Beyond Trade Costs: Firms' Endogenous Access to International Markets

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November 7, 2006

Abstract

Contrary to what has been standard in the international trade literature, we argue that firms' access to international markets should not be just reduced to exogenous factors such as trade costs. Instead, we defend that market access can also be endogenous, since firms can affect international trade patterns by acting strategically against rivals. In particular, we endogenize firms' competitiveness through commitment power advantages in R&D. In this setting we show that: (1) higher efficiency of R&D (like low trade costs) makes trade more easy (given that R&D increases the profitability of exports); (2) firms with higher commitment power in R&D are more competitive (since they have larger incentives to innovate) and as a result these firms also have better access to export markets.

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

JEL Classification: F12, L13, L25, O31.

*The author is grateful to Dermot Leahy, Francesca Sanna-Randaccio, Gianmarco Ottaviano, Jan I. Haaland, Leo Grünfeld, Paula Fontoura, Pedro Pita Barros, Pedro Pontes, Peter Neary, Renato Flôres and Victor Norman for helpful discussion and comments during the preparation of this work. The usual disclaimer applies.

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1 Introduction

Since von Thünen (1826) trade costs have been in the cornerstone of many economic analyses[1]. In fact, not only trade costs were fundamental to the classical location theory (Weber, 1909; Hotelling, 1929, Christaller, 1933 and Lösh, 1940), but also to the 'new' trade theory (Krugman, 1980 and Brander, 1981), to the 'new' economic geography (Krugman, 1991 and Venables, 1996) and to the multinational firms literature (Horstman and Markusen, 1992 and Brainard, 1997).

Not surprising then that empirics have followed suit by trying to estimate trade costs magnitudes in international trade (Moneta, 1959; Waters, 1970; Finger and Yeats, 1976; Harrigan, 1993; Rauch, 1999 and Hummels 1999, 2001). Moreover, we must not forget that the most important empirical model in international economics is the gravity model where trade costs play the major role (see the excellent review on trade costs and gravity models by Anderson and Wincoop, 2004).

Trade costs are then widely recognized as being central for a myriad of economic issues such as the location of industry, international trade and multinational activity. In addition, trade costs are very often pointed out in empirical studies as one of the reasons for the increase in the world trade in the last decades (Baier and Bergstrand, 2001) and to explain why countries do not trade as much as they should according to economic theory (Trefler, 1995 and Anderson and Wincoop, 2003).

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

For that we use a Cournot duopoly model where firms invest in process R&D as in Leahy and Neary (1997). However we also allow for firms to differ (or not) in the capacity to commit to their R&D decisions. Accordingly, a firm is said to have commitment power in R&D when she can commit to the output stage, i.e.: when R&D is chosen in a previous stage to outputs. We then compare different models with alternative formalizations of R&D competition.

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

Although having firms with different commitment power in R&D gives the firm with higher commitment power a first mover advantage, in the spirit of von Stackelberg (1934), the consequences of a R&D leader advantage are much more pervasive than a simple output Stackelberg leader advantage. 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 such is never possible since there, firms are always symmetric in terms of competitiveness independently of being a leader or a follower.

The endogenous competitiveness property of our model is particular 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 commitment power in R&D over-invest in innovation not only in order 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 then heavily on recognizing 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).

Actually, as showed by Roberts and Tybout (1997), only the more competitive firms are active in international markets. Roberts and Tybout (1997) empirical evidence started a whole new literature on heterogeneous firms. Melitz (2003), for instances, noticed that only with heterogeneous firms it is possible to have firms with different levels of international market access. However, in Melitz (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[2]. As a result, in Melitz (2003) it is also impossible for firms to affect rivals behavior in terms of market access.

In this paper, instead, asymmetries between firms are endogenized[3]. This allows us first to present one reason for firm heterogeneity (R&D competition); second to explain why firms can have different levels of market access (asymmetries in competitiveness) and third to explain why the more compet-

[2]Melitz (2003) generates firm heterogeneity by allocating productivity levels to firms randomly accordingly to some *ex-ante* statistical distribution.

[3]However, we use a much more simpler model than the one used by Melitz (2003) to obtain this result

itive firms are more active internationally (strategic competition). We then provide theoretical predictions that are in accordance with the empirical results of Roberts and Tybout (1997).

In this sense we argue that although trade costs are central for international exchanges, its role has been probably overstressed by the international trade literature leaving no room to look at other factors. In effect, we will also show that, similar 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 this way technological progress, similar to the one that we have assisted 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 (foreign variables are indicate by an asterisk). Each country has one firm: the home and the foreign firm that are initially symmetric. The two firms produce the same homogenous good for local production 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 represents the domestic sales of the home firm and x^{*} the exports of the foreign firm to the home country (similar interpretation holds for q^{*} and x). Instead a and b stand respectively for the intercept of demand and for an inverse measure of market size (with $a = a^{*}$ and $b = b^{*}$).

In turn the home firm profits can be written as:

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

where $t > 0$ is a general measure of all impediments to trade that affects symmetrically both the home and the foreign firm, i.e.: $t = t^{*}$; in turn C and Γ are the home firm 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:

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

where k is R&D investment by the home firm (k^* for the foreign firm), θ is the cost-reducing effect of R&D, γ is the cost of R&D and c is the initial marginal cost. The foreign firm has a similar cost structure with $c = c^*$, $\theta = \theta^*$ and $\gamma = \gamma^*$. This symmetry in technology is assumed 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 relates θ, γ and b:

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

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 measure of technological progress. We will show that, similar to a reduction in trade costs, technological progress (i.e.: an increase in η) can also conduce to an increase in international trade flows.

2.1 Commitment Power in R&D

In game terms a firm has commitment power in R&D if she can commit to 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, she can use R&D with two objectives: to improve her own productive efficiency and also to affect the rival strategic decisions. When a firm does not have commitment power in R&D, instead, only the former holds.

We then make use of the concept of commitment power in R&D in order to analyze the effects of alternative R&D competition configurations on trade patterns. Accordingly, we consider three games that differ on the firms' commitment ability in R&D. In the first game both the home and the foreign firm have commitment power in R&D (*commitment* game); in the second game instead both firms have no commitment power in R&D (*no-commitment* game); and in the third game only the home firm has commitment power in R&D (*home-commitment* game). We will identify these alternative games by the upper-scripts C, NC and HC, respectively.

In this sense the *home-commitment* game is a type of Stackelberg (1934) leader game, since the home firms has a first mover advantage in R&D[4]. *Commitment* power in R&D therefore gives *leader* advantages to a firm that competes with another one that lacks such capability. As a result, and as it will be seen bellow, firms with different *commitment* capabilities can become endogenously asymmetric because their R&D choices internalize the differences that they have at this level.

As shown in figure 1, the timing of these three games is then the following. In the *commitment game*, in the first stage the home and the foreign firm choose R&D levels (k and k^*, respectively) and in the second stage they choose output levels (q, x for the home firm and q^*, x^* for the foreign firm). In the *no-commitment* game there is only one stage where both the home and the foreign firm choose simultaneously R&D and output levels (respectively k, q, x and k^*, q^*, x^*). Finally in the *home-commitment* game, in the first stage the home firm chooses R&D (k), in the second stage the foreign firm decides if she enters the market and in the third stage the home firm chooses outputs (q and x) while the foreign firm, in case she had decided to enter, chooses both outputs (q^* and x^*) and R&D levels (k^*)[5].

We are now ready to define the production equilibrium of the different commitment games.

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[4] Bagwell (1995) gives a precise definition of the assumptions behind a game where firms have differences in *commitment* power. First, moves in the game are sequential with some players committing to actions before other players select their respective actions. Second, late moving players perfectly observe actions selected by first movers. In the *home-commitment* game we adopt Bagwell's (1995) definition.

[5] Note that the focus of this paper is not the entry decision of the foreign firm (see instead Spence, 1977). However, as defended by Hamilton and Slutsky (1990), in order to justify the first mover advantage in the context of our model it can be helpful to think of the home firm as an incumbent that moves first in R&D than the entrant foreign firm.

Stage \ Game	Commitment Game	No-Commitment Game	Home-Commitment Game
Stage 1	k, k*	q, x, k, q*, x*, k*	k
Stage 2	q, x, q*, x*		F: entry decision
Stage 3			q, x, q*, x*, k*

Figure 1: Timing of the Games

3 Production and Entry

The model as usual is solved by backward induction. However in spite of considering alternative games that differ in the order of moves of the players, they can all be solved in a similar fashion for outputs. Accordingly, to compute outputs just make use of the outputs first order conditions $\frac{d\Pi}{dq}$, $\frac{d\Pi}{dx}$ and $\frac{d\Pi^*}{dq^*}$, $\frac{d\Pi^*}{dx^*}$ to obtain:

$$\begin{aligned} q &= \tfrac{D+t+2\theta k-\theta k^*}{3b} \\ x &= \tfrac{D-2t+2\theta k-\theta k^*}{3b} \\ q^* &= \tfrac{D+t+2\theta k^*-\theta k}{3b} \\ x^* &= \tfrac{D-2t+2\theta k^*-\theta k}{3b} \end{aligned} \qquad (5)$$

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

For R&D investment we can proceed in a similar fashion by working with the R&D first order conditions $\frac{d\Pi}{dk}$ and $\frac{d\Pi^*}{dk^*}$. These first order conditions however depend on whatever a firm has commitment power or not. In particular, if the home firm has commitment power, her R&D first order condition can be decomposed into:

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

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

[6] Note that the whole R&D first order condition for the home firms is: $\frac{d\Pi}{dk} = \frac{\partial\Pi}{\partial k} + \frac{\partial\Pi}{\partial q}\frac{dq}{dk} +$

in a previous stage to outputs, i.e.: when a firm has *commitment* power in R&D (as the home and the foreign firm in the *commitment* game and the home firm in the *home-commitment* game). On the contrary, R&D is non-strategic if the second and third terms are zero. This happens for example if a firm chooses R&D and outputs simultaneously, i.e.: when a firm has *no-commitment* power in R&D (as the home and the foreign firm in the *no-commitment* game and the foreign firm in the *home-commitment* game).

As a result, in the *commitment* game the R&D expressions boil down to:

$$\begin{aligned} k^{C} &= \tfrac{4\theta}{3\gamma}\left(q^{C}+x^{C}\right) \\ k^{*C} &= \tfrac{4\theta}{3\gamma}\left(q^{*C}+x^{*C}\right) \end{aligned} \tag{7}$$

In the *no-commitment* game, in turn:

$$\begin{aligned} k^{NC} &= \tfrac{\theta}{\gamma}\left(q^{NC}+x^{NC}\right) \\ k^{*NC} &= \tfrac{\theta}{\gamma}\left(q^{*NC}+x^{*NC}\right) \end{aligned} \tag{8}$$

While in the *home-commitment* game:

$$\begin{aligned} k^{HC} &= \tfrac{4\theta}{3\gamma}\left(q^{HC}+x^{HC}\right) \\ k^{*HC} &= \tfrac{\theta}{\gamma}\left(q^{*HC}+x^{*HC}\right) \end{aligned} \tag{9}$$

As it can be seen, when the home and the foreign firm have symmetric commitment power in R&D (*no-commitment* and *commitment* games) they also have symmetric incentives to invest in R&D. On the contrary, if the home and the foreign firm have asymmetric commitment power (*home commitment* game) then the home and the foreign firm also have asymmetric incentives to invest in R&D.

Having the R&D expressions, we can also analyze the entry decision of the foreign firm in the *home-commitment* game. To be precise, the foreign firm will only enter the market if she can make positive profits. To check this, substitute the foreign firm R&D expression (equation 9) into the foreign firm profit expression, to get:

$\frac{\partial \Pi}{\partial x}\frac{dx}{dk}+\frac{\partial \Pi}{\partial q^*}\frac{dq^*}{dk}+\frac{\partial \Pi}{\partial x^*}\frac{dx^*}{dk}$. However, from the outputs first order conditions $\frac{\partial \Pi}{\partial q}=\frac{\partial \Pi}{\partial x}=0$, and as such these terms cancel-out.

$$\Pi^{*HC} = \frac{b}{2}\left((2-\eta)\left(\left(q^{*HC}\right)^2 + \left(x^{*HC}\right)^2\right) - 2\eta q^{*HC} x^{*HC}\right) \tag{10}$$

Then $\Pi^* > 0$ if $(q^{*2} + x^{*2}) > \frac{2\eta}{2-\eta} q^* x^*$. Note however that as long as the second order condition holds ($0 < \eta < \frac{9}{16}$, see appendix) then also $\frac{2\eta}{2-\eta} < 1$. This implies that the previous relation is always satisfied since in these type of models, due to trade costs, local sales are always higher than exports. Therefore the foreign firm always enters the market[7].

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

$$\begin{aligned} q^C &= q^{*C} = \tfrac{3D+t(3-4\eta)}{b(9-8\eta)} \\ x^C &= x^{*C} = \tfrac{3D-t(6-4\eta)}{b(9-8\eta)} \\ k^C &= k^{*C} = \tfrac{4\theta(2D-t)}{b\gamma(9-8\eta)} \end{aligned} \tag{11}$$

Instead in the *no-commitment* game we have:

$$\begin{aligned} q^{NC} &= q^{*NC} = \tfrac{D+t(1-\eta)}{b(3-2\eta)} \\ x^{NC} &= x^{*NC} = \tfrac{D-t(2-\eta)}{b(3-2\eta)} \\ k^{NC} &= k^{*NC} = \tfrac{\theta(2D-t)}{b\gamma(3-2\eta)} \end{aligned} \tag{12}$$

Finally in the *home-commitment* game:

[7] This is so because we have not assumed any exogenous fixed cost of entry and all fixed costs are endogenous to R&D. As a result when the foreign firms decides on the amount of R&D to invest, she does so such that it does not prevent her to enter the market.

$$
\begin{aligned}
q^{HC} &= \frac{3D(1-2\eta)+t\big((3-11\eta)+8\eta^2\big)}{b(9-4\eta(7-4\eta))} \\
x^{HC} &= \frac{3D(1-2\eta)-t\big((6-17\eta)+8\eta^2\big)}{b(9-4\eta(7-4\eta))} \\
q^{*HC} &= \frac{D(3-8\eta)+t\big((3-10\eta)+8\eta^2\big)}{b(9-4\eta(7-4\eta))} \\
x^{*HC} &= \frac{D(3-8\eta)-t\big(2(3-9\eta)+8\eta^2\big)}{b(9-4\eta(7-4\eta))} \\
k^{HC} &= \frac{4\theta(2D-t)(1-2\eta)}{b\gamma(9-4\eta(7-4\eta))} \\
k^{*HC} &= \frac{\theta(2D-t)(3-8\eta)}{b\gamma(9-4\eta(7-4\eta))}
\end{aligned}
\quad (13)
$$

Therefore when firms have symmetric commitment power in R&D they also end up symmetric, i.e.: firms produce and invest the same. On the contrary when firms are asymmetric in commitment power they become endogenously asymmetric, i.e.: firms are initially symmetric in terms of technology but even so they end up producing and investing differently. In the next sections we will analyze the consequences of this endogenous asymmetry on firms' competitiveness.

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

4 Overlapping Markets Condition

In this section we analyze what is usually called the overlapping markets condition (see for example Head et al., 2002). The overlapping markets condition defines under what cases trade is profitable for a firm, i.e.: that a firm can overlap the market of the foreign rival. In mathematical terms, the overlapping markets condition is simply defined as the threshold level of trade costs between autarchy and trade. We then define $\hat{t}_{OMC}$ as the overlapping markets condition for the home firm and $\hat{t}^*_{OMC}$ for the foreign firm[8].

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

Since in the *commitment* game and in the *no-commitment* game the home and the foreign firm are symmetric, which implies that the two firms have the same level of access to international markets, the home and the foreign firm also have the same overlapping markets condition. Specifically for the *commitment* game:

$$\hat{t}^{C}_{OMC} = \hat{t}^{*C}_{OMC} < \frac{3D}{2(3-2\eta)} \tag{14}$$

And for the *no-commitment* game:

$$\hat{t}^{NC}_{OMC} = \hat{t}^{*NC}_{OMC} < \frac{D}{2-\eta} \tag{15}$$

In turn, in the *home-commitment* game since the home and the foreign firm are asymmetric, which implies that the two firms have different levels of access to international markets, the home and the foreign firm also have different overlapping markets conditions:

$$\begin{aligned} \hat{t}^{HC}_{OMC} &< \frac{3(1-2\eta)}{6-\eta(17-8\eta)}D \\ \hat{t}^{*HC}_{OMC} &< \frac{1}{2}\frac{(3-8\eta)}{3-\eta(9-4\eta)}D \end{aligned} \tag{16}$$

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

To conclude this section note that given that $t > 0$ we also want that $\hat{t}_{OMC}$ and $\hat{t}^{*}_{OMC}$ are also positive. As it can be easily checked, as long as the second order condition holds both $\hat{t}^{C}_{OMC}$ and $\hat{t}^{NC}_{OMC}$ satisfy this requisite. The same does not happen, however, with $\hat{t}^{HC}_{OMC}$ and $\hat{t}^{*HC}_{OMC}$. We then exclude parameter values that make $\hat{t}^{HC}_{OMC}$ and $\hat{t}^{*HC}_{OMC}$ negative. This is equivalent to say that we need to restrict η to be comprehended in the interval (see appendix):

$$0 < \hat{\eta} < \frac{3}{8} \tag{17}$$

In order to have the different commitment games in this paper comparable, from now on we will assume that this restriction is always satisfied in all of the three games (*commitment*, *no-commitment* and *home-commitment* games).

5 R&D and Trade

The international trade theory highlights so much the role of trade costs on the firms' ability to export that this emphasis causes other factors to be downplayed. Our purpose in this paper is to call the attention to some of these other factors, in particular, R&D investment. As we will show in this section, R&D investment is central for international trade patterns for at least two reasons. First, R&D can have the same type of effects as trade costs on market access: higher efficiency of R&D, as low trade costs, increases trade (and *vice-versa*). Second, R&D competition introduces some new dimensions previously disregard in the trade literature: market access as being endogenous to firms' strategic decisions.

To study the effects of R&D on international trade note first that the derivatives of the different overlapping markets conditions in relation to η are always positive in the *commitment* and *no-commitment* games (see also appendix):

$$\frac{d\left(\hat{t}^{C}_{OMC}\right)}{d\eta} > 0 \text{ and } \frac{d\left(\hat{t}^{NC}_{OMC}\right)}{d\eta} > 0 \tag{18}$$

Then, when firms are symmetric in commitment power, higher return on R&D makes trade easier for firms, i.e.: high η increases the autarchy threshold level of trade costs. This is so, because higher return on R&D makes firms more competitive and therefore more prepared to face the difficulties involved in international trade.

As a result, for high η, firms' exports under the *commitment* and *no-commitment* games also increase:

$$\frac{d\left(x^{C}\right)}{d\eta} > 0 \text{ and } \frac{d\left(x^{NC}\right)}{d\eta} > 0 \tag{19}$$

In the *home-commitment* game the derivatives of the overlapping markets conditions in relation to η has however a different behavior for the lower commitment power foreign firm:

$$\frac{d\left(\hat{t}^{HC}_{OMC}\right)}{d\eta} > 0$$

$$\frac{d\left(\hat{t}^{*HC}_{OMC}\right)}{d\eta} > 0 \text{ for } 0 < \eta < \frac{3-\sqrt{3}}{8} \text{ and } \frac{d\left(\hat{t}^{*HC}_{OMC}\right)}{d\eta} < 0 \text{ for } \frac{3-\sqrt{3}}{8} < \eta < \frac{3}{8} \tag{20}$$

Then, when firms are asymmetric in commitment power, only the firm with the first mover advantage in R&D (the home firm) has better market access when η increases, i.e.: with high η the home firm can export even for higher trade costs. However, for the follower foreign firm that does not hold totally: the foreign firm's access to exports markets only increases with η if R&D is not too efficient; instead, when R&D is very efficient the foreign firm's access to international markets deteriorates.

Not surprisingly then that in the *home-commitment* game only the exports of the more competitive firm (the higher commitment power home firm) always benefit from an increase in η. Accordingly, and as shown in appendix, the less competitive firm loses in terms of exports when technological competition becomes very fierce (high η):

$$\frac{d\left(x^{HC}\right)}{d\eta} > 0$$

$$\frac{d\left(x^{*HC}\right)}{d\eta} > 0 \text{ for } 0 < \eta < \frac{3-\sqrt{3}}{8} \text{ and } \frac{d\left(x^{*HC}\right)}{d\eta} < 0 \text{ for } \frac{3-\sqrt{3}}{8} < \eta < \frac{3}{8} \tag{21}$$

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

Remark 3 *In an international oligopoly, higher efficiency of R&D makes trade easier for firms. A firm with no commitment power in R&D that faces another one with commitment power in R&D, however, can be hurt when R&D is very efficient.*

So far we have just showed the first part of our argument: that other factors besides trade costs can 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 do this it can be helpful to analyze first the implications of the endogenous asymmetry property of our model.

We have said previously that in the *home-commitment* game, firms become endogenously asymmetric due to different levels of commitment power in R&D. 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. Conversely, such is not possible in the *commitment* and *no-commitment* games. It is therefore important to know how much of the asymmetry between the home and the foreign firm amounts to.

To study this note that the following relations hold in the *home-commitment* game:

$$\begin{aligned} k^{HC} &> k^{*HC} \\ q^{HC} + x^{HC} &> q^{*HC} + x^{*HC} \\ x^{HC} &> x^{*HC} \end{aligned} \tag{22}$$

Then, in the *home-commitment* game the home firm, due to her higher commitment power in R&D, ends up investing and producing more than the foreign firm (see appendix). In particular the higher commitment home firm is more active internationally (once it exports more) than the lower commitment foreign firm.

Remark 4 *In an international duopoly, the firm with higher commitment power in R&D is more competitive and therefore exports more, given that she invest more in R&D.*

How does this competitiveness differences reflects on the home and the foreign firm levels of access to international markets? We can study this by analyzing the relation between the different overlapping markets conditions in the alternative commitment games (see proof in appendix):

$$\hat{t}^{HC}_{OMC} > \hat{t}^{C}_{OMC} = \hat{t}^{*C}_{OMC} > \hat{t}^{NC}_{OMC} = \hat{t}^{*NC}_{OMC} > \hat{t}^{*HC}_{OMC} \tag{23}$$

Hence, a firm has better market access when she invests strategically in R&D (the home firm in the *home-commitment* game and the home and the foreign firm in the *commitment* game) comparatively to when a firm does not invest strategically (the home and the foreign firm in the *no-commitment* game and the foreign firm in the *home-commitment* game).

Since the nature of competition matters, however, the firm that has better market access is the one that has commitment power but faces a rival that lacks such ability (i.e.: the home firm in the *home-commitment* game). At the bottom of the market access ranking is instead the firm with no commitment power that competes with another one that has such capability (i.e.: the foreign firm in the *home-commitment* game). In the in-between positions is first the firm with commitment power but that faces a rival with the same ability (the home and the foreign firm in the *commitment* game); and then the firm with no commitment power but that faces a rival in the same conditions (the home and the foreign firm in the *no-commitment* game).

As a result, a firm is more active internationally when she is more competitive (i.e.: when she has commitment power in R&D). However, as above, leading in commitment power relatively to rivals comes as a plus, while lagging behind in commitment power relatively to rivals comes as a minus (see appendix):

$$x^{HC} > x^{C} = x^{*C} > x^{NC} = x^{*NC} > x^{*HC} \tag{24}$$

As before, the rational for this result is that the firm with higher commitment power over-invests in R&D in order to restrain the international activity of the lower commitment power rival. In fact, a firm with no commitment power in R&D exports less when she faces a rival with commitment power than when the rival has also no commitment power.

Remark 5 *In an international duopoly, access to international markets depends on a firm capacity to commit to R&D and the nature of competition vis-à-vis to rivals. Accordingly, a firm that leads in commitment power (i.e.: the more competitive firm) has better access to international markets than a firm that lags behind in commitment power.*

What this remark tell us is that firms' market access not only depends in 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 her own level of international market access but also that of competitors, because innovation affects the competitiveness balance in the market.

In this sense R&D competition can explain two stylized facts on international trade patterns: first, the increase in the world trade in the last century; and second, the asymmetry in international trade patterns, i.e.: that only the more competitive firms export and that these firms are usually from more advanced countries. 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. Also, we can explain the asymmetry in international trade patterns as the outcome of strategic interactions between firms, because strategic competition in R&D allows leading technological firms to have better access to international markets and to deter lagging 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. Instead we have stressed the role of endogenous factors as technological competition. According to this view, firms by themselves can also affect market access by acting strategically against rivals. In particular we have endogenized firms competitiveness through commitment power advantages in R&D.

In this setting, we have showed that when R&D is more efficient (i.e.: technological progress), firms have in general better chances to penetrate foreign markets, similar to what happens with low transport costs. The exception to this is when a firm lags behind in terms of R&D competitiveness: very high R&D efficiency can make things worst for these firms. Technological competition can therefore exclude firms with low R&D capacity from international trade. In this way, we can understand why international trade is so asymmetric (in the sense that the large bulk of international trade is amongst developed countries). Accordingly, firms from developing countries lack strategic competitive tools, as R&D investment, to be able to compete in international markets.

In addition we have also found that firms with higher commitment power in R&D are more competitive, since they have larger incentives to invest in R&D. As a consequence of this, firms with higher commitment power have also better access to export markets, once they are more competitive. This result can help to explain some of the empirical facts at the base of the firm heterogeneity literature started by Tybout and Roberts (1997). In particular that firms involved in international trade are usually larger in size and more competitive than purely domestic firms.

These type of issues have been previously unexplored in international trade given the difficulties involved in tackling with asymmetric firms. In fact, we have approached asymmetry in a very simple framework. Therefore, future work should aim at extending our analysis to more general set-ups.

A Appendix: General Proofs

R&D First Order Condition The R&D maximization problem for the home firm is:

$$\begin{aligned} Max_k\ \Pi &= (P - C)\, q + (P^* - C - t)\, x - \Gamma - \Delta \\ s.r. &: \ C = c - \theta k \geq 0 \text{ and } k \geq 0 \end{aligned}$$

To solve this problem we use the Kuhn-Tucker method. First, write the Lagrangian function (denoting the Lagrange multiplier by λ):

$$L = \Pi + \lambda\, (c - \theta k)$$

The Kuhn-Tucker conditions for the home firm in case she has commitment power are:

$$\begin{aligned} \tfrac{\partial L}{\partial k} &= \tfrac{4}{3}\theta\, (q + x) - \gamma k - \lambda\theta \leq 0, \qquad k \geq 0, \qquad \text{and} \qquad k\tfrac{\partial L}{\partial k} = 0 \\ \tfrac{\partial L}{\partial \lambda} &= c - \theta k \geq 0, \qquad \lambda \geq 0, \qquad \text{and} \qquad \lambda\tfrac{\partial L}{\partial \lambda} = 0 \end{aligned}$$

The non-negativity and the complementary-slackness conditions on λ (respectively $\lambda \geq 0$ and $\lambda\, (\partial L/\partial\lambda) = 0$) imply that for $\lambda = 0$, we have $k < c/\theta$; while for $\lambda > 0$, instead $k = c/\theta$ (since $\theta > 0$). Then, if $\lambda = 0$ and $k < c/\theta$ results $k = \frac{\theta}{\gamma}\, (rq + (1 - r)\, x)$. In this case, the complementary-slackness condition on k $(k\, (\partial L/\partial k) = 0)$ and, consequently, all other Kuhn-Tucker conditions are satisfied. On the contrary, if $\lambda > 0$ and $k = c/\theta$, the complementary-slackness condition on k is never satisfied, since $k\, (\partial L/\partial k) \neq 0$.

Therefore, the general R&D expression when the home firm has commitment power is:

$$k = \tfrac{4\theta}{3\gamma}\, (q + x) \ \text{ for } C \text{ and } HC \text{ games}$$

In turn, when the home firm has no commitment power, the general R&D expressions are:

$$k^{NC} = \tfrac{\theta}{\gamma}\, (q + x)$$

To see this, just substitute the partial derivative of the Lagrangian in order to k for:

$$\tfrac{\partial L}{\partial k} = \theta\, (q + x) - \gamma k - \lambda\theta \leq 0$$

After, proceed in the same fashion as before. The general R&D expressions for the foreign firm apply by symmetry.

Second Order Condition To find the second order condition substitute in the profit expressions (equations 2) for the general output expressions (equation 5) and then compute the second order derivatives in order to k or k^*. In all of the different commitment games we obtain:

$$\frac{d^2\Pi}{dk^2} = \frac{d^2\Pi^*}{dk^{*2}} = -\frac{\gamma(9-16\eta)}{9} < 0$$

This implies that for the second order condition to hold, we need that $0 < \eta < \frac{9}{16}$.

Sign of $\hat{t}^{HC}_{OMC}$ and $\hat{t}^{*HC}_{OMC}$ In the interval of the second order condition $\hat{t}^{HC}_{OMC}$ and $\hat{t}^{*HC}_{OMC}$ satisfy:

$$\begin{aligned} \hat{t}^{HC}_{OMC} &> 0 \text{ for } 0 < \eta < \tfrac{1}{2} \\ \hat{t}^{*HC}_{OMC} &> 0 \text{ for } 0 < \eta < \tfrac{3}{8} \end{aligned}$$

We then restrict the parameter space in the model so that $0 < \eta < \frac{3}{8}$.

Proof of Remark 3 The derivatives of the different overlapping market conditions in relation to η equal:

$$\begin{aligned} \frac{d\left(\hat{t}^{C}_{OMC}\right)}{d\eta} &= \frac{d\hat{t}\left({}^{*C}_{OMC}\right)}{d\eta} = \frac{3D}{(3-2\eta)^2} \\ \frac{d\left(\hat{t}^{NC}_{OMC}\right)}{d\eta} &= \frac{d\left(\hat{t}^{*NC}_{OMC}\right)}{d\eta} = \frac{D}{(2-\eta)^2} \\ \frac{d\left(\hat{t}^{HC}_{OMC}\right)}{d\eta} &= \frac{3D(5-16\eta(1-\eta))}{(6-\eta(17-8\eta))^2} \\ \frac{d\left(\hat{t}^{*HC}_{OMC}\right)}{d\eta} &= \frac{D(3-8\eta(3-4\eta))}{2(3-\eta(9-4\eta))^2} \end{aligned}$$

In turn, the derivatives of exports in relation to η are:

$$\begin{aligned} \frac{d\left(x^{C}\right)}{d\eta} &= \frac{d\left(x^{*C}\right)}{d\eta} = \frac{12(2D-t)}{b(9-8\eta)^2} \\ \frac{d\left(x^{NC}\right)}{d\eta} &= \frac{d\left(x^{*NC}\right)}{d\eta} = \frac{2D-t}{b(3-2\eta)^2} \\ \frac{d\left(x^{HC}\right)}{d\eta} &= \frac{3(2D-t)(5-16\eta(1-\eta))}{b(9-4\eta(7-4\eta))^2} \\ \frac{d\left(x^{*HC}\right)}{d\eta} &= \frac{2(2D-t)(3-\eta(24-32\eta))}{b(9-4\eta(7-4\eta))^2} \end{aligned}$$

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

Proof of Remark 4 The following relations hold as long as $0 < \eta < \frac{3}{8}$:

$$\begin{aligned} k^{HC} - k^{*HC} &= \tfrac{\theta(2D-t)}{b\gamma(9-4\eta(7-4\eta))} > 0 \\ \left(q^{HC} + x\right) - \left(q^{*HC} + x^{*HC}\right) &= \tfrac{2\theta^2(2D-t)}{b^2\gamma(9-4\eta(7-4\eta))} > 0 \\ x^{HC} - x^{*HC} &= \tfrac{\theta^2(2D-t)}{\gamma b^2(9-4\eta(7-4\eta))} > 0 \end{aligned}$$

Proof of Remark 5 The following relations hold as long as $0 < \eta < \frac{3}{8}$:

$$\begin{aligned} \hat{t}^{HC}_{OMC} - \hat{t}^{C}_{OMC} &= \tfrac{3D\eta}{2(6-\eta(17-8\eta))(3-2\eta)} > 0 \\ \hat{t}^{C}_{OMC} - \hat{t}^{NC}_{OMC} &= \tfrac{D\eta}{2(3-2\eta)(2-\eta)} > 0 \\ \hat{t}^{NC}_{OMC} - \hat{t}^{*HC}_{OMC} &= \tfrac{D\eta}{2(2-\eta)(3-\eta(9-4\eta))} > 0 \\ x^{HC} - x^{C} &= \tfrac{3\eta(2D-t)}{b(9-4\eta(7-4\eta))(9-8\eta)} > 0 \\ x^{C} - x^{NC} &= \tfrac{\eta(2D-t)}{b(9-8\eta)(3-2\eta)} > 0 \\ x^{NC} - x^{*HC} &= \tfrac{\eta(2D-t)}{b(3-2\eta)(9-4\eta(7-4\eta))} > 0 \end{aligned}$$

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