frac{3-\sqrt{3}}{8} < \eta < \frac{3}{8}
\end{gathered} \tag{17}
$$

Then, when firms are symmetric in commitment power, higher return on R&D (high η) makes trade easier for both the home and the foreign firm.

When the home and the foreign firm are asymmetric in commitment power, however, only the R&D leader (the home firm) benefits when η increases. For the R&D follower (the foreign firm) this does not hold completely: the foreign firm's access to export markets only increases with η if R&D is not too efficient; when R&D is very efficient, however, foreign firm's access to international markets deteriorates.

The rational for this result is that when the return on R&D is very high, the home firm can use the first-mover advantage in R&D more effectively to export more and to force the foreign firm to export less.

Proposition 4 *In an international oligopoly, market access by the firm with higher commitment power always increases with the return on R&D. This is not the case for the firm with lower commitment power when the return on R&D is high.*

So far we have just showed the first part of our argument: that other factors besides trade costs can also affect firms' access to international markets, specifically R&D. We proceed now to the second part of our argument that market access can be endogenous to firms' strategic decisions.

To show this we first analyze the implications of the endogenous competitiveness asymmetry property of the asymmetric commitment power game. We have said previously that in the asymmetric commitment power game, firms become endogenously asymmetric due to different levels of R&D commitment power. In effect, in spite of the fact that the home and the foreign firm are initially exactly symmetric in terms of technology, they end up producing and investing in R&D differently. It is therefore important to know how much the asymmetry between the home and the foreign firm amounts to. To study this, note that the following relations hold (see appendix):

$$\begin{aligned} k_A &> k_A^* \\ q_A + x_A &> q_A^* + x_A^* \\ x_A &> x_A^* \\ x_A &> q_A^* \end{aligned} \tag{18}$$

Then, the firm with higher R&D commitment power (home firm) is more efficient (i.e.: invests more in R&D), is bigger in size (i.e.: produces more) and is more active internationally (i.e.: exports more). In fact, the competitiveness level of the home firm is so high that it even allows it to sell more in the foreign country than the foreign firm itself.

Proposition 5 *In an international duopoly, the firm with higher R&D commitment power exports more because it is more competitive and bigger in size.*

Since market access is then endogenous to firms' strategic choices and competitive environment, this also affects trade volumes under the three games. In particular we observe the following relation (see proof in appendix):

$$X_S > X_A > X_B \tag{19}$$

with $X_S = x_S + x_S^*$, $X_A = x_A + x_A^*$ and $X_B = x_B + x_B^*$. Therefore, trade volumes are higher when firms invest in R&D and are symmetric in R&D commitment power. In turn, trade volumes are lower when firms do not invest in R&D. In the middle of the trade volumes rank is the scenario where firms invest in R&D and are asymmetric in R&D commitment power. Note that $X_S > X_A$, because as we have seen in the previous section, the no commitment power firm has always worst market access than a firm with commitment power.

In this sense symmetry in competitiveness levels (symmetric commitment power game) encourages more trade than when firms are asymmetric in competitiveness (asymmetric commitment power game). In any case the possibility of investing in R&D increases trade volumes relatively to cases where there is no R&D investment.

Proposition 6 *In an international duopoly, the volume of trade is always higher when firms can invest in R&D.*

We therefore believe that R&D competition can help to explain two stylized facts on international trade patterns: first, the increase in the world trade in the last century; and second, asymmetries in international trade patterns, i.e.: only the more competitive firms export.

Accordingly, we can explain the increase in the world trade not only as a result of a reduction in trade costs but also as a direct consequence of technological progress. The rational for this is that higher R&D efficiency facilitates access to international markets. Also, we can explain asymmetries in international trade patterns as the outcome of strategic interactions between firms. The intuition behind this is that strategic competition in R&D allows leading technological firms to have better access to international markets and to deter lagging technological firms from international activity.

6 Discussion

In this paper, we have argued that firms' exporting behavior is not only related with exogenous factors such as trade costs, but also with endogenous factors such as technological competition. According to this view, firms can also affect their market access by acting strategically against rivals.

In order to analyze this issue we have compared three models that differed in terms of technological competition dynamics. In the first case considered firms were not allowed to invest in R&D, in the second firms had symmetric R&D capacities, and in the third we introduced an R&D leader-follower set-up.

From the comparison of the three R&D scenarios, we found that trade volumes are always higher when firms can invest in R&D. Furthermore technological progress (i.e.: higher efficiency of R&D) promotes trade, similarly to what happens with low transport costs. In this sense, R&D competition, and not only trade costs, can also explain the increase in world trade in the last century.

In turn, the asymmetric commitment power R&D case proved to be particularly interesting since it allowed us to endogenize firms' competitiveness. In particular, we have showed that the firm with higher R&D commitment power becomes endogenously more competitive than the firm with no commitment power. As a consequence, firms with higher commitment power also have better access to export markets. Furthermore, the only case where a firm does not benefit from technological progress is when the firm is a technology follower. For these firms, very high R&D efficiency can reduce exports. Technological competition can therefore exclude firms with low R&D capacity from international trade. This result can help to explain some of the empirical facts at the base of the firm heterogeneity literature (see Roberts and Tybout, 1997 and Bernard et al., 2003); in particular the fact that firms involved in international trade are usually larger in size and more competitive than purely domestic firms.

A Appendix

Proof of Proposition 3 (Relation between $\hat{t}$ in the Three Games)

$$\begin{aligned}
\hat{t}_A - \hat{t}_S &= \tfrac{3\eta D}{2(6-\eta(17-8\eta))(3-2\eta)} > 0 \\
\hat{t}_S - \hat{t}_B &= \tfrac{\eta D}{3-2\eta} > 0 \\
\hat{t}_B - \hat{t}_A^* &= \tfrac{-D\eta(1-4\eta)}{2(3-\eta(9-4\eta))}
\end{aligned}$$

It can be easily seen that $\hat{t}_B > \hat{t}_A^*$ if $\eta > \frac{1}{4}$ and the reverse for $\eta < \frac{1}{4}$.

Proof of Proposition 4 (Influence of η in $\hat{t}$, x and x^*) For the symmetric commitment power game we have:

$$\begin{aligned}
\tfrac{d\hat{t}_S}{d\eta} &= \tfrac{3D}{(3-2\eta)^2} > 0 \\
\tfrac{dx_S}{d\eta} &= \tfrac{12(2D-t)}{b(9-8\eta)^2} > 0
\end{aligned}$$

And for the asymmetric commitment power game we have:

$$\begin{aligned}
\tfrac{d\left(\hat{t}_A\right)}{d\eta} &= \tfrac{3D(5-16\eta(1-\eta))}{(6-\eta(17-8\eta))^2} > 0 \\
\tfrac{d(x_A)}{d\eta} &= \tfrac{3(2D-t)(5-16\eta(1-\eta))}{b(9-4\eta(7-4\eta))^2} > 0 \\
\tfrac{d\left(\hat{t}_A^*\right)}{d\eta} &= \tfrac{D(3-8\eta(3-4\eta))}{2(3-\eta(9-4\eta))^2} \\
\tfrac{d\left(x_A^*\right)}{d\eta} &= \tfrac{2(2D-t)(3-\eta(24-32\eta))}{b(9-4\eta(7-4\eta))^2}
\end{aligned}$$

Summing up: $\frac{d\left(\hat{t}_A\right)}{d\eta}$ and $\frac{d(x_A)}{d\eta}$ are positive as long as $0 < \eta < \frac{3}{8}$. Instead, $\frac{d\left(\hat{t}_A^*\right)}{d\eta}$ and $\frac{d\left(x_A^*\right)}{d\eta}$ are positive for $0 < \eta < \frac{3-\sqrt{3}}{8}$ but negative for $\frac{3-\sqrt{3}}{8} < \eta < \frac{3}{8}$.

Proof of Proposition 5 (Commitment versus No Commitment Power)

$$\begin{aligned}
k_A - k_A^* &= \tfrac{\theta(2D-t)}{b\gamma(9-4\eta(7-4\eta))} > 0 \\
(q_A + x_A) - (q_A^* + x_A^*) &= \tfrac{2\theta^2(2D-t)}{b^2\gamma(9-4\eta(7-4\eta))} > 0 \\
x_A - x_A^* &= \tfrac{\theta^2(2D-t)}{\gamma b^2(9-4\eta(7-4\eta))} > 0 \\
x_A - q_A^* &= \tfrac{2\eta(D-8t\eta)+9t(3\eta-1)}{b(9-4\eta(7-4\eta))} > 0
\end{aligned}$$

Proof of Proposition 6 (Trade Volumes under the Three Games)

$$
\begin{aligned}
X_B &= x_B + x_B^* = \tfrac{2(D-2t)}{3b} \\
X_S &= x_S + x_S^* = 2\tfrac{3D-2t(3-2\eta)}{b(9-8\eta)} \\
X_A &= x_A + x_A^* = \tfrac{2D(3-7\eta)-t(12-\eta(35-16\eta))}{b(9-4\eta(7-4\eta))}
\end{aligned}
$$

Then it follows:

$$
\begin{aligned}
X_S - X_A &= \tfrac{\eta(3-8\eta)(2D-t)}{b(9-4\eta(7-4\eta))(9-8\eta)} > 0 \\
X_A - X_B &= \tfrac{\eta(7-16\eta)(2D-t)}{3b(9-4\eta(7-4\eta))} > 0
\end{aligned}
$$

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